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CONSTRUCTION Management of Industrial Projects

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Construction Management for Industrial Projects

A Modular Guide for Project Managers

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WILEY

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This book is dedicated to the spirits of my mother and my father, my wife and my children Maey, Hisham and Mayar.

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Preface

The development of any country depends on increasing investment in industrial projects. Although there are many types of industrial projects, such as food processing plants, automobile manufacturing plants, and wind farm construction, the author has chosen oil and gas projects as the main source from which to draw examples throughout this book. The principles herein are meant to be universal and can be applied to any industrial project, but oil and gas projects were chosen as the primary focus because of the author's experience in this area and because, even now, with climate change and other questions about energy, oil and gas are still the primary fuels which drive economies and worldwide development.

Project management is the main tool to achieving a successful project. This book focuses on using practical tools and methods that are widely and successfully used in project management for industrial projects. Most engineers study subjects that focus on project management in housing projects, administration projects and commercial buildings or other similar projects, but industrial projects have their own requirements and characteristics that set them apart from those other types of projects.

This book is not only addressed to graduating engineers who wish to improve their skills in project management, but it is also helpful to upper level management. This book covers all of the project management subjects from an industrial project point of view. The aim of this book is to be helpful to any engineering discipline or any staff in sharing or applying work of an industrial project.

Why do senior managers accept certain projects and refuse others? Why does a company have huge investments in a certain country but no investments on other countries, especially in oil and gas projects? Certainly, it isn't just because "that's where the oil is," because there are countries that are extremely rich in oil and gas reserves in which there is little investment. These questions are important for understanding project management as a discipline and why using the tools of project management correctly will lead to successful projects.

Knowledge is power. When you understand well, you will do well. So in this book we will illustrate exactly what the project manager is thinking when he is working on a project and what his objectives and goals are. On the other hand, we will discuss what team members may be thinking through the project stages and what their objectives and goals are.

The main tools in managing the project, which are time, resources, cost, and quality management, shall be illustrated by using practical examples from petroleum projects. In addition to that, this book presents all the types of contracts and methods of technical and commercial evaluation for the tenders, with highlights on the FIDIC contract and its advantages.

I have worked on major rehabilitation projects for offshore structures with the best international companies from the owner, working with the engineering offices, the contractors, and the suppliers. Often, the project management staff and all the team members have ideal skills and competence as described in many textbooks, but unfortunately, the end users are not fully satisfied, which is a situation that usually faces us in industrial projects. The solution to this problem is proposed by using a whole building commissioning system that is used successfully in administration building, and this management system is clearly illustrated in this book.

This book tries to be practical and, at the same time, match with the Project Management Professional (PMP) guide, so we selected one hundred questions from the PMP exam to help you obtain the certificate. But we chose questions that present actual cases we face in managing industrial projects.

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1

Introduction

Most project management books focus on the management of building projects, such as housing, administration, and commercial building projects. Likewise, most engineering faculties focus on housing projects in their curricula, while industrial projects are, for the most part, in the oil and gas sector and other process industries. The aim of this book is to focus on the main tools of project management that are essential to industrial projects, focusing on, but not limited by, projects in the oil and gas sector.

A good place to start, for anyone wishing to be a project manager, is to obtain a Project Management Professional (PMP) certificate, which is a credential offered by the Project Management Institute (PMI). As of March 31, 2010, there were 375,959 active PMP certified individuals worldwide.

This credential is obtained by documenting 3 to 5 years of work experience in project management, completing 35 hours of project management related training, and scoring a certain percentage of questions on a written, multiple choice examination.

This book provides questions and answers for the subjects that are more traditional in the PMP exam, but it will be more beneficial to focus on practical life applications, so these questions are tailored to help in situations that are faced in real projects. It would not be beneficial to take this exam and receive certification but later fail in real, practical projects.

The definition of a project is a series of activities that have a start and finish time. A project, in general, is unique, and no project is similar to another. This is very important, because one should know that the problem one may face in managing a project may be unique. Also, one should have a creative mind in order to get to the right solution without a reference, so that the professionalism of the project manager depends on his or her previous experience.

Real life is like the theater, where everyone has a role in the story. So, you may be in the project play as an owner, engineering office, contractor, supplier, or service provider doing logistic service for the project. You may be at a higher level in the organization or at a lower level. In any case, you play a role in this story, so you should understand the whole story – who does what, and who is responsible for this and that issue. With this information, you will succeed at any project you are working on.

Chapter two discusses the scope of projects and the main characteristics of project management. To have a complete grasp of project management, one must first understand these basic principles and see how they work in the real world.

For us as engineers, a feasibility study is a mystery, because we are rarely working in this phase. Chapter three explains our role as engineers in the feasibility study. This chapter presents the main tools of economics to use in deciding whether to proceed with the new project. It also describes the scientific way to choose between the various alternatives. The principal of statistics is described in this chapter, in addition to the theory of probability from a practical point of view, and how we can use these tools to make the right decision. The Monte-Carlo simulation technique is presented, as it is the main tool in a feasibility study for oil and gas projects, which is the main tool that we use in the decision tree method. The decision tree method is very important and easy to use, and anyone who has read about it or attended a course on it is eager to apply it. However, the actual application of this method can be difficult. In this chapter, a practical way of applying the decision tree method in conjunction with the Monte-Carlo simulation is presented.

Time management is a primary tool in project management. There are many methods for making a time schedule for a project, and these methods will be discussed in chapter four. In addition, a method for estimating activities and project time using a traditional case study in a petrochemical project will be presented in this chapter.

Resources management is another element in project management. Resource management is the main area that should be controlled by the project manager and the team member. Chapter five provides the key to understanding resources management for the project manager and the team member, as well. It is very important that when you join a new project the team members know what the project manager is looking for and what he or she has in mind when choosing the team members. The project manager should have special skills and experience, as he or she is responsible for implementing project management strategy when handling an international project with labor from different countries and different cultures. The distribution of resources on a time schedule will also be discussed in chapter five.

Another main element in project management is cost. Therefore, chapter six presents a way to predict the cost estimate in each phase of a project, a way to define the project budget, and a method for monitoring the project cost during the project's time-frame.

Older project management principals focus on time, cost, and quality. Nowadays, and especially in our case as we are discussing the management for petrochemical, power stations, and other middle sized industrial projects, safety, health, and the environment are very important to these types of projects, and in some cases they will be the big challenges facing project managers and project sponsors. Therefore, the four elements presented in Figure (1.1) are the main constraints to project managers' decisions and should be managed by a project manager and his or her team members. This will also be covered in chapter six.

Contracts are the chain that connects the primary parties of the projects, such as the owners, the engineering firm, and the contractors. Chapter seven describes the tender and bidding procedure and some of the ways to evaluate the bidders technically and commercially, especially in an international environment.

The market is open, and as an owner you can choose any contractors or engineering firm from any country all over the world, so there is a lot of competition between international companies to provide good quality to their products or services. Therefore, all the international companies follow the standards of the International Organization for Standardization (ISO) and apply the total quality management system as stated by the ISO. This will be discussed from a practical standpoint in chapter eight.

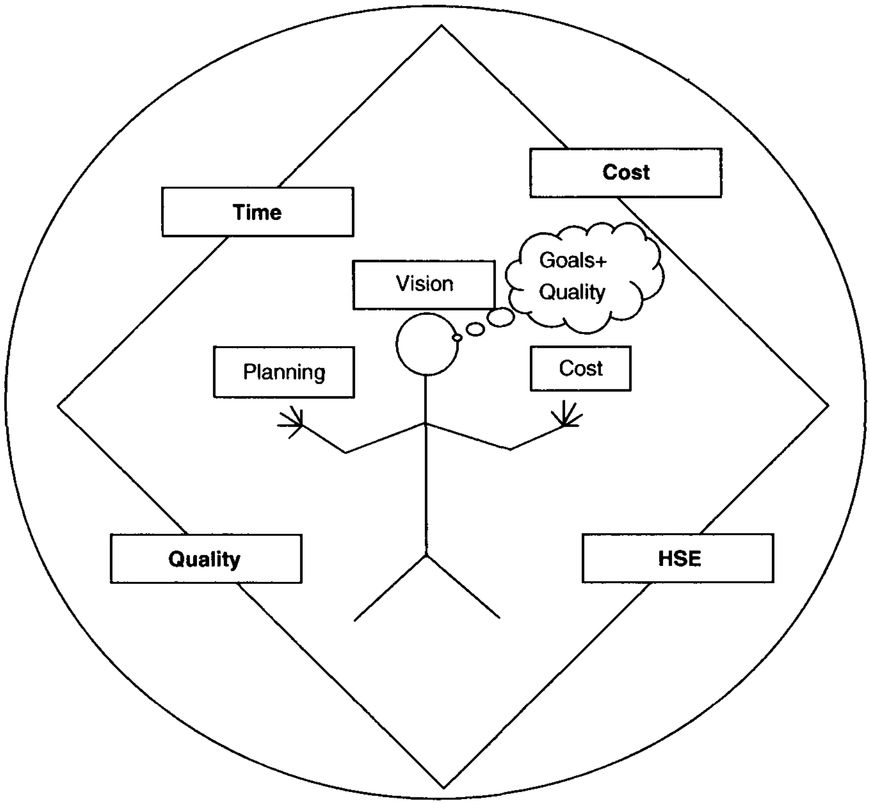

Figure 1.1 Project manager constraints.

Before starting a project, one should have a scientific way to expect the problems that he or she will face on the project during implementation and to solve them in a timely manner without affecting cost, time-frame, and quality. Risk assessment, which is discussed in chapter three, is about economic assessment, and this form of risk assessment is essentially qualitative. It is not feasible in the implementation phase. For that phase, a more quantitative risk assessment is appropriate, in order to exectute the project properly. This is discussed in chapter nine.

In chapter ten there are one hundred questions with answers that may be seen on the PMP exam. However, these questions are chosen to serve our practical purposes, as these questions are not for the exam but are complementary for a project that presents these practical cases.

2

Project Management

2.1 The Principle of Project Management

The subject of project management has recently become as a key concern in various engineering fields. The proliferation of mega-projects worldwide, aiming to take best advantage of the latest technological developments, itself demands new or improved methods of project management to cope with the fast developing.

As the concept of a *project* differs fundamentally from that of *daily or routine operations*, it follows that a number of principles and conceptions of project management must also diverge from those followed in the realm of daily operations management.

In **operations management**, production managers tend generally to focus on production / output volume per unit time — usually the current week compared to the previous week and-or the same week last year; profits accumulated and–or compared for the same time unit(s); sales or operational orders accumulated and–or compared for the same time unit(s); actual versus budgeted expenditure for the current quarter and the same quarter the year before; and sales revenue and sales volume for a given product compared to the performance of competitors producing / marketing a similar product.

Project management may be defined as the planning, organization, direction, and control of all kinds of resources in a specific time period for achieving a specific objective comprised of various financial and non-financial targets.

This should help clarify the difference in outlook of the project manager and the operations manager. The project manager's goal is to finish the project on time. Then he evaluates where he will relocate after finishing the project. The operations manager, on the other hand, never wants daily production to stop, and cannot dream of work stopping — as distinct from the project manager's goal of overall task completion.

2.2 Project Characteristics

The selection and assignment of the most appropriate personnel at different locations within the same company constitutes one of the most critical skills in the project manager's arsenal. In some international projects, personnel originate from different countries, cultures, educations, employment, and possess a range of different skills. With all those differences, they must work together to complete the work in a specific time and definite target.

The project manager has to coordinate the deployment of available personnel, and the range of skills they bring, to accomplish project goals on time and and on budget. This skill has become increasingly important as most projects bring together so many different disciplines. In construction projects, for example, there is a team for constructing the reinforcing concrete (for example); other teams for finishing the work, such as plumbing and electrical installations — and every branch entails deployment of its own specialized technologies and skills, which it is the project manager's job to coordinate. On the project manager's shoulders devolves the requirement of ensuring the highest-quality work on time.

Two drivers contend for the project manager's attention: that of ***cost*** and that of ***time***. Only one of these can be the project's main driver, and the responsibility falls on the shoulders of the project manager to find the right balance in each project. It is inevitably a balancing act because the selection of the main driver in each project is not determined by the project manager alone but by discussion and consultation between the project manager, its director, its sponsor, and other major stakeholders.

In some projects, reducing cost is the major factor whereas meeting the time target(s) is a subordinate consideration. For example, in the building of houses, mosques, churches, museums, and other projects that have a social aspect, the owner's investment may not be significantly affected by some extension of the time needed for the project's completion. On the other hand, with hotel construction projects, or oil and gas extraction and-or refinery construction projects, the owner's projected profits are extremely sensitive to unanticipated extensions of the completion date. For example, if the gain of production from an oil/gas project project is 50,000 barrels of oil per day, with an oil price of $80, every day that can be saved gains the owner $4,000,000; the owner of a hotel under construction will similarly be concerned to minimize losses in room rental revenues arising from project completion delays. It is the responsibility of the project manager to ensure *both* that all staff working on the project are kept fully aware of the main driver and its importance in material terms such as these, *and* to find ways that work teams involved in the design or execution of the project are encouraged to provide their own proposals, recommendations, and action steps that strengthen the ability and resolve of the entire workforce to are in the same direction of the project driver in reducing the time or cost.

At the same time, in each specific case, it falls to the project manager to figure out how best to balance how specific proposals affect the constraints of the cost/time tradeoff. For example, during a housing project, a proposal might come up from the engineers to use a type of cement to provide a rapid setting to reduce the time of construction, but it will increase the cost. Is this proposal acceptable? Certainly, it will not be accepted. On the other hand, consider the case of the construction of an oil or gas plant or new offshore platform, in which a proposal comes forward to use materials that are the cheapest, but require extra time to import from abroad which will delay the project some days. Is this proposal acceptable? Of course, this proposal is unacceptable, but if the same proposal was raised in the other project like residential, administration buildings or any similar projects, the proposal would indeed be excellent and acceptable.

These simplified but not unrealistic examples underline the importance of the clearest possible lines of communication being maintained between the project manager and the various personnel. No matter whether the driver happens to be time or cost, it is the driver sets the direction and if everyone involved in a project works hard, but in different directions, that effort becomes wasted. The same caveat applies to dealings between the project manager and elements outside but involved with the project, such as suppliers and contractors, so that their proposals in the supply materials and construction should be embraced and adjusted according to the criteria driving the project overall.

Project characteristics can be summarized as follows:

- A project has a specific target.
- A project is unique and cannot be replicated with the same task and resources expecting to give the same results.
- The focus is on the owner requirements and his or her expectations from the project.
- It is not routine work, but there are some tasks that are routine.
- A project consists of a number of activities that contribute to the project as a whole.
- There is a specific time in which to finish a project.
- A project is complex in that it works by a number of individuals from different departments.
- Project managers must be flexible to cover any change that occurs during the project.
- There are uncertainty factors such as the performance of individuals and their skills for some of the unfamiliar work or unknown external influences that may not have happened before.
- The total cost is defined and has a limited budget.
- A project gives unique opportunities to acquire new skills.
- It gives impetus to the project manager to learn to work under changing circumstances, as the nature of the project is to change.
- There are risks with each step of the project, and the project manager should manage the risks to reach the project goal at the end.

2.3 Project Life Cycle

The project definition is a set of activities that has a start time, time period, and end time. These activities vary from project to project depending on the nature of the project. For example, a cultural or social project or civil project — such as the construction of a residential building, hospital, road and bridges or industrial projects — is different in its characteristics. The examination that follows limits its scope to on industrial projects.

Civil projects, in general, vary from project to project depending on the size and value of the project. It can be anything from constructing a guard room to constructing a nuclear plant. Therefore, the quality varies depending on 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 do not wish to have a global competition. For, increasing the quality will increase the project total cost that they will execute, as if these companies have quality assurance tracking systems that will also increase the cost of the project as a whole. Therefore, they often apply the quality control only within the structure safety of the building.

In the case of major projects, there are many execution companies or engineering offices working. Therefore, we must also take into account that firms implementing quality assurance procedures are necessary and vital, as well as the quality control carried out in all phases of the project based on the project specifications.

Stages of construction projects start with a feasibility study, followed by preliminary studies of the project, following detailed studies with detailed drawings. Then, the operation crew will receive the project to run.

In all these stages, there are many types of quality control that are required to obtain a successful project that can return benefits and appropriate return money to the owner and all parties participants in that project. Figure (2.1) shows the life cycle of any project.

From this figure, it is clear that a feasibility study accounts for only 5% of the progress of the project, while completion of the engineering designs comprise only 25% of the project's progress. By far, the biggest project stage in terms of time and costs is the execution phase.

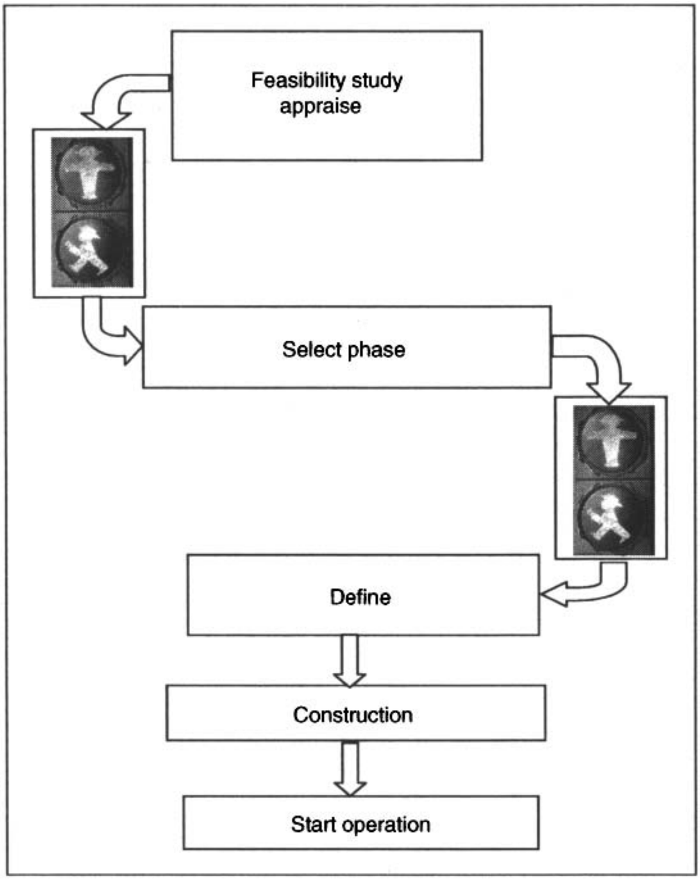

Figure 2.1 Project life cycle.

As shown in Figure (2.1), after the feasibility study senior management should have a definite answer for the following question: Will the project continue or will it be terminated? Here is the gate if there is a positive situation, then cross the gate to the next stage to the preliminary studies, which will provide a more accurate assessment of the project. After that, another decision will need to be made on whether the project will move forward to the detailed engineering and construction phase.

At each phase of the project, there is a role for the owner, the contractor, and the consulting engineer. Each system has its own method of project management, and every stage of these methods has its own characteristics and circumstances, which follow a

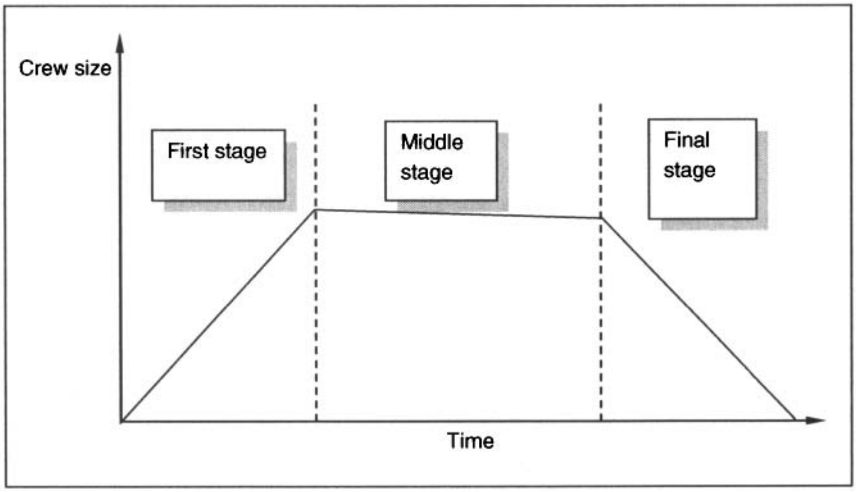

Figure 2.2 Change of crew size during project life time.

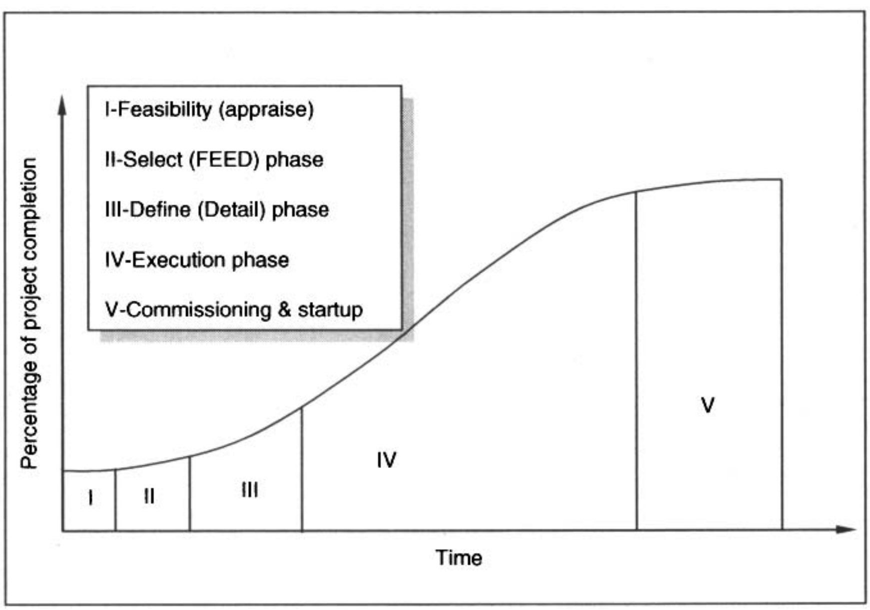

Figure 2.3 Industrial project main phases.

change in the area of employment Scope Of Work (SOW) that clarifies each stage for each of the three parties.A characteristic of the project life cycle is that is changes from time to time. In each period there is a different number of personnel and employment in the project. For example, at the beginning of the project the number may be very small but then increases when the number of activities being carried out increases and then gradually decreases until the end of the project. Figure (2.2) shows the change in the number of personnel in the project.

From the above figure, it is noted that the project manager should have the necessary skills to deal with the changes that occur during the life cycle of the project.

2.3.1 Initiation of the Project

In any major projects there is involvement of many project managers, as there is an owner, an engineering consultant, and a contractor. All of them should go through the same steps that we will discuss, but each person does it based on his or her goals, target, and company system.

In general, any project starts from a creation of a formal document called the project charter. The project charter is described in the Project Management Professional (PMP) guide, but its name is different from one company to another. This document is extremely important for getting a project started in the right direction.

There are many reasons for starting a project. In general, for commercial and industrial companies, making money is the reason for doing a project. However, in some cases, there are many other reasons for doing projects, such as to follow government regulations and laws, to enhance the health, safety, and environment (HSE) for a company, or to help with oil disposal and the instant cleaning of the Gulf of Mexico due to the oil spill that happened in 2010. In some industrial and commercial companies, the projects stay current with developing technology.

A project charter is defined in Project Management Professional Book of Knowledge (PMPBOK) and is expanded in the third edition due to the importance of this paper. It also recommends that the contract with the customer will be completed before the approval of the project charter.

Noting that, the definition of the customer is wide-ranging as everyone including the project managers, are a supplier and customer at the same time.

When the contract is signed by the customer the scope of work and deliverables should be clear, because the number of changes that can be made to the scope after the contract is signed is very limited. Therefore, there will be enough information to be included in the project charter.

The definition of the project charter in PMPBOK is a document that formally authorizes a project and includes directly or by reference to other documents the business needs and the product descriptions.

This document is usually made by the senior project manager, as the project manager will not be defined in this stage, so the document should be simple, precise, and accurate. To put the reference is not recommended because the top senior management does not have time to go deeply in the document. Also, I agree with Newell (2005) that this document should be small. If it is a big document you will face many questions and inquiries.

This document usually contains the following:

- The name of the project
- The purpose of the project
- The business need for this project
- The rough time schedule is defined by the project time period
- The budget of the project
- The profit from the project using the payout method (discussed further in Chapter 3)
- The project manager in any situation

After signing this document the project manager will be selected through a discussion between the project sponsor and the senior managers. In the case of a small project, the project manager has been defined, so there is no need to include his name. In addition, the project manager will prepare this document under the supervision of the project sponsor.

It is better that the project manger prepare this document, as he or she will be the most involved in the project and will closely understand the target and goals for the senior manager.

2.3.1.1 Getting to the Scope Baseline

As previously discussed, everyone in the project is a customer and a supplier at the same time, including the owner who is a supplier to the operation department in his company or any other end user.

The key topic in any contract between two parties is to define the scope. As defined by PMPBOK, the term scope may refer to the following:

- Product scope, which includes the features and functions that characterize a product or service
- Project scope, which is the work that must be done to deliver a product with the specified features and function to the end user

The product, which will be delivered through the project, should satisfy both the customer and the stakeholder.

The scope should be prepared after clearly defining all the stakeholders. Take more time in this stage, because, in most projects, the scope baseline takes weeks, or even months, not days, to finish. Take ideas as needed from the key persons who are sharing in the project, so that they are satisfied with the scope as it is and won't demand changes to it later.

So, after many meetings reduce the unnecessary items from the scope, or define part of the scope to the supplier so that the scope baseline is documented and approved by the concerned stakeholder.

After you define the scope of work, be sure it is clear to the supplier who will provide this service. You should use any communication and skills necessary to make the scope of work clear to the supplier. An engineering company will provide a list of deliverables. After you send the company the scope, be sure that the deliverables match with your requirements and that everyone has read any statement based on his or her background and previous experience.

It is better to return to similar projects and look at the work break down structure (WBS), and then review if you are missing anything from the deliverables list. In major projects, every discipline should review the deliverables list received.

This document needs to be clear because it will be read by many people. The SOW is the most important part of the statement of requirement document (SOR), because most of the conflict in any project is due to a misunderstanding of the scope of work. In some cases, the supplier may provide a small user manual to use for maintenance service. On the other hand, the operation and maintenance engineers may be waiting to receive a comprehensive user guide as they have a full responsibility to do the maintenance in house and avoid using the supplier in minor maintenance situations based on their policy, or they are afraid that the supplier will be out of business or has merged with another company, which traditionally happens. After receiving this manual, you may be in crisis because the supplier is doing what you are requesting, but the end user is not satisfied. In this case, you will change the order. From this example in the deliverable list, the contractor will deliver the "user manual" but it is different from the stakeholder's expectation.

This situation is repeated many times in oil and gas projects. However, if we apply the whole building commissioning system methodology, as presented and discussed deeply in Chapter 8, these problems may not occur. The acceptance criteria, the test procedure, and criteria should be defined in the scope of work. So try all of the deliverables that are tangible and measurable items that can be easily understood.

2.3.2 Feasibility Study

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

The phase of the feasibility study is the second step after the emergence of the idea of the owner. The owners in an oil and gas project are the geologist and petroleum engineering team, whose idea is based on oil and gas reservoir characteristics.

The economic study for the project will be performed by personnel from a high level of the organization and with high skill, as this study will include the expected fluctuation of the price for oil and gas and other petrochemical products during the project lifetime. Their experience is based similar, previous projects, so they have records and lessons learned from the previous projects.

In this initial phase, the selection of the team or the consultant office that will perform this feasibility study is important. In some cases there may be input from an engineering firm to perform generic engineering study about the project and estimate the cost based on their experience.

The phase of the feasibility study, also called the appraise phase, is followed by the preliminary (FEED) study phase. These two phases are very essential and critical because 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, which is the stage of defining the goal of the project. For these reasons, we must take great care with the economic data during this phase. The economic aspect is important at this stage, but the engineering input is very limited.

2.3.3 Feed (Preliminary) Engineering

This stage is the second phase after the completion of the feasibility study for a project. This phase of preliminary engineering studies, which is known as feed engineering, is not less important than the first phase.

This phase of engineering is one of the most important and most dangerous stages of engineering and professionalism of the project since 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 performs this study should have strong experience in these types of projects.

For example, a Liquefied Natural Gas (LNG) project is a type of project that needs an experienced office. Another example would be offshore projects that use Floating Production Storage and Offloading (FPSO) and that also need a special consulting office that has worked on this type of project before.

In the case of small projects such as residential or administrative building or a small factory, the phase of feed engineering is to deliver the type of structure, whether it would be a steel or concrete structure. If a concrete structure is decided, the engineer should define it as a pre-cast concrete, pre-stress concrete, or normal concrete and then determine the type of slab structure system if it will be solid slab, flat slab, hollow blocks, or others. Also, this phase defines the location of the columns and the structure system and if it will use a frame or shear wall for a high-rise building.

In summary, the preliminary engineering is to provide a comparison between these alternatives and the variation depending on the size of the building itself and the requirements of the owner. The reasonable structure system and similar mechanical or electrical system will be selected, so this stage is called a select phase.

In the case of major projects such as a petrochemical plant or new platforms, there will be other studies in this stage such as geotechnical studies, met ocean studies, seismic studies, and environmental studies.

The main element of this study is to provide the layout depending on the road design, location of the building, and hazard area classification in the petroleum projects.

Moreover, it needs to select the foundation type, if it is a shallow foundation or driven or rotary piles based on the geotechnical studies.

In the case of oil and gas projects, we need to study carefully the mode of transfers and trade-offs of the product and select the appropriate methods of transferring between the available alternatives options.

Now it is clear that, as a result of the seriousness of that stage and the need for extensive experience, in the case of large projects the owner should have competent engineers and administrative organization that have the ability to follow up on initial studies in order to achieve the goal of the project and coordination between the various project disciplines, such as civil, mechanical, electrical, and chemical, as all the disciplines usually intersect at this stage.

Generally, regardless of the size of the project the owner must prepare the Statement Of Requirement (SOR) document during the preparation of engineering requirements. The SOR will be a complete document containing all the owner information and needs concerning the project and the objective of the project.

This document is a start-up phase of the mission documents quality assurance system, as this document must contain all that is requested by the owner. The SOR document must outline the whole project and have a document containing all particulars of the project and its objectives and proposals and the required specifications of the owner.

This document also contains the technical information available from the owner, such as the location of the land and its coordinates system and its specifications. Noting that, this document will be a part of the contract document between the owner and the engineering firm, noting that the engineering firm will provide the Cost Time and Resources (CTR) sheets based on this document.

Table 2.1

Title:-	**Statement of Requirements (SOR) Preparation**
What	The SOR is a formal document. It can vary from being a one-page document (minor projects) to a sizeable document incorporating the "basis of design," i.e., plant, pipe sizes, pressures, etc.
Why	The SOR is intended to document, in a clear and unambiguous manner, the key engineering inputs and the major engineering requirements and management tasks that have to be completed in order to meet a particular business objective, this objective being clearly defined at the beginning of the SOR. The completed SOR is intended to identify the factors that the business sponsoring the project considers important to the ultimate success of the project, as well as being a high level specification of project deliverables.
How	Create a formal document, depending on the project needs.
When	Within the project framework, the SOR will form an integral part of the select stage DSP, and it is required for the chosen option at the end of Selection, and the project should not continue into Define until the SOR has been approved.
Who	In practice, the SOR is usually prepared by the project personnel who liase closely with the business unit personnel (SPA). It is important that the BU formally approves the SOR as it is effectively a contract between the BU and the project team defining high-level deliverables and expectations. Similarly, because of the significance, a change management procedure should be established that will ensure all the changes receive the necessary approval.

In the case of projects such as gas, an LNG gas liquefaction project is to determine the amount of gas, type, and specifications, which need to process and transfer with the clarification of temperature, pressure, and all other technical data for the final product to be shipped or transported outside. This is one of the most important data to be mentioned in the document, which is to identify the project lifetime. Specifications required by the owner in the project should be defined clearly and precisely in this document.

It should be noted that we must hold many of the regular meetings between the owner, technical team, and the consulting engineering responsible for the preparation of initial studies. Through that the SOR may be amended several times, and each time the document must contain the date and revision number as to contain all of the requirements of civil, architectural, electrical, mechanical and others found in the project.

We may recall here that in quality assurance we must be sure that the final document resides with all the parties and that everyone is working through this document, and it must be done to determine the number of meetings and the exact schedule of meetings needed to reach the target required.

The SOR document is not only required for the new project, but it is also needed in the case of modification to the buildings or in the plant. In the case of small buildings, the owner should define the required number of apartments, floors, and stories or any other requirements the owner feels is a benefit to his target.

Upon receipt of the engineering office, the SOR document is to respond to the owner document with another document that is called the Basis of Design (BOD). Through the document the engineering firm will clarify the code and engineering specifications, which will operate in the design as well as the calculation methods, theory, and computer software that will be used.

This document may state the required number of copies of the drawings that will be sent to the owner and the sizes of those drawings.

In addition, the engineering firm should request any missing data and require a third party to supplement information such as weather and environmental factors. This document will be review by the owner carefully and can be amended many times until satisfies the two parties.

At this stage, it is important to make sure that both the owner and the engineering firm have the same concept and there is a complete agreement among all the technical aspects. In the preparation of any drawings, we are now in the FEED studies, in which the drawings should be delivered to the owner to review and give input. The owner and the engineering firm should agree on the number of reviews of the document, and if it goes over the specified time it means that the owner has accepted it. This is very important in controlling the project's timeline.

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 follow-up time according to the schedule agreed upon in advance. We may need to consult a specialized engineer in planning who is the Planner Engineer. The engineer should be specialized in cost control, the estimated cost of the project, and the expected time, which is comparable in the feasibility study.

After clearly selecting the equipment and the project layout in its final stage, the project cost estimate will be more precise, and, as the end of the initial study approaches then one can obtain the nearest possible accuracy of the cost of the project as a whole. It is worth mentioning that investment projects, such as petroleum projects, that have any savings in time, bring a big return where the return of income or expense is calculated by the day.

It is imperative that we note here that at this stage one should not overlook the way in which to determine the maintenance of the buildings and the facilities foundation in oil and gas plants in the future, which can be done by establishing the age of the structure and defining the structure lifetime, type of structure, and the ways of maintenance. The project site itself and the surrounding environment must be considered to determine the ways to protect it from weather, reducing the cost of maintenance over time by selecting different methods of maintenance.

For example, you can protect a reinforced concrete foundation from corrosion by protecting the reinforcing steel, for example, through a system of expensive protection at the beginning of the construction with a periodic low-cost maintenance. On the other hand, we can use a low-cost alternative during construction and high-cost regular maintenance as a simple example if we don't use any external protection system.

The structure, the mode of operation, and the 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. To answer this question, you must decide if it needs additional tanks as standby for maintenance purposes or not.

In this phase many other initial design decisions must be made, and therefore this stage, as previously mentioned, requires high experience, since any error would lead major problems during operation, which could cost a lot of money and could be prevented by a low-cost solution in this phase.

2.3.4 Detail Engineering

At the end of this phase, the engineering office will deliver the full construction drawings and specifications for the whole project that contain all the details that the contractor will execute. In this phase, there will be a large number of engineering hours, so it is necessary to have good coordination between the different disciplines.

Changes might occur in the cooperation between departments, and therefore it varies depending on the performance of the work of managers. The system of quality assurance is a benefit as it provides us with the basic functioning of all departments, despite any change in personnel. These problems often occur at the stage of the study that requires the cooperation of extensive, vital, and influential team members among the various departments of engineering such as civil, architectural, mechanical, and electrical department.

For example, when the managers of the Department of Civil and Mechanical Engineering have a strong relationship and there are regular meetings, good work will come from it and the meetings and correspondence will be fruitful.

You can easily determine whether your business might benefit from the quality assurance systems or not by taking a closer look at past experiences. When you meet with the team and you find that the goals and expectations are not clear between colleagues, then you should ask yourself if the majority of problems can be avoided if individuals committed to work through preselected and agreed-upon measures. All colleagues should fully and clearly know their roles.

The system of quality assurance in this stage is important as it organizes the work, everyone knows the target of the project, and everyone's responsibility in the project is clear. The concept of quality is defined with a supported document. The documents are regarded as the executive arm of the process of the application of quality. Therefore, any amendment or correction in the drawings should go through the procedure and agreed system.

The drawings should be sent in a specified time to the client for review and discussion through an official transmittal letter to control the process time. Any comments or inquires should be discussed and made through agreement between the two technical parties, then the modification will be made by the engineering firm and resent to the client through the same communication procedure.

To avoid duplicating copies of the drawings or confusing versions of them, every document should be dated, and the reviews should also be dated. This system should be used throughout, until the final stage of the project. The final approval of the drawings should be sealed with a stamp indicating "Approve For Construction" that these are the final drawings for approval of the construction.

After the completion of the detailed engineering phase, the specifications and drawings are ready for the execution phase. You can imagine that in some projects the documents may reach hundreds of volumes, especially the specifications and other operation manuals, as well as volumes of maintenance and repairs.

2.3.5 Decision Support Package

This package of documents is usually put together by the project manager and the project team, then it is presented to senior management to help them make decisions, as in Figure (2.1) to provide green or red light to go to another stage of the project or stop the project. A decision will be made at every project gate in order to enter another stage, and this is very important after the feasibility study and feed engineering phase. In order to define exactly the DSP and how to implement it, the following questions should be answered.

2.3.5.1 What is the DSP?

The Select Decision Support Package (Select DSP) is a compilation of key project information used to support decision-making at this gate. The decision to be made is generally whether or not to fund the Define stage of the project. Therefore, the DSP must accurately support the team's recommendation with particular emphasis on potential rewards and risks. The project should not progress through the gate to the next stage until the project team presents the Gatekeeper with the "key to the gate" -- the Decision Support Package (DSP). This document should include information taken from the Select stage activities that is necessary for the Gatekeeper to review and approve the project for the next stage. A plan for the next stage incorporates the following:

- A clear set of expectations
- Signed SOR
- PEP (including project specific WBS)
- Conceptual factored Class 3 estimate
- Holistic risk assessment
- Exit strategy
- Output from applicable VIP
- Defined list of capital and manpower resources for the next stage

This decision should be aligned with the business goal, strategy, and objectives, and it must be determined based on the needs or deliverables of the appraise stage.

The DSP includes three major components: the Executive Summary, the DSP Notification Document, and the DSP Reference Document.

2.3.5.2 *Executive Summary*

The Executive Summary is a stand-alone document that provides an overview of the project. The executive summary may range from just one page to ten or more pages, depending on the size of the project. The Executive Summary includes:

- Project Overview (includes SOR)
- Business Case
- Decision & Risk Analysis
- Plan for Project and Next Steps

2.3.5.3 *DSP Notification Document*

The Notification Document provides a short formal written (or electronic) record summarizing the opportunities or options to be moved forward into the next stage, together with documentation addressing those opportunities or options that are being dropped. It is intended to be shared with all stakeholders of the project.

2.3.5.4 *DSP Reference Document*

The Reference Document contains all other reference materials such as project schedule details, contract work scopes, etc., which have been succinctly presented in the Executive Summary. This documentation is retained as reference material, and it isn't formally distributed outside of the project team.

2.3.5.5 *Why Is It Important?*

The Select DSP allows the Gatekeeper to make an informed decision as to the next course of action in relation to any specific project, i.e., the key to the Define gate. It will provide information on the best identified project approaches and analyses concepts, and it will include prelim cost estimates to confirm project viability in line with the business strategy. In addition, one of the most important uses of the DSP is to ensure that the right people are selected for the next stage of the project, even before you get to that stage.

Using information provided in the Select DSP, the Gatekeeper either:

- approves the project, giving the team the ability to pass through the gate to the next Select stage;
- defers the project, based on portfolio management;
- "kills" the project; or
- recycles the project.

Keep in mind that "recycling" a project back through a stage should be a rare occurrence, and it is not really a desired option. A recycled project often indicates a failure in communication between the Gatekeeper and the project team.

2.3.5.6 *How Can We Implement this Document?*

The Select DSP is a compilation of key project information used to support decision-making at this gate. This is a formal document that will be issued and presented to the Gatekeeper for review at the end of the Select Stage.

2.3.5.7 *When Is the Reasonable Time?*

The project should not progress through the gate to the next stage until the project team presents it to the Gatekeeper, who is usually the senior manager with the "key to the gate," which is the DSP. This applies at all gate stages within project life cycle.

2.3.5.8 *Who Is Responsible for this Document?*

Single-Point Accountability (SPA) for the project, who is usually the overall project team leader, should deliver the Select DSP in line with Gatekeeper's expectations. They should be assisted where required by appropriate resources needed to provide overall project assurance as well as an increased involvement by the project teams. It is essential for the project's success that the correct team is formed to deliver the select deliverables and DSP. The select stage of the project should not proceed unless there is a clear business commitment to these deliverables through resource allocation and support. Project lifecycle commences at the beginning of select.

2.3.6 Design Management

The target is to control the design stage to provide high quality with a better price.

The design input is all technical information necessary for the design process. To be clear, the basis of this information comes from the owner through the statement of requirement (SOR) document, so the engineering firm should review this document clearly, and if there is any confusion or misunderstanding it should be finished and clarified in the document and through meetings.

Instructions for controlling the design are often provided in the contract. The client puts in some instructions to control the whole process or request some specific action, such as a representative from the audit during the design phase.

The designer must take into account the available materials in the local market of the project country and its location, and they must match with the capabilities of the owner. The designers must have a contact with and full knowledge of the best equipment, machinery, and available materials.

The design must be in conformity 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 the environment are critical subjects now days, so every design should match with health, safety, and environmental regulations.

The computer is one of the basic tools now in the design process as well as in the recording and storage of information, with the possibility of changing the design easily. It is easy now to modify the drawings by using Computer Aided Design (CAD) software in order to obtain more precise information with the access to information through various forms of tables and diagrams.

The design output must be compatible with all design requirements, and design should be reviewed through the internal audit. The design must be compared to an old design that has been approved for similar projects. Any engineering firm should have a procedure such as a checklist to review the design.

The audits of design review are intended to be on a regular basis. In the case of important stages in the design, the audit must have complete documentation and could take the form of analytical forms such as the analysis of collapse, with an assessment of the risk of Failure Mode and Effects Analysis (FMEA). In the case of oil and gas projects, operating risks such as Hazard Operation (HAZOP) are being studied. The review will be conducted by engineers with higher experience.

2.3.7 Execution Phase

Now everything is ready for this stage, and this stage involves both quality assurance and quality control, especially in the reinforced concrete works and in the concrete itself composed of many materials such as cement, sand and coarse aggregate, water, and additives in addition to steel bars. Therefore, it is essential to control the quality of each element separately, as well as the whole mixture. In addition to that, the quality control should follow restrictions during the preparation of wooden form, the preparation and installation the steel bars, and pouring and curing concrete.

It is clear here that the contractor should have a strong, capable organization, capable of good quality control, and documents that define the time and date in which the work was carried out and who receives the materials. At the same time, it's important to determine the number of samples of concrete and define the exact time, date, and result of each test.

Often during execution some changes occur in the construction drawings of the project as a result of the presence of some of the problems at the site during the construction or the presence of some ideas and suggestions that can reduce the time of the project.

However, it is important that the change of work be done through documents in order to manage the changes and build them into the drawings.

The supervisors and the owner must have their special organization. The owner organization in most cases has two scenarios:

- The owner will establish 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 the capability for local and international competition, if and only if the concept of quality assurance of the contractor project team is very clear and has experience in a comprehensive quality system, because the aim of all the competitors on the international scene, since the period of working through an integrated system, is to confirm the quality of the work and quality control in all stages of execution in order to achieve full customer satisfaction.

2.3.8 Commissioning and Startup

The importance of this stage varies depending on the nature and size of the project itself. In the case of housing projects, commissioning and start-up will be applied to the building during the finishing activities of being completed in phases as per each floor or by each stage of completion as receive the masonry work, then plastering and painting, and so on. The team formed by the owner and consultant is to receive the work in this stage. The work will be a list of the parts that need repair from the contractor, such as an HVAC system, painting, and so on.

It is a different story in the case of industrial projects such as constructing pipelines, pumps, and turbine engines, or a new plant. In this case, a new team will formulate consisting of members of the projects and operating personnel who receive work and have the head of the team. Noting that, this team should be competent and have previous experience in commissioning and startup. The team will have a specific target to start the operation where the reception is not performed until after the primary operation. Start up and commissioning at this stage is to make sure that all the mechanical systems work efficiently and safely without any leakage or error in the operation. This stage takes a period of time depending on the size of the project and may extend to months.

The cooperation between the operation and project team is very essential. The operation starts according to the schedule for this specific stage. It can be in hour units, and all the parties should agree on this schedule to provide a smooth transition in a safe manner, because increasing temperatures and pressure without previous study may cause a disaster. So again, competent people and a good schedule are the keys for successful commissioning and startup.

2.4 Is this Project Successful?

When you see a huge oil or gas plant and want to ask yourself "Is this a successful project?" the first thing that jump to the mind is the money profit only, but when determining whether a project successful, you should focus on the management of the project. You might see a high-rise building and think that the project seems successful, but is the project management 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 is the actual cost and budget?
3. Is the project performance according to the required specifications?

For the last question, we can answer yes because for a big project we cannot agree or approve anything with less quality or that is beyond specification. It is safe to assume that the quality is a red line that cannot be crossed or negotiated. Therefore, the successful project manager has to achieve the goal of the project and satisfy all stakeholders. At the same time, the completion of the project on time and cost will not be more than the approved budget.

2.4.1 Project Management Goals

Every project should have a specific target or targets, and each target should be defined for all the team members in the project.

In any project, we will have the following element:

- Money
- Manpower
- Machines

The target of project management is to use the above elements to achieve the project with less cost and high quality. Therefore, every job in the project must manage one or more of the available resources and optimize the use of the resources in order to reduce the losses and achieve the project target within the time constraint, cost, and quality.

Based on the PMP guide, project management is characterized by multiple areas or topics that must be managed at the same time. These topics are as follows:

1. Project integration management
2. Project scope management
3. Project time management
4. Project cost management

5. Quality management
6. Human resource management
7. Communication management
8. Procurement management
9. Risk management

Based on Kotter, J.P (1996), there is a good differentiation between the management and leader. Management is a set of processes that can keep a complicated system of people and technology running smoothly. The most important aspects of management include planning, budgeting, organizing, staffing, controlling, and problem solving. Leadership is a set of processes that creates organization or adapts to significantly changing circumstances. Leadership defines what the future should look like, aligns people with that vision, and inspires them to make it happen despite the obstacles.

2.4.1.1 Project Integration Management

The purpose of integrated management is to ensure that all elements of the project that are interdependent have a good correlation between them. It is done through good planning and the existence of an operational plan for the project, which is the interdependence between the members of the team. At the same time, find a way to control the project performance in case of any change in the project.

2.4.1.2 Project Scope Management

The extent of the project, its size, and what must be fixed and known need to be established. Therefore, we must take the necessary actions to ensure that all work required has been known with specific planning and that only the work necessary to achieve the success of the project is done. This is done by identifying the volume of work and planning.

2.4.1.3 Project Time Management

The project must have a specific start and finish date, and the duration of the implementation of the project must also be defined either by the owner or by the contractor who will carry out the activity or by the agreement between both.

So that we can finish the project according to the schedule and manage the project time, the schedule plan must be done for all the activities and the time of each activity and the relation between them must be defined.

No one can achieve the project on schedule if the time commitment for each activity is not followed.

2.4.1.4 Project Cost Management

To determine the time required at each of the activities of the project, the resources should be allocated to the execution of the activity by the individuals, materials, and equipment.

Therefore, the cost of each activity and the rate of spending on each activity have to be estimated to obtain the cash flows through the project.

Managing the cost of the project requires actions and steps to ensure that, in the end, the total money spent on the execution of the activities equals the budget allocated for the project, which will be allocated from the initial cost estimate.

2.4.1.5 Project Quality Management

There is no doubt that the quality borders are a commitment to quality specifications, both for the materials and processes. In most cases, quality is overlooked when discussing the projects and only focusing on time and costs. However, it does not mean that quality is less important than time and costs, but the relationship between these three elements are very dependent on each other. So, to be clear, any activity is considered to have been finished only if it matches the specifications. There is no doubt that these specifications have a significant impact on determining the cost of the activity.

It is clear already that the management of a project is done through a set of plans for the time, cost, and quality. The preparation and implementation of these plans should be shared with all the team. It is normal that any failure of any function of the organization affects the entire project, in terms of time or cost or quality.

2.4.1.6 Project Human Resource Management

It is essential to use order steps and reasonable tools that allow making good use of manpower. The establishment of a good organization, according to the needs of the project and the needs of individuals, is very essential. The work of human resources should match with the schedule planning of the project. There must be conformity between the individual objectives and project objectives through motivation and knowing that the continued success of the project is a success for all. To be profitable and gain a strategic win is the basis for the interaction between project management and personnel.

2.4.1.7 Project Communications Management

There must be a procedure for providing good communication between members of the team by planning and holding regular meetings for team members and other partners in the project.

The way of transferring information between the team members should be identified and quick and easy. Now there are many types of technology that can achieve management and good communication, such as networks, e-mail, and meetings that can be held through a video conference.

2.4.1.8 Project Risk Management

Each project has its own risk, whether the result of technical aspects or the result of procedures and the project execution sequence. Therefore, the risk should be managed by identifying it first, setting priorities, and then finding a solution according to the type of event, its likelihood of occurring, and its potential impact on the project.

This must be followed by periodic follow-up phase and precise for each item, which will have high imapct on the project with the assurance of the distribution of responsibilities and authorities for each item that will have a high impact on the project.

2.4.1.9 Project Procurement Management

Every project depends on the procurement of materials or equipment. Therefore, it is necessary to prepare procedures to deal with external vendors to make the purchases serve specific objectives of the project.

Therefore, we must determine purchasing strategies as well as the nature of the contracts and how to manage the identification and follow-up of procurement procedures. We must also identify how to maintain the quality of purchases or services provided to the project.

2.5 Project Management Tasks

Every manager in the project organization is responsible for planning and monitoring this plan and assuring that the executive work matches with the plan. To achieve that, he should coordinate with other managers and provide a report to the project manager.

The main items in planning and monitoring process are the following:

- Define project objective
- Define the work
- Define the work time period
- Define the available and required resources
- Define the cost
- Review and evaluate the master plan
- Accept the master plan
- Follow up execution
- Follow up cost
- Compare between 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 thing in management is to identify the target of the project management process as in the planning, execution, and follow-up. There are three factors that affect and/or are affected by resources time and funding.

The following is a summary for all the tools available to the project manager for managing the project for success.

2.5.1 Define the Project Target

Identify the objectives of the project in the first phase of the planning stages. The project objectives must be defined from the beginning, such as the completion of the project in less time or a reduced cost.

For projects on the technical side, we must identify where possible the output, the final words of the basic components of the project.

2.5.2 Define the Scope of Work

The required work should be defined precisely as it is the basic plan for the project in three main areas: determining the work required,

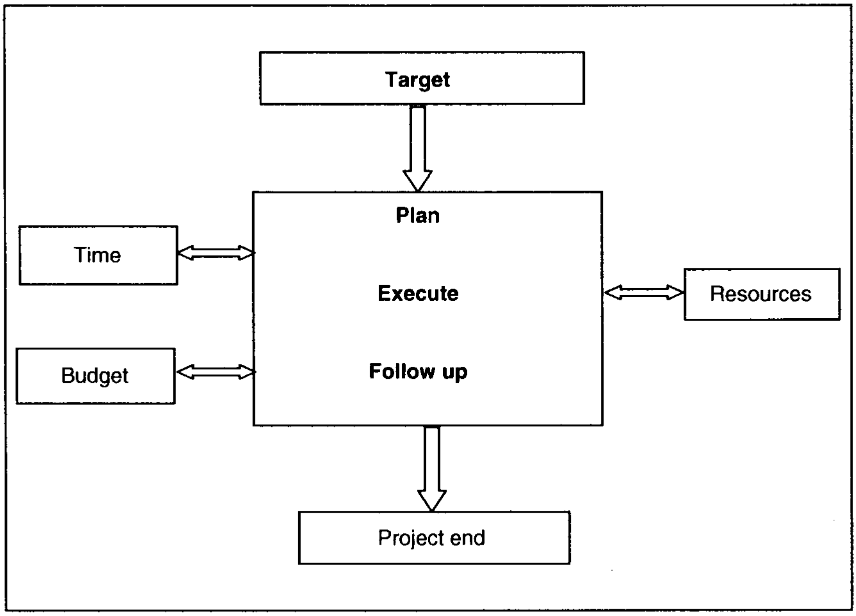

Figure 2.4 Project management.

the resources and budgets for the work, and the time required for the implementation of the work. So, it is clear that the success of the planning process as a whole depends to a large extent on the identification of the work.

2.5.3 Define the Time Frame

One important factor in determining the objectives of the project is to develop a plan for the project through a time schedule. It should be developed in the form of a base scale of the project, and the main objective of the base scale of the project is to put the project time in clear steps by preparing the calendar, which is one of the main pillars in the management of any project.

2.5.4 Define the Available Resources

The basic tool for identifying resources required is a list of work that outlines the required labor, materials, and other services for each of the activities and our numbers if we have a schedule for these actions. Then you can now have a clear idea of the necessary resources at different periods. At the same time, it is required to compile information on available resources and plan work required to achieve the project.

2.5.5 Define the Cost

The cost can be determined by the following:

- The quantity of resources required to implement any action
- Cost rates for each supplier of the resources
- The time of each work activity
- Fixed costs based on the activities

The cost of the project varies according to the size of the project, and consequently the time of the implementation of any work depends on the time schedule for the project. Therefore, the budget for the project should agree with the rate of spending on the project in relation to the schedule prepared by the project team.

2.5.6 Evaluate the Master Plan

Upon completion of all the previous steps, we evaluate the master plan of the project and how it will achieve agreed objectives of the project in terms of time and costs. There is often a need to amend the plan, often in the field of resources, as they usually clear the requirement for a certain type of a large amount of resources in one specific application. Accordingly, it will be in the line of the settlement of the rescheduling of resources of some activities, which does not affect the master plan of the project. At the beginning, the schedule must be made through discussions between the owner and the contractor. Then the timetable will be agreed upon by all parties to achieve the success of each party according to its objectives.

2.5.7 Accept the Master Plan

Store the master plan securely as it will be the basic reference in the future. After the approval, storing it is an important step for the planner, who is to keep the original master plan without any change to return to it if there is any confusion.

Review the execution plan and the performance through this plan, as there usually will be changes in this plan according.

2.5.8 Schedule Follow Up

After all the previous steps, the execution phase will start. Then start tracking the progress of work by registering the amount of work done and the used resources. This will apply to the activities that took place as well as the activities under the operation.

Follow-up schedules are adjusted periodically in order to be commensurate with the actual on site. We must therefore do the follow-up periodically and as agreed at the beginning of the project.

2.5.9 Cost Follow up

The cost should be follow up periodically with an agreed period of time to track the project cost and compare it to the estimated cost of the project that was identified through the budget and approved by the owner.

We must follow the paid cost and the cost that is due to others with the time of the purchase orders and contracts of employment. Any deviation gives a snapshot of the position to evaluate the deviations at the same time, and then we can expect the total cost at the end of the project.

2.5.10 Comparing Between Actual Work and Master Plan Cost

The effective project manager must follow-up on the progress of the work. Follow-up costs in themselves do not represent the control of the project, and that control of the project includes several steps that will lead to taking the steps geared towards the achievement of the objectives of the project.

The first step is to compare the progress of the work plan. It is clear that the most important indicator is the date for completion of the project calculated by the critical path. If there was any delay in activities on the critical path, it will inevitably lead to delays in the date of completion of the project.

The project manager should also monitor the activities rather than the critical path, as any significant delay with low performance rates may lead to influence on the critical path.

For the activities which finished, it would be sufficient to compare the actual costs to the estimated budget for each activity.

2.5.11 Performance Evaluation

There are two main important indicators used to assess the performance of the project. The first is the date for the completion of the project, and the second is the cost of the project and is not intended here is the use of these indicators on the activities of separate or a specified period of time. It is only intended to follow the general direction of the project through these indicators on the relatively long periods of time. It is not a dangerous imbalance in one or some of the activities, but the big problem is a deviation in the general direction of these indicators.

2.6 Project Manager Skill

From the previous discussions, it is obvious that the main player in any project is the project manager, as he carries the load of formulating the team.

When thinking about selections of the project manager, consider that this role is different from operations and routine work as the project is unique and may not have been done before.

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. Then the number increases with time, and when the end of the project is near, there will be less than before. Therefore, the behavior of the project manager must be flexible according to the variables of the project.

The project manager deals with all levels and different individuals from various departments and other parties. The project manager must be a good listener and must be able to guide and persuade. He or she must have previous experience in the same type of project and have the necessary technical information to manage the project in an efficient manner. In addition to that, he or she must have the skills of project management in terms of managing time, costs, resources, communications, and contracts.

The skill of communication is very important, as the facts do not always present themselves. The best ideas in the world would not be known without communication. Therefore, communication and providing specific and clear instructions is important, as any misunderstanding can cause a loss of time and money at the same time. On the other hand, communication with the higher levels is necessary in order to provide summaries of the performance of the project in a way that allows senior management to help with the project and not vice versa.

Finally, the project manger must have the ability to have a more accurate sense of a broad vision for the whole project. He or she must have the capability to manage dialogue, especially in meetings, which is regarded as the strongest means of communication to reach the goal that is the main success of the project.

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3

Economic Risk Analysis

3.1 Introduction

This chapter discusses the main variables affecting an economic study. Assessing and managing investments in a new project involves a complex interaction of many variables. Any big organization will have a range and variety of projects to perform. Prioritizing them requires applying economic tools to complete a risk assessment for each.

Uncertainty, a constant preoccupation in any economic study, is assessed by applying the Monte Carlo method for simulating the chain of decisions to be taken under uncertainty is most widely used in industrial projects.

The major risks in any project will be the following:

- Economic risk and value
- Technical risk
- Political risk

Economic risk is affected by market predictions and changes in currency rates, inflation rate, and energy prices, among others.

Technical risk is affected by the engineering study applying new technology, as in the case of oil and gas exploration and production projects in which there is always a probability to find a "dry" well after drilling. **Political risk** depends on the country, as some countries have political stability, and in other countries political conditions are unstable.

3.2 Project Cash Flow

Net cash flow is the key to all investment decisions. This number enables the conversion of all elements of the project to their effective cost, from which the different projects relative necesaity and usefulness can be realistically compared.

Net cash flow (NCF) is used:

1. To measure the return of the project and liquidity over the work of the project
2. To calculate economic return by the net present value NPV
3. To calculate the risk assessment of the project
4. To reduce taxes on the life of the project

Net cash flow each year is calculated as the revenue from the project after subtracting the expense cost every year:

- Net cash flow = revenue − (operating cost + additional indirect expenses + taxes + investment + depreciation)

Revenue is the owner's income from the project every year. It is calculated as a function of the volume of production that the project produces multiplied by the price for this product.

Operating cost consists of the direct cost, the cost of the materials used in the product, and the indirect cost, the salary for the management level, computers, furniture, and others.

Taxes, the most time-consuming subtask in the working-up of net cash flow (NCF) estimates, are a critical element of project management. There are production taxes, sales taxes, property taxes, state or regional income taxes, and corporate income taxes to be taken into account, among others. The applicability and amount of various taxes are functions of the location of the project and the laws govern such projects in whatever the country.

There is more than one way to compare different projects. A good rule of thumb is that any investment project should be profit-based. Therefore, the owner is normally involved in the feasibility study phase, making a comparison between more than one project in order to determine the revenue that suits the required interest rate that it deems appropriate to the company goal. Different economic calculation methods that assist decision-making are illustrated in this chapter.

Making a comparison is very important in feasibility studies for any project. It is important that in any of these methods you should identify the net cash flow.

Figure (3.1) shows the net cash flow diagram. For the beginning of the project, a lot of money will be spent to build the infrastructure or to purchase machines and other necessary equipment required to deliver the required product. The value of these assets is called a capital cost (CAPEX), and most of this expenditure arises at the project's outset.

Assume that a project will start after one year. In this year, you sold your product. Hence, knowing the price and the number of products you will sell will enable you to define the revenue in the first year and to carry the calculation-estimate forward, into the second year, third year, and for the lifetime of the project.

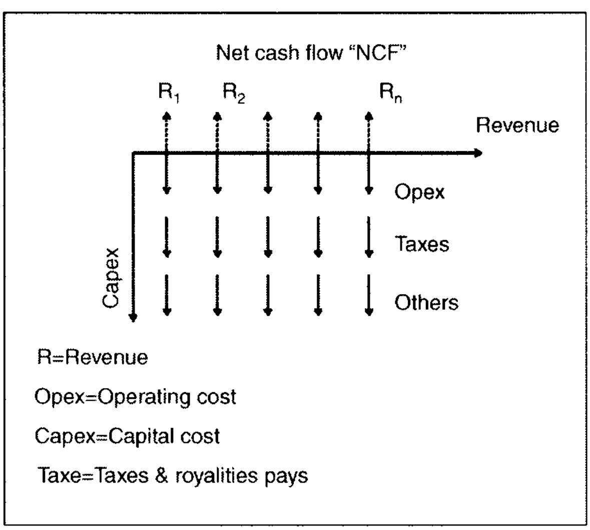

Figure 3.1 Net cash flow diagram.

The number of products for every year can be known, but with uncertainty. Also, when you seek to establish the price of the product, this number may not be so simple to obtain: it varies from year to year, and further uncertainty about this number must increase with time. Determining the value of a price requires a specialized consultant for types of project investments such as building hotels, which is different than a factory for producing children's games, or a steel-making centre. Therefore, a strong market research study is needed that identifies the competition, works out the market demographics, and uncovers global market trends that would assist developing an export strategy for the product.

In the oil and gas business, there are specialist teams in the main office of each international company that provide advice about each country. Any country that has this development also has a team to perform this calculation, as the revenue in this case will be the volume of barrels of oil that can be produced every day, which depends on the reservoir, where uncertainty lies in predicting its volume. However, the oil price will be set by the company's headquarters as it develops a strategic plan for future prices.

For example, a reservoir for oil and gas can be predicted, but it is constrained by operational capabilities, which include managing the reserve to maintain the pressure inside the reservoir by limiting the production. From Figure (3.2) it is shown that production will

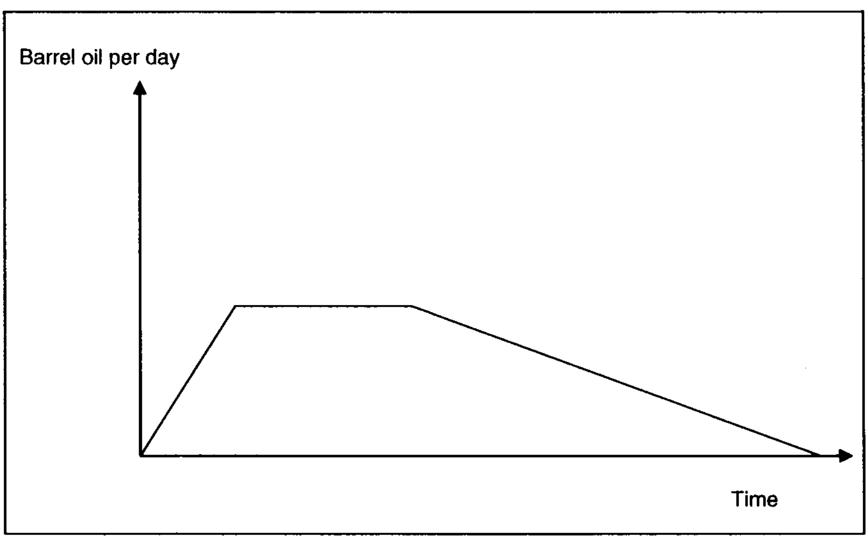

Figure 3.2 Production performance over project life time.

increase in the first few years, and after that it will be stable for a few years, and then it will decline until reaching the uneconomic limit of the well, which should be defined. As this limit, the expenses will be higher than the gain, so the well will be shut off.

As shown in Figure (3.1), the revenue is a positive to the cash flow, but every year there will be an expense due to operation, maintenance for the equipment, and other expenses. The operation and maintenance cost is called the OPEX. In addition to the operation cost, there will be taxes that will be paid to the government, which will usually be a percentage from the production.

Any equipment has a lifetime. From an engineering point of view, the equipment and building lifetime is defined as being usable until it fails or is functionally not usable. But there is also a financial lifetime from a financial point of view. All equipment has a value when it is new, but with time its value reduces, and when you need to dispose of it through sale, it will have another price. This price is called the book value. Each year there will be a depreciating cost for this equipment. The value of this depreciation is governed by a schedule used by the tax authority of the host government.

Assume you purchase a new car that costs $20,000 now. The next year you want to sell it, and according to the market its value is $15,000. Therefore, you assume that the value of your asset reduces from $20,000 to $15,000. But what about after 4 years? Assume the book value drops to $12,000 in the fourth year after you purchased the car, but in the market it will cost $10,000. In a private company this is not a problem, as you will simply lose money on the sale. But for a government or public company, this will be a problem, especially in developing countries where relatively stringent rules may compel sale of the car at a price based on the book value or higher.

The depreciating value of any equipment will be deducted from the corporation's taxes. The rate of depreciation can be calculated by different methods, but all of these methods are used based on the government's tax laws. The most common depreciation method will be illustrated.

3.2.1 Depreciation Methods

In the case of oil and gas, capitalized items for depreciation include casing, tubing, flow lines, tanks, platforms, and other equipment. Tangible investments are basically related to any item that has a life in excess of one year.

Campbell, et. al. (1987) mention that the depreciation write-offs depend on the type of expenditures. The law presently divides investments into two categories: 5- and 7-year lives. The depreciation schedule for each project life is presented. The life year values under the 1987 laws in the USA are derived from a 200% declining value over 5 years, often referred to as a 40% declining value in Europe and Canada. Depreciation in the 7-year category converts to a 28.6 % declining balance in those countries. The 7-year category covers virtually every petroleum investment except for drilling equipment (5 years), oil refining equipment (10 years), and transmission pipeline and related equipment (15 years).

Depreciation begins when the project is classified as "ready for service." The definition of ready for service varies among companies. Some define ready for service as capable of producing, while others require production actually to take place before depreciation: gas wells, for example, are often completed but not hooked up. Processing plants take several years to build, and start-up offshore platforms are constructed and wells are drilled, but production cannot commence until the product is disposed of. The same situation exists in remote, onshore areas. In each of these cases, a delay can be expected between technical completion of the project and the initial flow of revenue.

The question that arises here is whether a tangible investment capable of working, but not active, is ready for service and can be depreciated. Opinions and practice vary. Some argue that capable of working is the same as ready for service. Others take a more conservative position and begin depreciation only after products are sold. Decisions regarding the correct approach depend on the legal staff's opinion. The "capable of working" interpretation

Table 3.1 Financial life time

5 year life	Automobiles
	Trucks
	Drilling equipment
	Computer
10 year life	Crude oil refining equipment
15 year life	Transmission pipeline and equipment
31.5 year life	Buildings

lowers the after-tax cost of investment by beginning depreciation write-offs earlier. The various depreciation methods will be as follows for different industrial projects:

3.2.1.1 Straight-Line Method

The rate of depreciation is calculated by the following equation:

$$D_t = (1/n)(c - sv), \tag{3.1}$$

where C = original cost of capitalized investment, D_t = depreciation in year, t, SV = salvage value of capitalize investment, and N = number of years of depreciation.

This method can be illustrated by the following example, where it is assumed that the value of the equipment after 5 years is equal to $10,000, and this price is based on the value of the equipment at the sale after five years.

It is worth mentioning that salvage value is usually taken to equal zero.

Depreciation rate per year = (50000–10000)/5 = $8,000.

Table 3.2 Straight-line method

Year	Depreciation Value Per Year	Book Value at the End of the Year
0	8000	50000
1	8000	42000
2	8000	34000
3	8000	26000
4	8000	18000
5	8000	10000

3.2.1.2 Declining-Balance Method

$$D_t = 1 - \left(\frac{sv}{c}\right)^{\frac{1}{4}}. \tag{3.2}$$

$$\text{Depreciation rate per year} = 1 - \left(\frac{10000}{50000}\right)^{1/5}.$$

Table 3.3 Declining–balance method

Year	Depreciation Value Per Year	Book Value at the End of the Year
0		50000
1	50000 × 0.3 = 15000	35000
2	35000 × 0.3 = 10500	24500
3	24500 × 0.3 = 7350	17150
4	17150 × 0.3 = 5150	12000
5	12000 × 0.3 = 3600	8400

3.2.1.3 Sum-of-the-Year-Digits

$$D_t = (y / SYD)(C - SV), \qquad (3.3)$$

where Y = the number of year remaining in depreciation, and SYD = the sum of year digits.

Table 3.4 Sum-of-the-year-digits

Year	Depreciation Value Per Year	Book Value at the End of the Year
0		50000
1	40000 × (5/15) = 13333	36700
2	40000 × (4/15) = 10670	26000
3	40000 × (3/15) = 8000	18000
4	40000 × (2/15) = 5330	12600
5	40000 × (1/15) = 2670	10000

3.2.1.4 Sinking-Fund Method

$$D_t = (C - SV) \times F \qquad (3.4)$$

where F = the factor for many values at 5 years for an interest rate assuming 7%.

First year = (50000 − 10000)(0.1774) = 7069.
Second year = 7096 + 0.06(7096) = 7521.8.

Table 3.5 Sinking-fund method

Year	Depreciation Value Per Year	Book Value at the End of the Year
0	–	50000
1	7100	42900
2	7520	35380
3	7970	27410
4	8450	18960
5	8960	10000

3.2.1.5 Service-Out Method

This method depends on the time period over which the equipment operates. For example, drilling equipment or digging tunnels where the rate of depreciation is associated with use. Assume that the cost of the equipment is around $12,0000 and the value of the equipment when sold at the end of the project, which is at the dig about 15,0000 meters, is $6000. In this case, we calculate the depreciation rate from the following equation:

$$\text{Depreciation rate} = (120000 - 6000) \ / \ 150000 = 0.76 \ \$ \ / \ \text{m}.$$

Therefore, it is used to calculate the value of the equipment after the first year, as it is known that the equipment was used to drill a total depth equal to 30,000 m, as shown from the following equation:

$$\text{Value of the equipment} = 120000 - (0.76 \times 30000) = \$97{,}200.$$

3.2.2 Method of Net Present Value (NPV)

The method of Net Present Value (NPV) is one of the most common, widely-used methods and one of the most important way upon which the decision-making tree will be displayed later.

It is important to identify the lifetime of the project and the cash flow during the years of the project from its the beginning to the end of the project's life time.

To calculate the equation by the current value, one must specify the discount rate, which is given by the following equation:

Table 3.6 Net present value calculation

Year	Discount Rate	Net Cash Flow	Net Present Value
0	1.0	-51785	-51785.00
1	0.909	20000	18181.80
2	0.826	20000	16528.80
3	0.7513	20000	0015026.20
4	0.683	20000	13659.00
NPV			11610.80

$$NPV = \frac{NCF_1}{(1+D)^1} + \frac{NCF_2}{(1+D)^2} + \ldots\ldots \frac{NCF_n}{(1+D)^n}, \tag{3.5}$$

where n is the number of years, and D is the discount rate that is equal to the value of the interest rate.

The following example illustrates the NPV calculation in the suit, in which the imposition of the discount rate is equal to 10%.

As an example, calculating the net present value is shown in Table (3.6).

3.2.2.1 *Inflation Rate*

When assuming the interest rate or discount rate, one must not forget the inflation rate. The rate of inflation may be assumed as a variable every year or a fixed value, and there are studies and economic research to calculate the rate of inflation. Its value differs from one country to another according to the nature of a country's economy observed over time. The following equation calculates the highest rate of return and includes the rate of inflation:

$$\begin{aligned}&\text{The nominal interest rate of return}\\&=(1+\text{inflation rate})\ (1+\text{interest rate})-1.\end{aligned} \tag{3.6}$$

The previous example includes an interest rate of 10% and assumes an inflation rate of 4%. The real interest rate or discount rate is figured by the following equation:

$$D = \frac{1.10}{1.04} = 1.0577 \tag{3.7}$$

Table 3.7 Net present value including inflammation

Year	(1)	(2)	(3)=(1)x (2)	(4)	(5)=(4) x (3)
	Net Cash Flow	**Inflation Rate**	**Net Cash Flow After Inflation**	**Discount Rate**	**Net Present Value**
0	–51785	1.0	–51785	1.0	–51785
1	20000	0.96	19231	0.95	18182
2	20000	0.92	18491	0.89	16529
3	20000	0.89	17780	0.85	15026
4	20000	0.85	17096	0.80	13660
Sum (NPV)					11612

When the inflation rate is constant, the net present value is stable under the assumption that the rate of return is fixed. When the difference value of the interest rate changes every year, the net present value will be different.

3.2.3 Minimum Internal Rate of Return (MIRR)

This method depends on calculating the value of *D*. Let the NPV equal zero, so that it will be calculated by the trial and error method.

$$NPV = NCF_1(1+D)^{-1} + NCF_2(1+D)^{-2} + \dots\dots + NCF_n(1+D)^{-n} \quad (3.8)$$

By knowing the NCF and setting the NPV is equal to zero, the value of *D* emerges as the projected interest rate of return that the company, organization, or individual investor will achieve after implementing the project. Every company should have defined their own minimum rate of return (MIRR). This rate is internal and specific to each company. For most international petroleum companies with branches in more than one country around the world, that number varies from country to country.

This number is determined after studies and many researches specific to each country according to the description of the political, social, and economic condition of that country. For example,

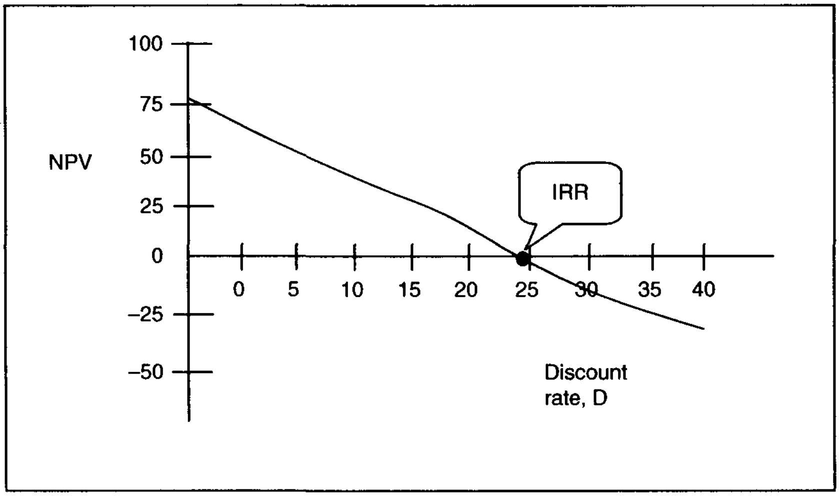

Figure 3.3 Calculate IRR.

investing in England or the USA is certainly different from Sudan, Nigeria or other African countries that lack political stability.

The internal minimum of return number is a secret and confidential number for each company, as these numbers govern their investment.

3.2.4 Payout Method

This method is the fastest and easiest way to calculate the time required to recover the invested money in the project, but it cannot account for the project interest rate of return. Calculating the time period is simple, as shown in Figure (3.4).

The time required to recover the money invested is called payout time. This factor depends on the expertise of the decision-maker. It is also a very important factor in politically unstable countries and any other situations in which the project decision-maker has an even greater responsibility to be able to recover the capital in the shortest possible time.

The disadvantage of this method is that it cannot calculate the interest rate of return for a project, which varies according to each project and the value of the initial investment. Broadly

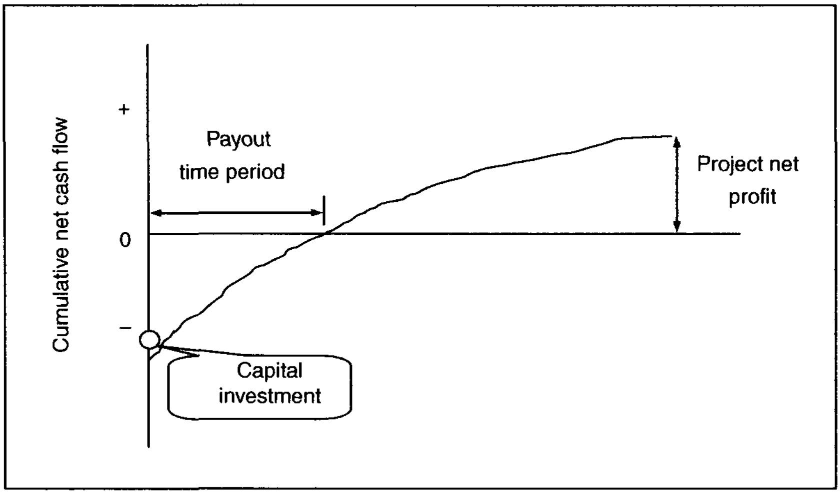

Figure 3.4 Payout method.

speaking, however, given a general idea of the itinerary of the project economically, the time it will take to recoup the investment is a major deciding factor in the management of the project.

In spite of the many advantages of the payout method, alone it is not a complete measure of the value of money for the following reasons:

- It does not indicate profit following payout.
- It does not measure total profit.
- Time value of money is not formally included.
- It varies depending on different types and magnitudes of investment.

3.3 Economic Risk Assessment

3.3.1 Probability Theory

To enable the best use of probability theory, some important basic principles of mathematical statistics are inserted in to the discussion at this point. We will clarify these statistical concepts using an analysis of test results derived from crushing samples of cylinder concrete to measure its strength.

The main statistical parameters will be the following:

- Arithmetic average
- Standard deviation
- Coefficient of variation

Arithmetic average is the average value of a set of results and is represented in the following equation:

$$\overline{X} = \frac{X_1 + X_2 + \ldots + X_n}{n}, \tag{3.9}$$

where n is the number of results, and X is read of each test result.

As a practical example of the statistical parameter, assume that we have two groups of concrete mixture from different ready mix suppliers. The first group has a concrete compressive strength after 28 days for three samples, which are 310 kg/cm^2, 300 kg/cm^2, and 290 kg/cm^2. When we calculate the arithmetic average using equation (3.9), the arithmetic mean of these readings are 300 kg/cm^2.

The second group has a test result for cube compressive strength after 28 days under the same conditions for the first group. The test results are 400 kg/cm^2, 300 kg/cm^2, and 200 kg/cm^2. When calculating the arithmetic mean, we find that it is equal to 300 kg/cm^2.

Because the two groups have the same value of the arithmetic mean, does that mean that the same mixing has the same quality? Will you accept the two mixing? We find that this is unacceptable by engineering standards, but when we consider the mean the two groups are the same, so one should choose another criterion by which to compare the results as we cannot accept the second group based on our judgment, which will not support us in court.

Standard deviation is a statistical factor that reflects near or far the reading results. From the arithmetic mean end, it is represented in the following equation:

$$S = \sqrt{\frac{(X_1 - \overline{X})^2 + (X_1 - \overline{X})^2 + \ldots\ldots\ldots + (X_n - \overline{X})^2}{n}}. \tag{3.10}$$

The standard deviation for the first group sample is

$$S = \sqrt{\frac{(310 - 300)^2 + (300 - 300)^2 + (290 - 300)^2}{3}}.$$

Mixing one, $S = 8.16$ kg/cm^2.

The standard deviation for the second group sample is

$$S = \sqrt{\frac{(400-300)^2 + (300-300)^2 + (200-300)^2}{3}}.$$

Mixing two, $S = 81.6$ kg/cm^2.

One can find that the standard deviation in the second group has a higher value than the first group. So the distribution of test data results is far away from the arithmetic mean rather than group one. From equation (3.10) one can find that the ideal case is when $S = 0$.

We note that the standard deviation has units, as seen in the previous example. Therefore, standard deviation can be used to compare between the two groups of data as in the previous example where the two groups give the value of 300 kg/cm^2 after 28 days. On the other hand, in the case of the comparison between the two different mixes of concrete, for instance, there is a resistance of 300 kg/cm^2 in one concrete and 500 kg/cm^2 in the second. In that case, the standard deviation is of no value. Therefore, we resort to the coefficient of variation.

The coefficient of variation is the true measure of quality control, as it determines the proportion after the readings for the average arithmetic profile. This factor has no units and is, therefore, used to determine the degree of product quality.

$$C.O.V = \frac{S}{\overline{X}} \tag{3.11}$$

As another example, assume there is a third concrete mix at another site to provide concrete strength after 28 days of 500 kg/cm^2. When you take three samples, it gives the results of strength after 28 days as 510 kg/cm^2 and 500 kg/cm^2 and 490 kg/cm^2. When calculating the arithmetic mean and standard deviation, we find the following results:

- Arithmetic mean = 500 kg/cm^2
- Standard deviation = 8.16 kg/cm^2

Comparing concrete from one site with a mean concrete strength of 300 kg/cm^2 and concrete from a second site with a mean concrete strength of 500 kg/cm^2, in which both sites have the same standard deviation as the above example, the coefficients of variation are as follows:

- Coefficient of variation of the first site = 0.03
- Coefficient of variation of the second site = 0.02

We note that the second site has a coefficient of variation less than the first location. That is, the standard deviation to the arithmetic average is less at the second site than at the first site. This means that the second site mix concrete has a higher quality. Therefore, the coefficient of variation is the standard quality control of concrete, and the closer to zero, the better the quality control is likely to be.

To illustrate probability distribution with a practical example, let us we have test results for 46 cube crushing strengths as shown in Table (3.7), and we need to define the statistical parameters for these numbers.

The raw data is collected in groups; the number of samples with a value between the range for every group is called the frequency. The frequency table from the raw data in Table (3.8) is tabulated in Table (3.9).

The data from Table (3.9) is presented graphically in Figure (3.5). To analyze the data, make a cumulative descending table, as shown

Table 3.8 Row data

340	298	422	340	305
356	320	382	297	267
355	312	340	366	349
311	306	368	382	404
326	350	322	448	350
358	384	346	365	303
398	306	298	339	344
378	282	320	360	360
367	341	326	325	352
384				

Table 3.9 Frequency table

ID	Group	Average Value	Frequency
1	260–280	270	1
2	280–300	290	3
3	300–320	310	6
4	320–340	330	6
5	340–360	350	12
6	360–380	370	7
7	380–400	390	5
8	400–420	410	1
9	420–440	430	1
10	440–460	450	1
Total			43

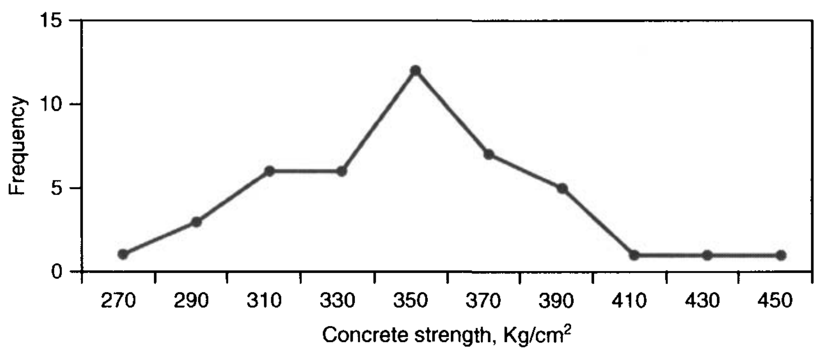

Figure 3.5 Frequency curve for concrete compressive strength data.

in Table (3.8). This table is presented graphically in Figure (3.6). From Table (3.10) one can find that from this set of data, sample results of concrete strength, one can see the cumulative descending data. For example, the probability of having a concrete strength that is less than 300kg/cm^2 is 9%.

From the cumulative descending curve, one may conclude that at some given point in time, 100% of the results of the samples have a strength less than 459 kg/cm^2. In the results of previous tests, we find that the samples have results less than or equal to 280 kg/cm^2, which is about 2% of the number of tested samples.

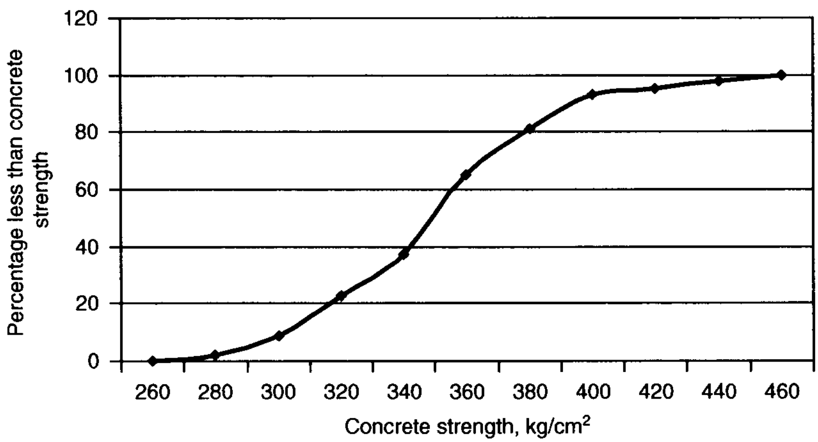

Figure 3.6 Cumulative distribution curve for concrete strength.

Table 3.10 Descending cumulative table

Group No.	Test Value	Reading Value Less than the Upper Limit	The Percentage Less than the Upper Limit
10	460	43	100
10	440	42	98
9	420	41	95
8	400	40	93
7	380	35	81
6	360	28	65
5	340	16	37
4	320	10	23
3	300	4	9
2	280	1	2
1	260	0	0

3.3.2 Probability Distribution of Variables

Most civil engineering problems deal with quantitative measures using the familiar deterministic formulations of engineering problems. However, there is nothing pre-determined about the real-life case, for example, when you assume you have a reinforced concrete column in drawings mentioning that its section is 500 mm × 500 mm. This means it will be around this exact number when you measure the column. It is possible that there could be some deviation, which is allowable in the code.

The theory of random variables has enables the analyst to furnish useful substitutes for less precise qualitative characteristics. Variables, whose specific values cannot be predicted with certainty before an experiment, can be presented by the probabilistic models and distributions.

3.3.2.1 Normal Distribution

Making only the assumption that any value within some range of values is possible, the normal distribution can be and is used to represent many phenomena. It is used in decision-making to model expectations about the inflation rate, or the future price of oil. This distribution is widely used in metering equipment, in which it can represent the distribution of measurement errors; in reservoir studies it can be used to predict soil permeability, the spaces between the grains and saturation as well as some economic data.

Equation:

$$f(x)=\left(\frac{1}{\sigma 2\pi^{0.5}}\right)e^{-0.5(x-\mu)^2/\sigma^2} \tag{3.12}$$

Mean:

$$\bar{x}=\frac{\sum x_i}{n} \tag{3.13}$$

where:
$\bar{x}$ = arithmetic mean of sample data
x_i = each individual value in sample
n = number of values in sample
cm = class mark
nc = number of values in class

Standard deviation is given by

$$\sigma_s = \left[\left(\frac{1}{n}\right)\sum x^2 - \mu^2\right]^{0.5} \tag{3.14}$$

where σ is the standard deviation, and μ is the arithmetic mean.

The Normal distribution is the most commonly used probability distribution, because it can generate information about a set of measurements without our having to know anything about *how* the phenomena of interest came to exist in the first place, or whether some values are more likely than others: its sole assumption is that any possible value within some range may be assigned some non-zero probability. As distinct from many of the other distributions discussed below, a normally-distributed variable is always indifferent to the passage of time. Analysis on this basis of measurements of the output of one and the same process are ideal candidates for the application of this tool. Thus, for example, it was found that the Normal distribution is the best probability curve to present concrete strength from laboratory tests performed on the concrete in most countries of the world. (The moment we have reason to know that the assumption of all outcomes being possible is inapplicable, other distributions should be considered, as will be seen below.)

The most significant characteristics of the Normal distribution for present purposes are:

- distribution is symmetric around the average; more precisely: the arithmetic mean of the curve is divided into two equal halves
- a Normal distribution matches the arithmetic mean and median lines and mode value that is most likely to occur
- area under the curve equals 1 and that the random variable in the outcomes of the cubes to, that this curve represents all the ∞ to -∞break it to take values from potential possibilities of the concrete's strength.

As a result, each curve depends on the value of the arithmetic mean and standard deviation, and any difference between the two parameters leads to a difference in the shape of the probability distribution. Therefore, the standard normal distribution is used to determine areas under a curve by knowing the standard deviation and arithmetic mean using another variable, Z, which is obtained from the following equation:

$$z = \frac{x - \bar{x}}{\sigma} \tag{3.15}$$

Table (3.11) shows the values of the area under the curve by knowing the value of z from the above equation. In the first column, the value of z and first row determine the accuracy to the nearest two decimal digits. From the table one can find that the area under the curve at z is equal to 1.64. The area under the curve for any value less than z is 0.5−0.4495, which is equal to about 0.0505. In other words, the probability of the variables has a value less than or equal to 5% as shown in Figure (3.7).

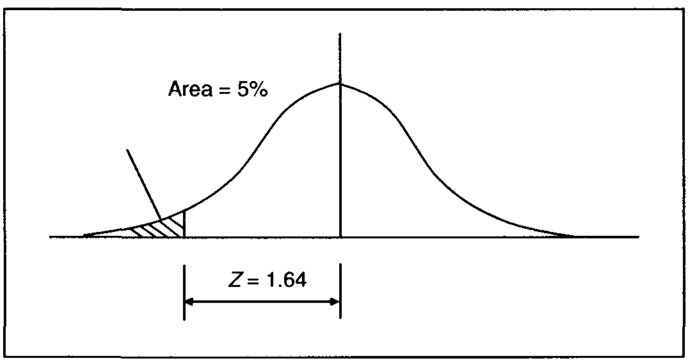

Figure 3.7 Normal distribution curve.

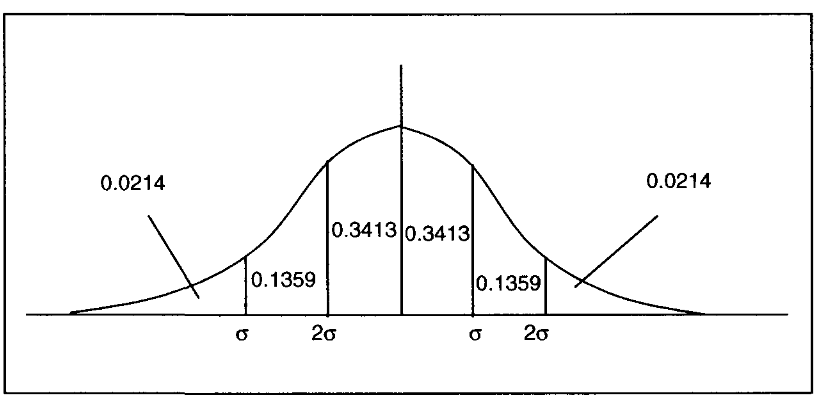

Figure 3.8 The division of areas under the normal distribution.

Table 3.11 The area under the curve of normal distribution

Z	0	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0	0	0.004	0.008	0.012	0.016	0.0199	0.0239	0.0279	0.0319	0.0359
0.1	0.0398	0.0438	0.0478	0.0517	0.0557	0.0596	0.0636	0.0675	0.0714	0.0753
0.2	0.0793	0.0832	0.0871	0.091	0.0948	0.0987	0.1026	0.1064	0.1103	0.1141
0.3	0.1179	0.1217	0.1255	0.1293	0.1331	0.1368	0.1406	0.1443	0.148	0.1517
0.4	0.1554	0.1591	0.1628	0.1664	0.17	0.1736	0.1772	0.1808	0.1844	0.1879
0.5	0.1915	0.195	0.1985	0.2019	0.2054	0.2088	0.2123	0.2157	0.219	0.2224
0.6	0.2257	0.2291	0.2324	0.2357	0.2389	0.2422	0.2454	0.2486	0.2517	0.2549
0.7	0.258	0.2611	0.2642	0.2673	0.2704	0.2734	0.2764	0.2794	0.2823	0.2852
0.8	0.2881	0.291	0.2939	0.2967	0.2995	0.3023	0.3051	0.3078	0.3106	0.3133
0.9	0.3159	0.3186	0.3212	0.3238	0.3264	0.3289	0.3315	0.334	0.3365	0.3389
1	0.3413	0.3438	0.3461	0.3485	0.3508	0.3531	0.3554	0.3577	0.3599	0.3621
1.1	0.3643	0.3665	0.3686	0.3708	0.3729	0.3749	0.377	0.379	0.381	0.383
1.2	0.3849	0.3869	0.3888	0.3907	0.3925	0.3944	0.3962	0.398	0.3997	0.4015
1.3	0.4032	0.4049	0.4066	0.4082	0.4099	0.4115	0.4131	0.4147	0.4162	0.4177
1.4	0.4192	0.4207	0.4222	0.4236	0.4251	0.4265	0.4279	0.4292	0.4306	0.4319
1.5	0.4332	0.4345	0.4357	0.437	0.4382	0.4394	0.4406	0.4418	0.4429	0.4441
1.6	0.4452	0.4463	0.4474	0.4484	0.4495	0.4505	0.4515	0.4525	0.4535	0.4545
1.7	0.4554	0.4564	0.4573	0.4582	0.4591	0.4599	0.4608	0.4616	0.4625	0.4633

1.8	0.4641	0.4649	0.4656	0.4664	0.4671	0.4678	0.4686	0.4693	0.4699	0.4706
1.9	0.4713	0.4719	0.4726	0.4732	0.4738	0.4744	0.475	0.4756	0.4761	0.4767
2	0.4772	0.4778	0.4783	0.4788	0.4793	0.4798	0.4803	0.4808	0.4812	0.4817
2.1	0.4821	0.4826	0.483	0.4834	0.4838	0.4842	0.4846	0.485	0.4854	0.4857
2.2	0.4861	0.4864	0.4868	0.4871	0.4875	0.4878	0.4881	0.4884	0.4887	0.489
2.3	0.4893	0.4896	0.4898	0.4901	0.4904	0.4906	0.4909	0.4911	0.4913	0.4916
2.4	0.4918	0.492	0.4922	0.4925	0.4927	0.4929	0.4931	0.4932	0.4934	0.4936
2.5	0.4938	0.494	0.4941	0.4943	0.4945	0.4946	0.4948	0.4949	0.4951	0.4952
2.6	0.4953	0.4955	0.4956	0.4957	0.4959	0.496	0.4961	0.4962	0.4963	0.4964
2.7	0.4965	0.4966	0.4967	0.4968	0.4969	0.497	0.4971	0.4972	0.4973	0.4974
2.8	0.4974	0.4975	0.4976	0.4977	0.4977	0.4978	0.4979	0.4979	0.498	0.4981
2.9	0.4981	0.4982	0.4982	0.4983	0.4984	0.4984	0.4985	0.4985	0.4986	0.4986
3	0.4987	0.4987	0.4987	0.4988	0.4988	0.4989	0.4989	0.4989	0.499	0.499
3.1	0.499	0.4991	0.4991	0.4991	0.4991	0.4992	0.4992	0.4992	0.4992	0.4993
3.2	0.4993	0.4993	0.4994	0.4994	0.4994	0.4994	0.4994	0.4994	0.4995	0.4995
3.3	0.4995	0.4995	0.4995	0.4996	0.4996	0.4996	0.4996	0.4996	0.4996	0.4997
3.4	0.4997	0.4997	0.4997	0.4997	0.4997	0.4997	0.4997	0.4997	0.4997	0.4998
3.5	0.4998	0.4998	0.4998	0.4998	0.4998	0.4998	0.4998	0.4998	0.4998	0.4998
4.0	0.49997									
5.0	0.49999									

Figure (3.8) shows the area under the curve when you add or decrease the value of the standard deviation of the arithmetic mean.

The area under the curve from the arithmetic mean value to one value of the standard deviation is equal to 34.13%, while in the area under the curve in Figure (3.8) for twice the standard deviation values is equal to 47.72%.

3.3.2.2 Log Normal Distribution

This distribution is used when a phenomenon does not take a negative value. Therefore, it is used in representing the size of the aquifer or reservoir properties such as permeability of the soil. It also represents real estate prices and others.

Equation:

$$f(x)=\left(\frac{1}{2\pi.\beta}\right)x^{-1}e^{-(inx-\sigma^2/2\beta^2)} \tag{3.16}$$

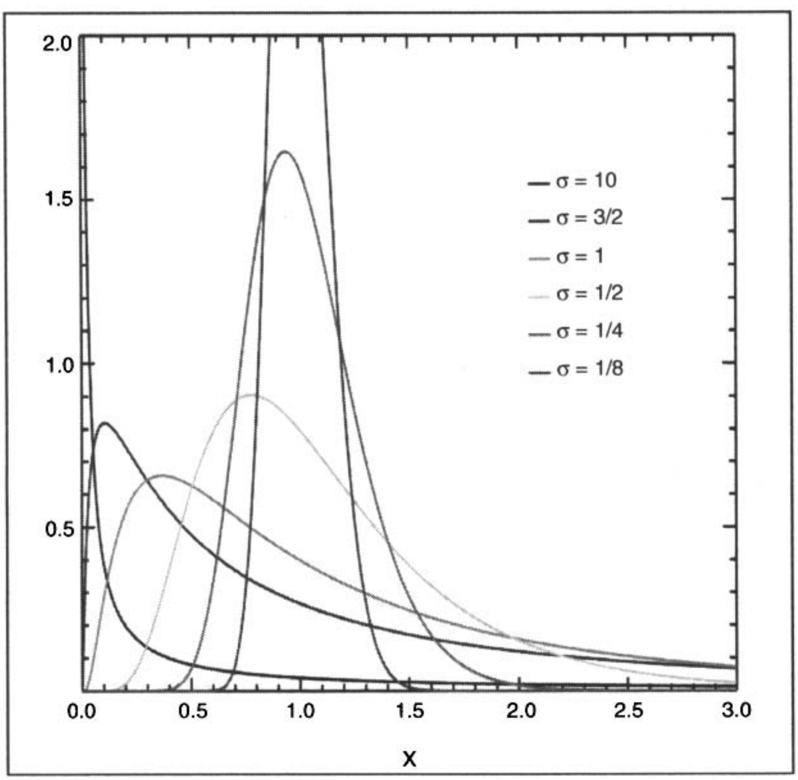

Figure 3.9 Lognormal distribution.

Mean:

$$\ln \bar{x}_G = \frac{\sum(\log x)}{n} = \mu_G \tag{3.17}$$

Standard Deviation:

$$\ln \sigma_s = [(\frac{1}{n})\Sigma(\ln x)^2 - (\ln \mu_G)^2]^{0.5} \tag{3.18}$$

3.3.2.3 Binominal Distribution

This distribution is used in the following situations:

- determination of geological hazards;
- calculation of the performance of the machine for the cost and the cost of spare parts;
- determination of the appropriate number of pumps with the appropriate pipeline size with the required fluid capacity and the number of additional machines;
- determination of the number of generators according to the requirement of the project and to determine the number of additional generators in the case of an emergency or malfunction in any machine.

To understand the nature of this distribution let us use the following:

Equation:

$$f(x) = \frac{n!}{n_s!(n-n_s)!}(f)^{n_s}(1-f)^{n-n_s} \tag{3.19}$$

Mean:

$$x = n.f \tag{3.20}$$

Standard Deviation:

$$\sigma_s = [n.f.(1-f)]^{0.5} \tag{3.21}$$

Example 1:

When playing by the coin, the probability of the queen appearing is P=.50. What is the probability that we get the queen twice when we lay down the currency 8 times?

$$F(x) = [8!/2!(6!)]\ (0.5)^2\ (0.5)^{8-2}$$
$$= 0.189$$

This means that when you take a coin 6 times, the probability that the image will appear twice is 0.189.

Example 2:

Assuming the probability of 0.7 when drilling a single well that has oil, what is the probability that we find oil in 25 wells when we drill 30 wells?

$$p = \frac{30!}{25!(30-25)!}(0.7)^{25}(1-0.7)^{30-25} = 0.0464$$

Therefore, we find that the likelihood of success of the individual well is 0.7, but the possibility that the 25 successful wells were drilled is 0.0464.

Example 3:

Assess the reliability of a system requiring 10,000 KW to meet system demand. Each generator has been rated 95% reliable (5% failure rate).

The company is comparing 3 alternatives: 2-5000 KW generators, 3-5000 KW, and 3-4000 KW generators.

When we do a comparison between normal and logarithmic distribution and the binominal distribution and look at the shape of each of the three curves, we find that the log curve and normal distribution curve are solid curves which are different from the Binominal distribution curve as in figure (3.10). Therefore,

Table 3.12 Alternative for example 3

2-5000		3-5000	3-4000	
10,000	0.9025	0.9928	12,000	0.8574
5,000	0.0950	0.0071	8,000	0.1354
0	0.0025	0.0001	4,000	0.0071
			0	0.0001
Total	1.000	1.000		1.000
Avg. Reliability	0.9500	0.9963		0.9685

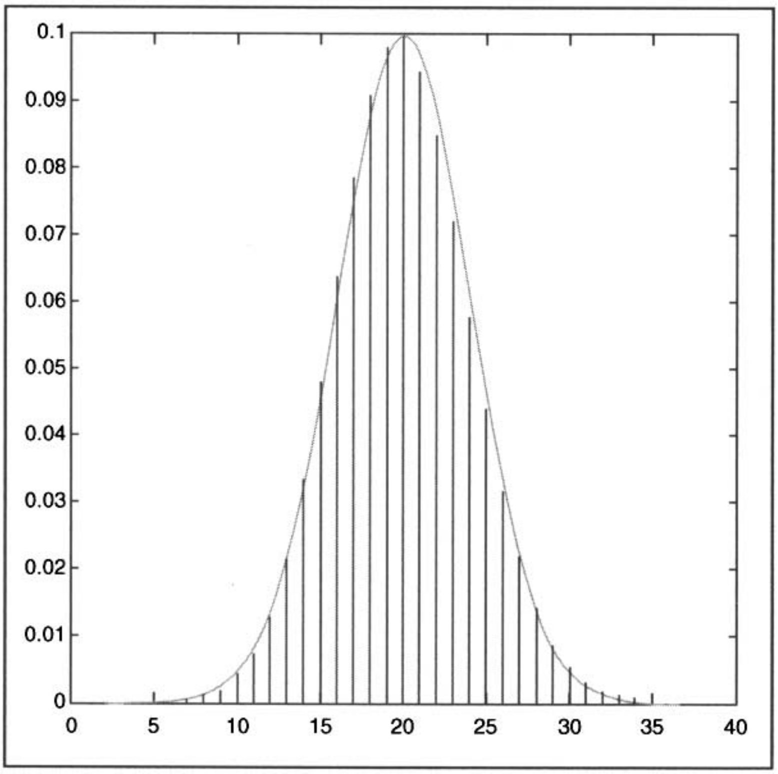

Figure 3.10 Binominal distribution.

the normal distribution is called the Probability Density Function (PDF). These PDF distribution curves are used in cases where descriptions of the natural phenomena or materials properties that can take any values, for example, when you calculate the heights of people in the building that you are in. You will find that the lowest number, for example, is 120.5 cm, and the highest number is 180.4 cm; and the heights of people can be any number between those numbers. But in the case of the last example, the number of drilling wells is between 1 and 25 wells. If we calculate the probability of success for 20 wells, we cannot say that there is a possibility of drilling 20.5, for example, because you cannot drill half a well. Therefore, in this case the probability distribution will be called the Probability Mass Function (PMF). This is very important when choosing the suitable distribution, which should match the natural phenomena for these variables. When defining the probability distributions for steel strength, oil price, or population, one should use the probability density function (PDF).

3.3.2.4 *Poisson Distribution*

This distribution is based on the number of times the event occurs within a specific time period, such as the number of times the phone rings per minute or the number of errors per page of a document

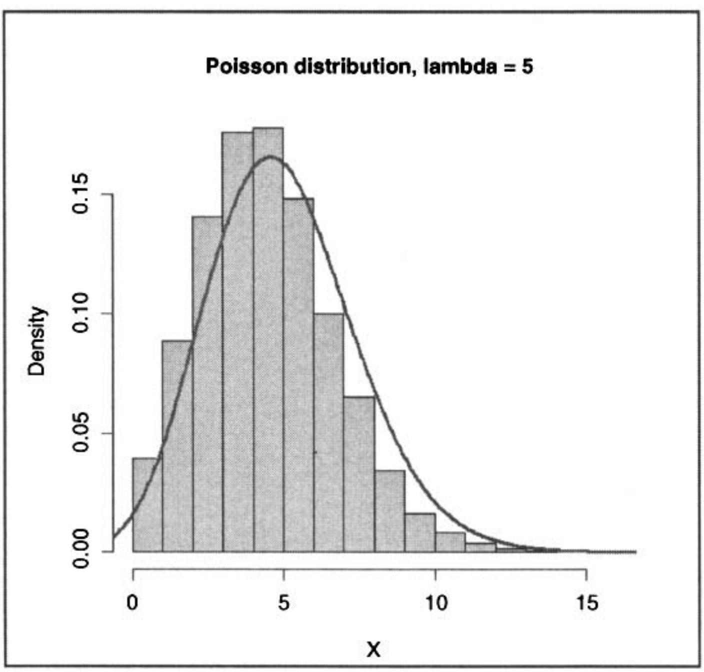

Figure 3.11 Poisson distribution.

overall, and that description is used in transport studies or in deciding upon the number of fuel stations to fuel cars, as well as in the design study for telephone lines.

Mean:

$$m_t = \lambda \tag{3.22}$$

Standard Deviation:

$$\sigma = \lambda \tag{3.23}$$

It will be a probabilistic mass function, as shown in Figure (3.11)

5-Exponential Distribution

This distribution represents the time period between the occurrences of unanticipated events. For example, the time period between the occurrences of electronic failures in equipment reflects this distribution and is the opposite of Poisson distribution. It can be used to describe time periods to be expected between machine failures: there are now extensive studies that use this model to determine the appropriate time period for maintenance of equipment, called mean time between failure (MTBF).

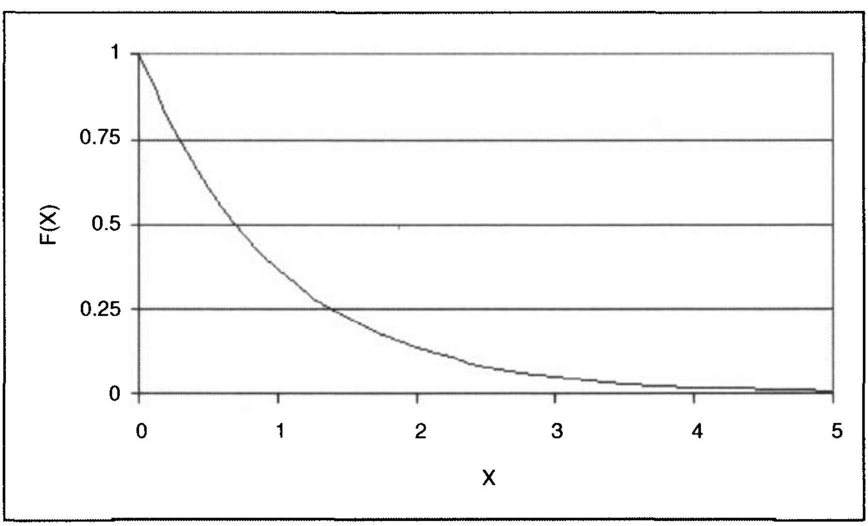

Figure 3.12 The exponential distribution.

Probability Density Function:

$$f_T(t) = \lambda e^{-\lambda t} \tag{3.24}$$

Mean:

$$M_t = 1/\lambda \tag{3.25}$$

Standard Deviation:

$$\sigma = 1/\lambda \tag{3.26}$$

3.3.2.5 *Weibull Distribution (Rayleigh Distribution)*

Wind speed is one of the phenomena for which the Weibull distribution is also used, for example, when planning, as part of machine parts production, quality control criteria for metals stress created by wind exposure. This distribution is complicated and,

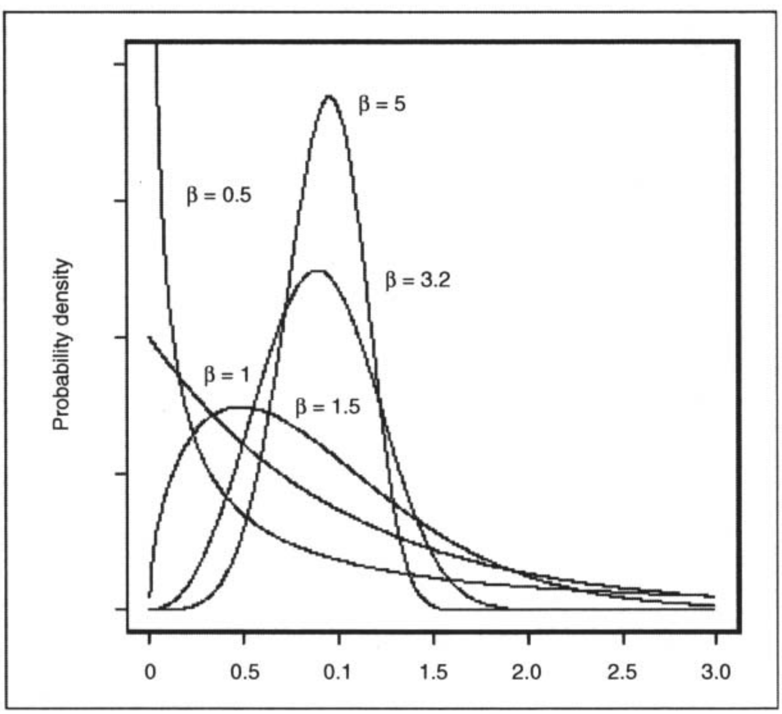

Figure 3.13 Weibull distribution.

therefore, is not recommended for use in the case of building a huge model of an entire problem when using the Monte-Carlo simulation.

3.3.2.6 *Gamma Distribution*

This distribution represents a large number of events and transactions such as inventory control or representation of economic theories, and the theory of risk insurance is also used in environmental studies, when there is a concentration of pollution. It is also used in studies where there is petroleum crude oil and gas condensate, and it can be used in the form of treatment in the case of oil in an aquifer.

Equation:

$$f(x) = \frac{1}{\beta^{\alpha} T(\alpha)} x^{\alpha-1} e^{-x/\beta} \tag{3.27}$$

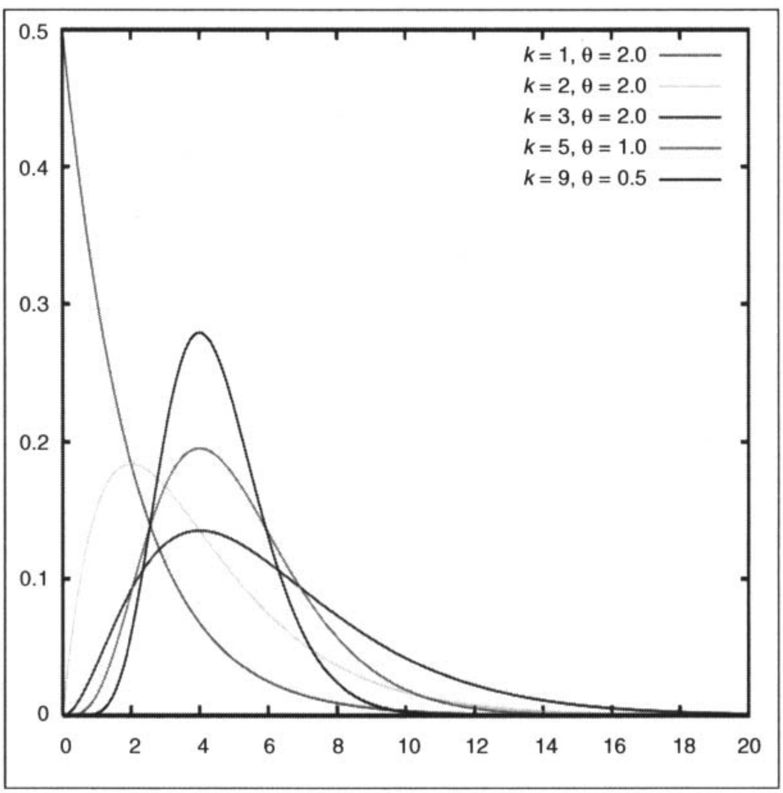

Figure 3.14 Gamma distribution.

Mean:

$$x = \alpha\beta \tag{3.28}$$

Standard Equation:

$$\sigma_s = \sqrt{\alpha\beta^2} \tag{3.29}$$

The different shapes of gamma distribution are presented in Figure (3.14).

3.3.2.7 Logistic Distribution

This distribution is used frequently to describe the population growth rate in a given period of time. It may also be used to represent interactions between chemicals.

$$f(x;\mu,s) = \frac{e^{-(x-\mu)/s}}{s(1+e^{-(x-\mu)/s})^2} \tag{3.30}$$

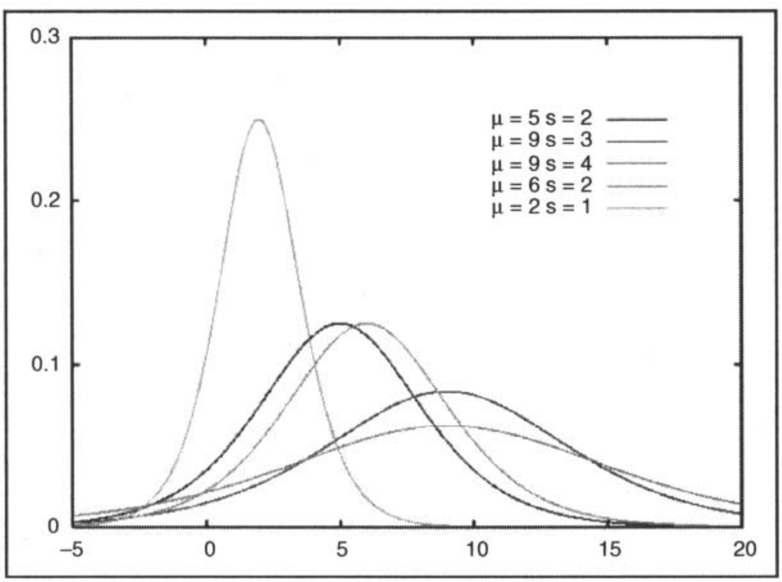

Figure 3.15 Logistic distribution.

3.3.2.8 Extreme Value (Gumbel Distribution)

This distribution is used when the intended expression of the maximum value of the event occurs in a period of time. Therefore, it is used for floods, earthquakes, or rain and is used to calculate the loads on the plane and study the fracture resistance of some materials.

$$f_z(z) = \alpha \exp\left[\alpha(z-u) - e^{\alpha(z-u)}\right], \tag{3.31}$$

$$F_z(z) = 1 - \exp(-e^{\alpha(z-u)}), \tag{3.32}$$

where $-\infty \le z \le \infty$.

$$m_z = u - \frac{\gamma}{\alpha}. \tag{3.33}$$

$$\sigma_z = \frac{\pi}{\alpha\sqrt{6}}. \tag{3.34}$$

3.3.2.9 Pareto Distribution

This distribution is commonly used in the analysis of various aspects of per capita income, changes in stock prices, variations in the population in a city, the patterns of staffing numbers in a company, even error rates in data communications circuits. It also represents certain kinds of changes in the distribution of natural resources.

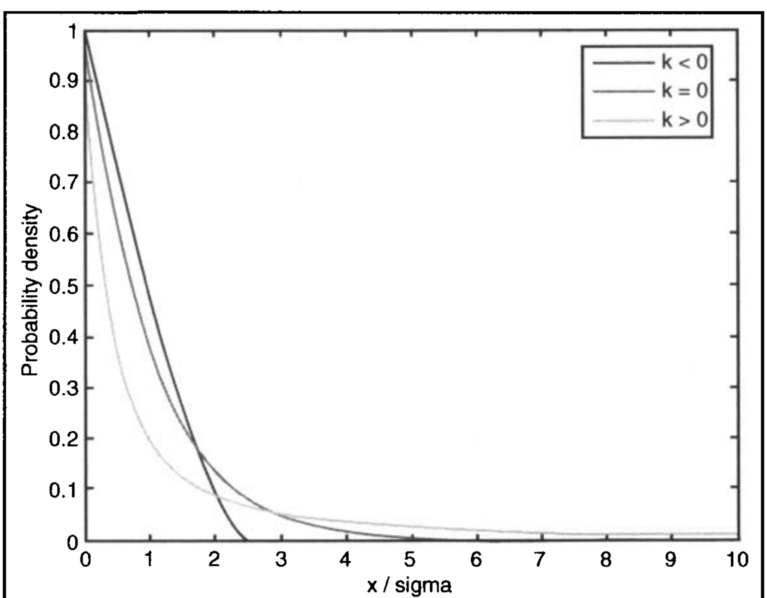

Figure 3.16 Pareto distribution.

It uses the Pareto principle, based on the idea that by doing 20% of work, 80% of the advantage of doing the entire job can be generated. Or in terms of quality improvement, a large majority of problems (80%) are produced by a few key causes (20%).

3.3.3 Distribution for Uncertainty Parameters

There are some variables whose distributions are difficult to identify, such as the project estimate cost. Further, the experiments and tests necessary to study the phenomenon are very expensive, for example defining the area and height of the oil reservoir. For that, we use the following distributions.

3.3.3.1 Triangular Distribution

This distribution is very important in the case of phenomenon where testing is very expensive. An example is when you select the size of an underground reservoir, and three tests are usually performed to obtain the minimum, the maximum, and most likely. This distribution is used in schedule planning (discussed in Chapter 4). It estimates the time required to complete the activity by considering three values: a minimum time, maximum time, and the most likely time to finish that activity.

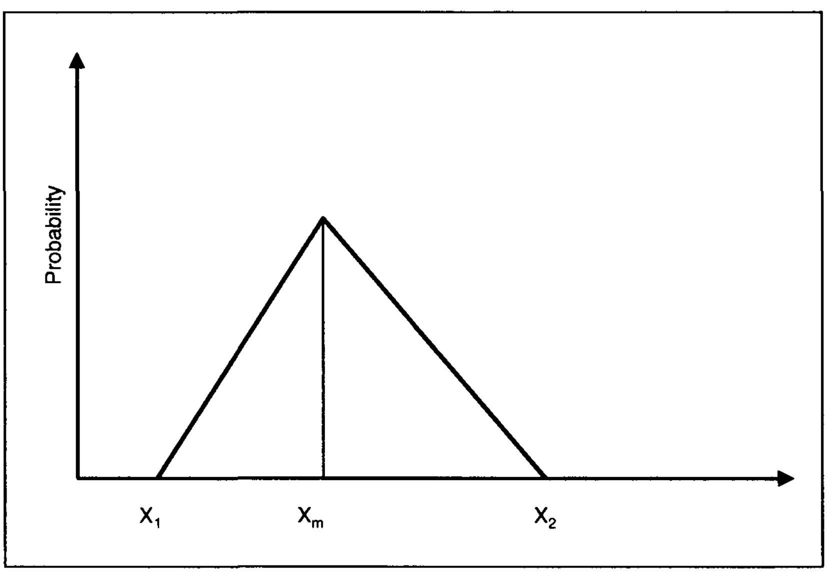

Figure 3.17 Triangular distribution.

In addition, it is also used to determine the estimated cost of a project where the maximum allowable value is about a 10–15% increase on the cost and the calculated minimum value is a 10–15% decrease for the calculated cost.

Triangular distribution is shown in Figure (3.17) where X_1, X_2, and X_m are the minimum, maximum, and most likely values, respectively.

Equation:

$$x = \frac{x_1 + x_m + x_2}{3} \tag{3.35}$$

$$\sigma_s = \left[\frac{(x_2 - x_1)(x_2^2 - x_1 x_2 + x_1^2) - x_m x_2 (x_2 - x_m) - x_1 x_m (x_m - x_1)}{18(x_2 - x_1)} \right]^{0.5} \tag{3.36}$$

3.3.3.2 *Uniform Distribution*

This distribution is shown in Figure (3.18) is used in any event where the values have the same probability of occurrence. For example, when you roll a die the probability of rolling a number between 1 and 6 is a constant, which its probability value is (1/6).

X_1 and X_2 are the minimum and maximum values, respectively.

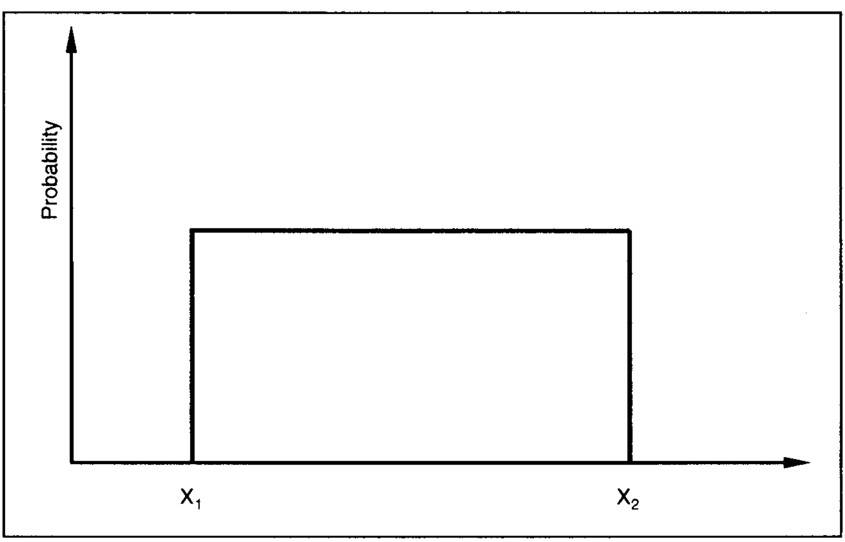

Figure 3.18 Rectangular distribution.

$$x = \frac{x_1 + x_2}{2} \tag{3.37}$$

$$\sigma_s = \left[\frac{(x_1 - x_2)^2}{12} \right]^{0.5} \tag{3.38}$$

3.3.4 Choosing the Appropriate Probability Distribution

Each type of probability distribution has its own properties, which gives every distribution the ability to represent a specific phenomenon. For example, we find that normal distribution may reliably represent concrete strength, while a logistic distribution can usefully represent an increase in population. Before building a model, one must be sure to choose the best probability distribution that represents the parameter of interest.

One may obtain the most suitable probability distribution by returning to previous references or researches, as many statistical studies have been performed for most engineering parameters. Alternatively, studying the phenomenon itself, directly, may provide a more appropriate route for selecting a suitable probability distribution. The second is performed through a test more than once, and the results are plotted and compared to the probability distributions.

As mentioned earlier, there is a way to choose the appropriate distribution mathematically, but each distribution has certain properties.

If there is raw data, as in the example of concrete strength, do the same procedure to define the frequency tables and curve by trying to choose the best probability distribution that can match with this curve.

One of the commonest methods used to choose the best probability distribution that match the test results of actual measured phenomena is the Chi-Square Test.

3.3.4.1 Chi-Square Test

The Chi-Square method relies upon the difference between the observed value (O) of a data-point obtained from some practical measurement and what its expected value (E) would be for some theoretically possible distribution of that same data-point. For each point of interest, the quotient of the square of that difference (which will necessarily be positive) and the value expected for that point in some known theoretical probability distribution (catalogued in reference handbooks on mathematical statistics), is summed over some portion of data-points already collected. This procedure yields a non-zero numerical result known as the χ^2-value. The theoretical probability distribution whose χ^2-value shows the smallest variance from the observed values tabulated as actual data is then selected as the most appropriate for modelling the distribution of the rest of these actual data. The following equation computes the χ^2-value:

$$\chi^2 = \sum_{i=1}^{k}\left[\frac{(O_i - E_i)^2}{E_i}\right] \tag{3.39}$$

where

O_i = an observed frequency

E_i = an expected (theoretical) frequency

i = the number of data-points from the table or portion thereof

From this equation, note that when distribution resulting from the practical test matches the probability distribution, the equation reduces to $\chi^2 = 0$.

The Chi-Square Test is highly reliable for small data samples of less than 30 values, and there is no requirement that the observed data be continuously generated. Many hand-held engineering calculators provide statistical routines that compute χ^2 values at the press of a button after the inputting pairs of O_i and E_i values.

3.4 Decision Tree

The decision tree is one of the basic tools and keys for the project manager in each decision-making process. It is considered a sound and logical way that leads to the selection of the proper decision. Recently, I considered that a person who does not know how to use a decision-making tree is a person living in an isolated cave. Here is proof that this method is the most common way.

The decision tree method is based on the probability of A, B, and C occurring and is calculated by:

$$Ps = P_A \times P_B \times P_C$$

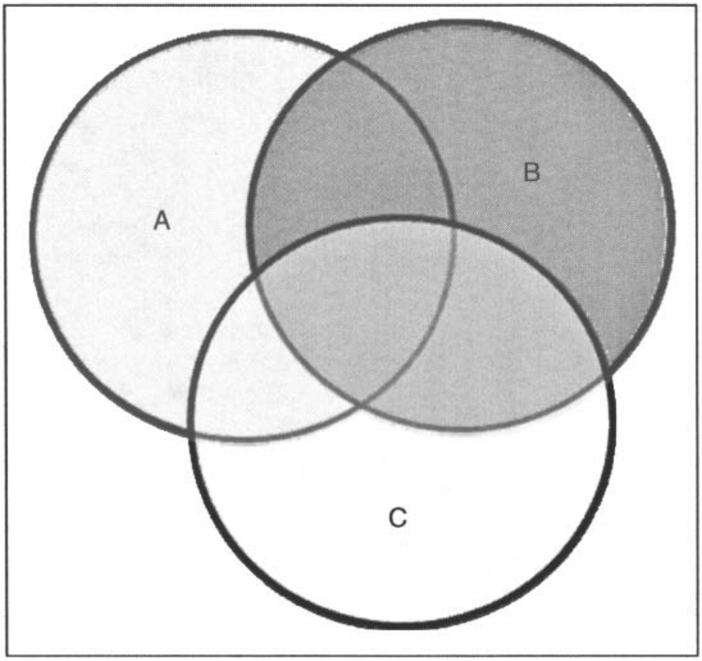

Figure 3.19 Probability theory.

This probability is presented in Figure (3.19). The probability of three events, A, B, and C, occurring at the same time will be presented by the intersection portion from the circle.

The core definition of risk is the probability of the event occurring multiplied by the output of this event: Risk Assessment = probability × consequence.

To explain the decision tree, let's use dice and assume that the first player to throw the dice will earn 6,000 pounds only if the result is a 6, but if it is another number, the player will lose the 1,000 pounds, and the expected value calculation will be as follows.

The possible emergence of a 6 is the probability of 1/6, so the expected value equation is as follows:

$$\text{Expected Value} = (1 / 6) \times 6000 - (5 / 6) \times 1000 = 166.7$$

The general equation, a difference of products, is as follows:

$$EV = P_s \times C_s - P_f \times C_f,$$

where P_s and P_f are the probability of success and probability of failure, respectively. C_s and C_f are the consequence in case of success and failure, respectively.

We find that the probability of rolling a 6 is the one-sixth, but the expected value of the payout is 166.7 pounds, which is greater than zero (the expected value of risk). A high expected value indicates that the risk is better. Therefore, when compared with the display of the other player, our player found the expected value greater.

This concept is the main decision-making tool that you would use if you had more than one project and you want to choose one of these projects. Therefore,it is important to be aware of calculating the probability of success of each project as well as the value of that success.

Therefore, in applying the decision tree method to solve an engineering problem, or in the feasibility study, one must specify the expected outcomes and possibility of solving the engineering problem. This will determine the likelihood of success. The focus should be to identify all the different ways to determine the likelihood of the event because it depends entirely on the experience from start to finish. Therefore, the experience is the key factor to the success of this method and can simply explain the manner of the following example.

This example of Proverbs is common in the case of decisions in engineering projects for the oil industry. You can imagine that all the decisions of drilling for oil depend on the possibility and existence of oil in the ground, and the volume of the amount of ground reservoir varies from a large reservoir to a medium and to a small. Therefore, decision makers should use the decision tree to determine whether the drilling work will do or not.

Figure (3.20) is a case study on making the decision to drill or not. If you drill, you have 2 possible outcomes – that the well will be dry or that the well will have oil.

If you have an oil reserve, you have three possible outcomes. The reserve may be high, low, or medium. Every outcome has its probability of occurrence. It is noted from the figure that the total probability is equal to one, based on the probability theory. In each scenario of outcomes, calculate the present value (PV).

By multiplying the probability with the present value (PV), one will obtain the expected value (EV). By adding all the values, you get the expected value of the project which in this case is 4.6 million dollars. Therefore, this project would have less expected value than a project somewhere else that might be worth more than 4.6 million dollars, and a decision could be made.

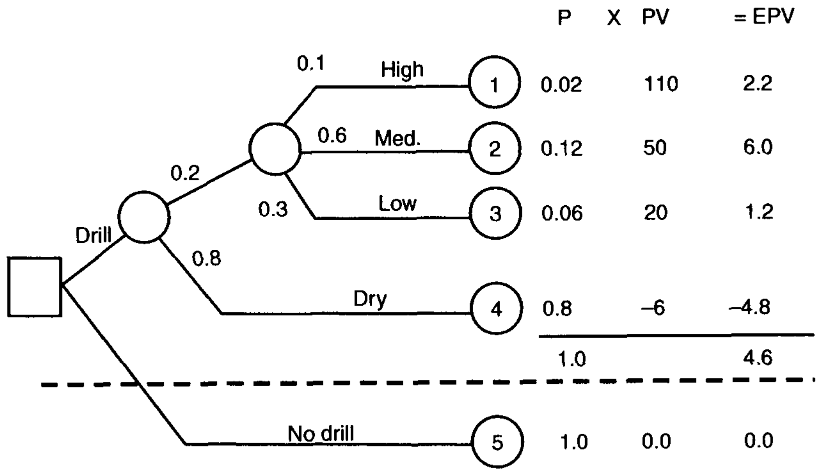

Figure 3.20 Case study one.

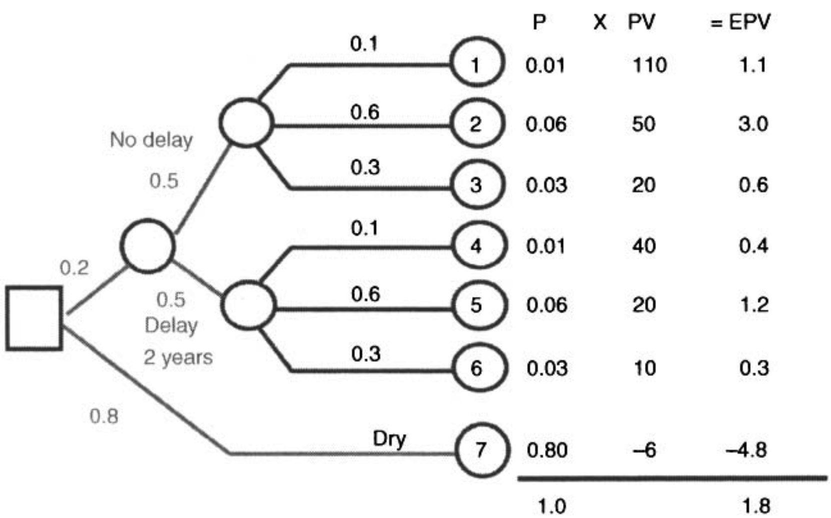

Figure 3.21 Case study two.

For example, if you find that your investment in a country gives the expected value of 8 million dollars, will you invest in any of the two countries? Naturally, you will not invest in the site in the example, but your decision will be clear that you will invest in the country that will give higher weight to the expected value of invested money.

Using the decision tree, potential problems you may encounter during the implementation of a project can be obvious, and this is evidenced by the following example in Figure (3.21), which is the same as the previous example with the possible delays in drilling wells. This usually happens in some countries that permit administrative bureaucracy where the delay is a result of administrative work for foreigner permits and correspondence paper or the equipment for custom paper work. This is an example where the auger is not available, and this is something that will have an impact on the accounts of the present value of investment, as in the following example. It is clear that the number of decision-making trees depends primarily on the experience, as it considers all the possible problems that can be urged as well as prospects.

Figure (3.22) presents another example for constructing a new facility, and you may cancel this project or group through the appraise phase (conceptual design). The possible outcomes from the study are that you will need a plant or not. Due to production there are three possible outcomes: abandon the facility, make no modifications, or modify the facility.

The decision tree is very easy to use, but the problem is how to calculate the probability for every event. You can assume the probability value using your experience, but it will affect the result.

The best way to calculate this probability is by using the Monte-Carlo simulation technique. In every case, start by building

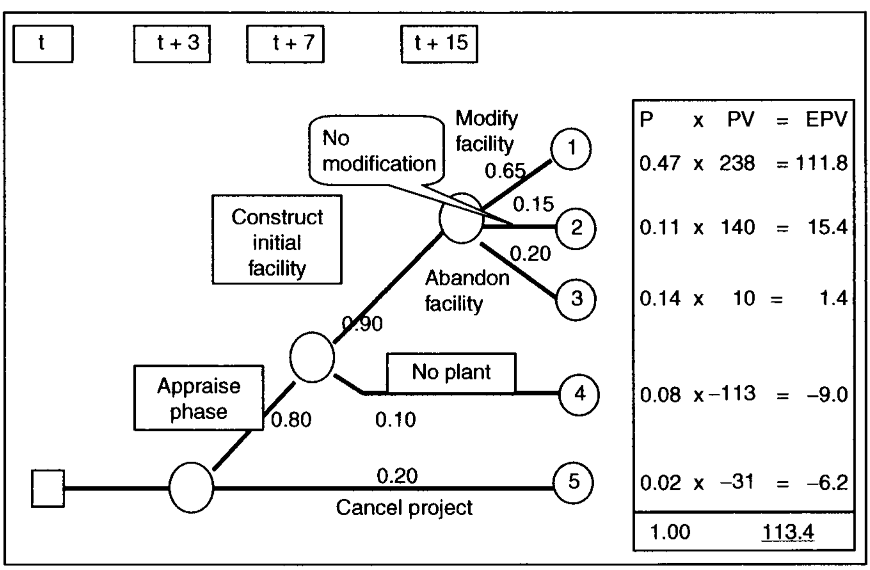

Figure 3.22 Case study three.

a model for a reservoir in an oil and gas project, and define the mean, standard deviation, and the probability distribution that are present in the reservoir model as area, height, porosity and others parameters. At the same time, build the model for the present-value calculation, and also define the parameters for each variable.

3.5 Monte-Carlo Simulation Technique

Simulation is the process of replicating the real world based on a set of assumptions and conceived models of reality.

Monte-Carlo simulation is required for problems involving random variables with known (assumed) probability distributions.

This method of simulation was started as an idea by Enrico Fermi in the 1930s. Stanisław Ulam in 1946 first had the idea and later contacted John von Neumann to work on it, and he started to use this simulation in a secret project. After World War II this simulation was published in many papers as a simulation technique.

The Monte-Carlo simulation technique is frequently used to verify results of analytical methods. Rushedi (1984) used the Monte-Carlo simulation approach to obtain the first two statistical moments (mean, value, and standard deviation) of the failure mode expression of brittle and ductile frames and, consequently, a system safety index. Ayyub and Halder (1985) suggested advanced simulation methods for the estimation of system reliability.

Fellow et. al. (1993) used the Monte-Carlo simulation program (M-Star) to understand the load and resistance factor design (LRFD). Nikolaos (1995) used the Monte-Carlo simulation to study the reliability of reinforced concrete members strengthened with carbon-fiber-reinforced plastic.

This method depends on simulating the case of study by its parameters, and each parameter will be represented by its probability distribution, mean, and standard deviation.

The simulation will have two parameters: a variable and uncertainty. For example, the length of the men in a country is a variable as it represents a normal distribution. But managing a project by time and cost is usually uncertain and is represented by a triangle distribution by knowing the minimum, maximum, and most likely.

So, the risk assessment for the cost estimate and the risk assessment for the project's time through the PERT method also uses Monte-Carlo simulation. If you want to predict the cost of a large project, you should break it into parts, define the cost of each part, and add them together. As will be discussed concerning time management in chapter four, the project's time schedule plan is also broken up into smaller activities and based on the PERT method.

Each random variable is described by its statistical parameters: mean, standard deviation, and type of distribution. The distribution type of the random variable is chosen among the different probability distributions provided by the program.

Figure (3.23) presents an overview of the Monte-Carlo simulation technique. The input data for the variables will be a probability distribution and, after simulation, one obtains the outputs by the graphs and statistical data.

The simulation model contains all the input data of the deterministic parameters, the random variables, and the equations. The model will run for at least 10,000 trials, as in the following flowchart. The Monte-Carlo simulation technique is simple and is presented in Figure (3.24).

The final output results in displays by software at the end of the simulation and contains the statistical parameters of the variable Z, describing the limit state equation of the cost and time.

After the whole trials are completed, this program will calculate and present the mean, standard deviation, and the statistical

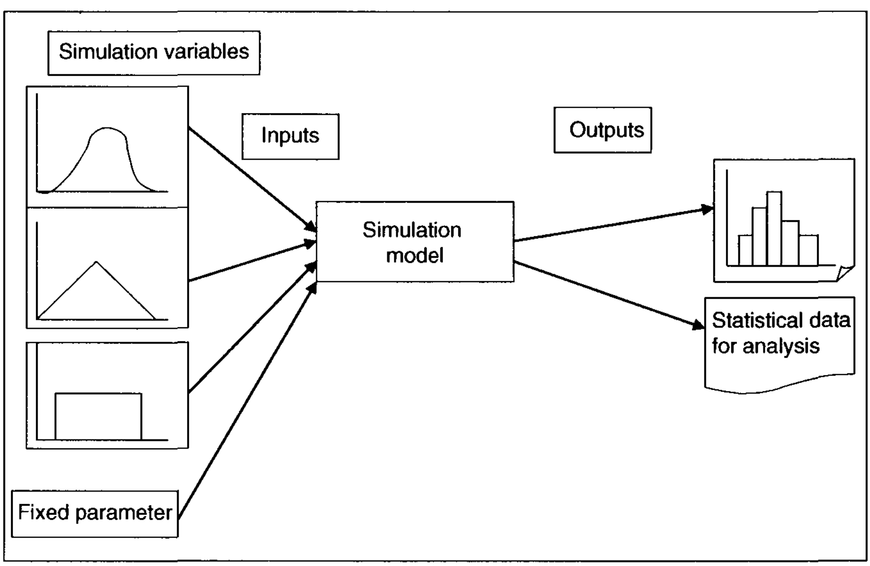

Figure 3.23 Monte Carlo simulation.

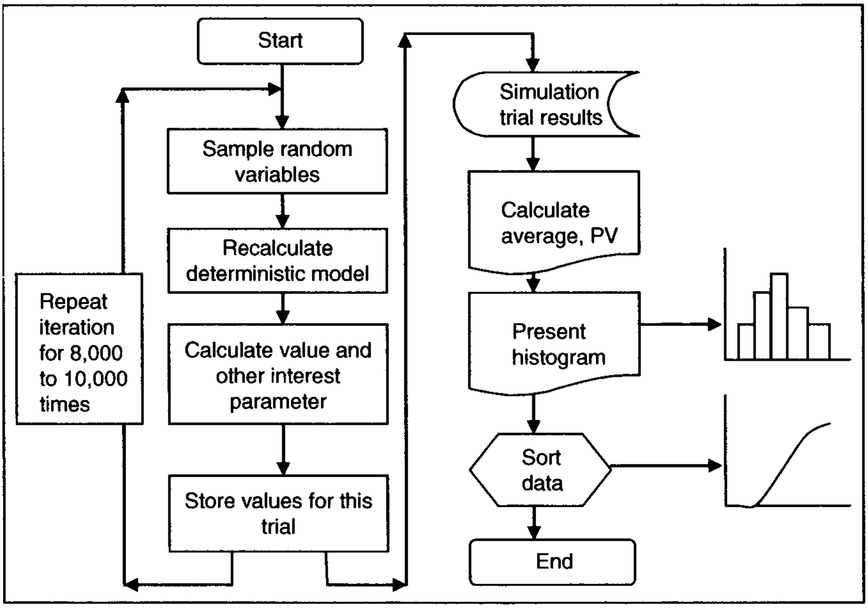

Figure 3.24 Flow chart for monte-carlo simulation.

parameters. Also, it can provide the frequency distribution of the value of outcomes of Z and determine the probability of increasing the cost to the limit of the budget.

As shown in Figure (3.25), the input data for all the variable parameters is selected by choosing the probability, arithmetic mean, and standard deviation or coefficient of variation. After running the simulation, the output will be a probabilities distribution curve.

Then, run the random numbers as per the "Mid-square Method" (Von Neumann and Metropolis, 1940s), which produces pseudo-random four digit numbers:

1. Start with a four digit seed number.
2. Square the seed and extract the center most four digits. (This is your sampling parameter.)
3. Use the sampling parameter as the seed for the next trial. Go to step 2.
4. Random number generators usually return a value between 0 and 1.

For any software you use to perform the simulation for the cost, time, or other risk criteria, the process can be summarized as follows.

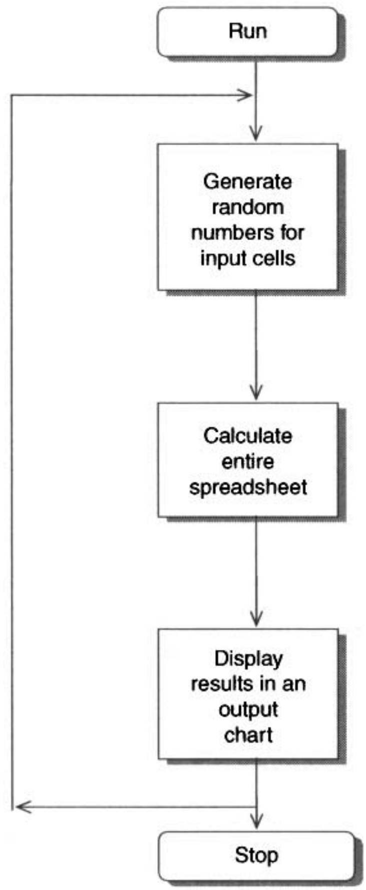

Figure 3.25 Monte-Carlo simulation consequence.

From the deterministic model, obtain the value of the output and other parameters. Then store the data for this trial and repeat these steps again for 8,000 and 10,000 times, so you have 10,000 output for the variable, so can calculate the arithmetic mean and standard deviation. Then draw the distribution or histogram curve and the cumulative curve.

3.6 Risk Adjusted Value (RAV)

Three elements contribute to project ranking: expected return, risk, and loss of funds. One problem concerns trading off each value. Return may indicate one ranking, risk another, and so on. The EPV and risk weighted values, however derived, include each of these components. Compare two projects, each with the same EMV. If the manager could lose $10 for a dry hole on one and $100 million on the second, EPV would imply that we would be indifferent between the two. Yet, in the real world, few managers would treat a potential $100 million loss the same as a $10 loss. A key assumption in EPV analysis is that the manager is risk neutral and the firm has unlimited capital. Neither assumption holds true in the real world.

Extending EPV to reality requires the concept of certainty equivalence. By definition, certainty equivalent is the value a manager would just be willing to accept in lieu of the risky investment. This point defines the value at which the manager is indifferent between the two alternatives. To illustrate, consider an investment with an EPV of $10 million. EPV includes a return, chance of success, and a potential loss. The actual outcome could be higher or lower than this value. Should someone start offering the manager a guaranteed amount less than $12 million, say $9 million, then $8 and so on until the manager said yes, the value eliciting the yes is the certainty equivalent or the indifference value.

Let's assume that two companies have different, but identical, prospects worth $10 million (EPV), each with a 100% WI, and an offer to farm out to a third party. The first party accepts a guaranteed offer of $6 million, while the second party accepts an offer for $4 million. Why would the indifference points differ? Because most managers are risk adverse, contrary to the primary assumption of EPV. And the degree of risk aversion depends on two basic components: the wealth of the firm (hence, freedom from bankruptcy) and the budget level. In this example, both firms are risk averse because they would accept a lower amount to reduce risk. Had either accepted the EPV they would be risk neutral, and occasionally we see investors who would want more (a true risk taker).

Cozzolino (1977) introduced the term risk adjusted value to integrate these concepts, as defined in Equation (3.40).

$$RAV = \left(\frac{-1}{r}\right) Ln\left[P_s e^{-r(R-C)} + (1-P_s)e^{-rC}\right] \tag{3.40}$$

where r = risk aversion level of firm, P_s = probability of success, R = NPV of success, C = NPV of failure, E = exponential function, and Ln = natural logarithm.

In the Cozzolino (1977) format examples, like those above that are used to solve for *r*, assuming that *RAV* is already established, if *R*, *C*, *RAV*, and *P* are known, the corporate risk aversion can be determined. Without performing an example, larger values for *r* imply more risk aversion while smaller values reflect lower risk aversion. Evidence suggests that an inverse relationship exists between capital budget size and risk aversion level. Smaller companies tend to be more risk averse and, thus, tend to spread their risk across as many projects as possible.

This basic format has been extended by Bourdaire et. al. (1985) to eliminate the need to estimate the risk component. By employing the elements of subjectivity and assuming an exponential utility function, Equation 3.41 results.

$$RAV = m - \frac{s^2}{2B} \tag{3.41}$$

where m = mean NPV, s^2 = standard deviation of distribution, and B = total monies budgeted for risky investments.

RAV under this format can be based on information typically generated in the evaluation. RAV also depends on the estimated value relative to the dispersion of the NPV outcome. More importantly, high dispersion projects may be ranked above projects with lower standard deviation if the dispersion relative to the budget is low. RAV depends on two basic relationships: m relative to s^2 and s^2 relative to B.

If the mean value of NPV that was calculated from the Monte-Carlo simulation is equal to 10 million dollars, then a standard deviation illustrates the dominance of the dispersion term, since \$10 – $(15)^2$ will be a very negative value. Now suppose that the investor is a large oil company with a budget of \$1,000 million. The RAV of the project is

$$RAV = 10 - \frac{225}{2x1000} = \$9.9 million\,.$$

For a smaller investor with a budget of only \$200 million, RAV becomes

$$RAV = 10 - \frac{225}{2x200} = \$9.4 million\,.$$

The breakeven RAV value for *B* is found by solving

$$RAV(breekeven) = \frac{s^2}{2xm} = \frac{225}{2x10} = 11.25\,.$$

We are not aware of anyone presently ranking on RAV, although more people are discussing it. Like other ideas portrayed in this book, we believe it should be included as part of the evaluation for a period of time. If RAV aids in decision-making, then include it permanently.

4

Time Planning

4.1 Introduction

The most fundamental skill of project management is how to read, design and amend the time schedule. The time schedule represents actual project performance and discloses expectations of what could occur as a result of its implementation.

The first step is to determine the purpose of the project. This must be carefully defined. Then, answer the following question: what is the project's driver – time or cost?

For over 20 years, schedules had been prepared manually. Now there are computer programs that deliver them. So, not surprisingly, there is more than one method for drawing up a project's time schedule. The choice itself depends upon the nature of the project and the presentation required for senior management's purposes.

How the schedule is prepared is the cornerstone of project management. It establishes how human resources and equipment are allocated, and discloses how costs are to be distributed along the project's timeline, enabling identification of possible ways to enhance cost controls as the project moves towards completion.

During World War I in the previous century, Henry L. Gantt used the first method considered scientific to prepare a project schedule. It begins with its representation of activities by simple rectangles. The method is used in project planning and work schedules at the time of production. The Gantt chart was used by putting a plan on a magnetic blackboard using rectangles of iron, whose length was a time unit.

This was developed into the S curve, used for monitoring performance of project follow-up activities.

Until the mid-1950s, however, there was little further development of project planning as a management. In 1957, there emerged two different teams working on project planning using networks.

The first team was prepared by way of Program Evaluation and Review Technique (PERT). This method relies heavily on mathematical-statistical probability theory.

The second team was using a network and depended on CPM (Critical Path Method).

CPM methods have share many of the methods used for PERT, but some of the objectives are different. Development of the actual project plan is done through the application of Operations Research methods.

The first team to employ the PERT method in a major practical case was working on the U.S. Navy's deployment of the POLARIS submarine-based missile system. At the time, in 1958, the Navy was seeking to produce rocket launchers in record time.

Using mathematical statistics, the PERT method can be applied to furnish some exactitude for the determination of a project's activity duration time. Maximum, minimum, and most-likely times are computed for each activity in order to obtain a fully elaborated estimate of the likelihood of completing the project, or critical parts of it, within a range that specifies the likeliest minimum and maximum probable durations.

Teamwork on critical path methods (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 period for maintenance and overhaul rotating machines, as well as construction work.

Because its approach requires identifying only one expected time period for each activity, and the project itself is laid out as a string of such activities on "the critical path," the calculation of the time required for different activities in a CPM-based approach to project-management planning was easier and less complex than what had been demanded of the team managing the the POLARIS project activities.

Today, the critical-path method — used with some other methods, utilizing computer software — is the most commonly-used methof of networking activities in project planning.

In the planning process, whatever is to be accomplished by the project is planned in accordance with the order and manner of the project's overall execution. There will often be some changes, and the time schedule will require adjustments in accordance with the changes in the project.

In order to do the work with a good plan, you must answer the following questions clearly:

- What are the activities that you want to execute?
- When will you execute these activities?
- Who will execute these activities?
- What are the equipment and tools required?
- What activities cannot be executed?

Answers to these questions are crucial for arranging the work in the most appropriate way. From that point, the project will become comprehensible to all others involved in its realization. Now your goal as a project management proferssional is to transform this information in a simple way, present it to all parties of the project, and make sure everything is clearly understood.

Your planning team target is to implement the project in a timely manner in accordance with the specific cost and, at the same time, achieve the required level of quality. Therefore, the planning of this project is needed for the following:

- To reduce the risks of the project to the lowest level possible
- To achieve the performance specifications of the project
- To establish organization for the implementation of business
- To develop procedures to control the project
- To achieve the best results in the shortest possible time

Due to unavailability of certain information, the planner cannot be expected to plan in detail every single minute of the project in advance of execution. Time must be available to adjust the plan schedule as more information becomes available.

If you ask people what makes a project successful, "a realistic schedule" usually tops the list. But ask them to be more specific, and several characteristics of a realistic schedule emerge. A realistic schedule does the following:

- Includes a detailed knowledge of the work to be done
- Has task sequences in the correct order
- Accounts for external constraints beyond the control of the team
- Can be accomplished on time, given the availability of skilled people and enough equipment

Finally, a realistic schedule takes into consideration all the objectives of the project. For example, a schedule may be just right for the project team, but if it misses the customer completion date by a mile, then it's clear the whole project will need reassessment. Building a project plan that includes all the necessary parts and achieves a realistic balance between cost, scheduling, and quality requires a careful, step-by-step process.

4.1.1 Plan Single Point of Accountability (SPA)

This will be done by the project manager with the planning team. First, define the team members that will perform the required activities. Be sure they have sufficient information on their potential and their relation to the size of the project. If you want to use another experienced planner from another project contracted to work with you, do so at the beginning of the project.

You should also know through the collection of information whether the working group had worked in similar projects, for projects have almost the same activities. For example, if you are working on an oil and gas project and the working group had worked on the same type of projects before, that experience is different than housing projects, hotels, road projects, or administration buildings.

Each type of project has its own characteristics. Therefore, the working group needs to have worked in a project that is similar to your project.

The planner must be efficient in planning, must have the ability to plan the project well, and must have good experience in the same type of project.

At the beginning of the work, it is very important to hold a meeting between the planning team, the official sponsor of the project or the director of the project, and the owner and his or her representative. The goal of this meeting is to clarify the main objectives of the project, identify priorities in the implementation of the driving force, which is time or cost, and determine what is desired from the project as a whole.

4.1.2 Starting the Plan

Before starting the project plan, we should go through the basic definitions that are usually used during plan implementation. These definitions are as follows:

- Task – a small work that will perform by one member
- Activity – consists of a set of tasks and is performed by different individuals
- Concurrent activities – activities that are performed in parallel
- Series activities – activities that are executed one after the other, as the second activity cannot start until the first activity is finished

Usually there is a conflict between the task and activity, and it can be clear if you have to prepare a technical report. An activity consists of tasks, such as collecting required information, performing a data analysis, preparing photos and figures, preparing the first revision of a report, and printing a report.

There are many ways to start planning, and you have to choose among them. A good way to begin is by identifying the key stages of the project. The main key stages of the project can be identified by holding a meeting with the experienced people on the project team from different disciplines, stakeholders, and sponsors. In this meeting, use a brainstorm technique among the attendees.

Every group should make suggestions on paper. Then the papers should be collected, and all the ideas and contributions, regardless of being logical or illogical, should be shared among everyone in the meeting. It is important to follow the following rules during the meeting:

- Be concerned about quantity and not quality, even if it turned out that some of the tasks and activities have been replicated.
- Stop any suspicion of an individual to avoid any idea of the critical observations bothering the participants.

The next step is very important, as it will now have a wide range of tasks. The next step of the action team is to filter such activities, and this is done by removing some of the tasks that are repeated or duplicated. Compile the tasks, including the interdependence of both the straight or parallel. The small number of tasks and activities reduced often ranges from 30 to 60, according to the size of the activity of the project. Then compile the activities at key stages of the project.

By using this method, you will reach high precision in the planning. This is considered the beginning step in the planning of the project as a whole.

Now you have the main stages of the project, and all the key stages were agreed on by the members of the project. Now you should order them in a logical order, but you should avoid the following:

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

All of the above will cause problems, as many attendees will push you to define dates. Please take care to not fall into this hole.

To avoid mistakes in the planning Project Logic Control, the key stages must be defined on the main wall of the office. Figures (4.1a) and (4.1b) show examples of the main stages of the project.

The advantages of the above method are that everyone has an opinion on the project, making everyone keen to the success of the project, and a person's idea or opinion reflects on the project. Therefore, a person will do his or her best to offer opinions that will match with the project goal.

It is noted from Figures (4.1a) and (4.1b) that the design phase has been divided into two stages, the first stage being (a) and the second being (b), in order to allow the sending of purchase orders from the start before the end of the first phase of the design.

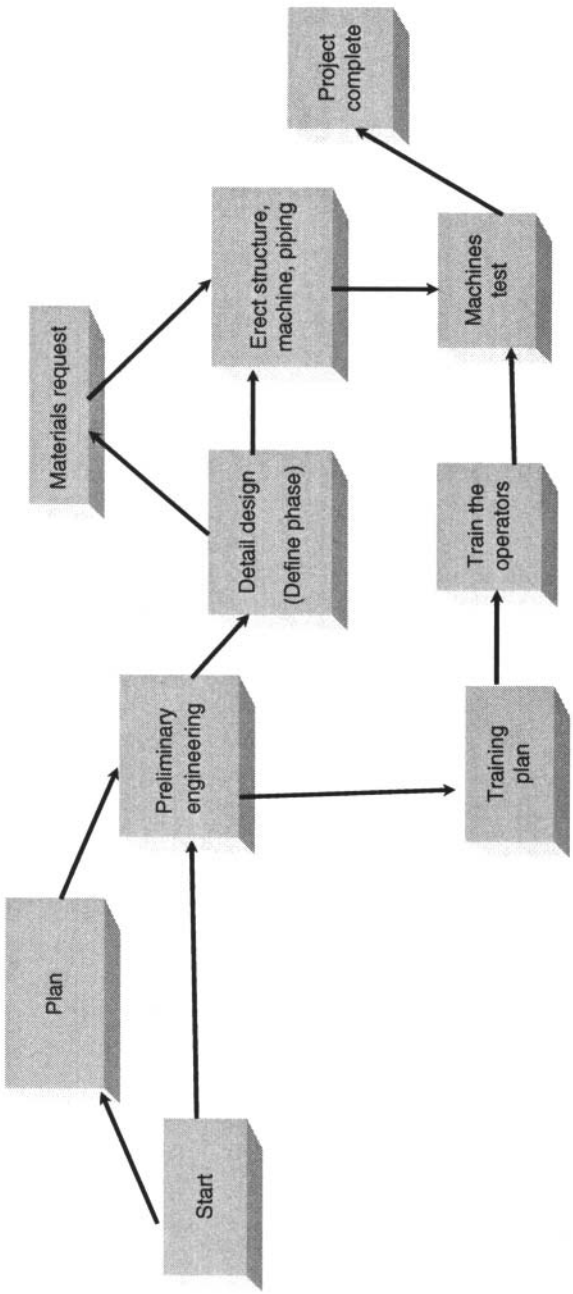

Figure 4.1a Project key stages.

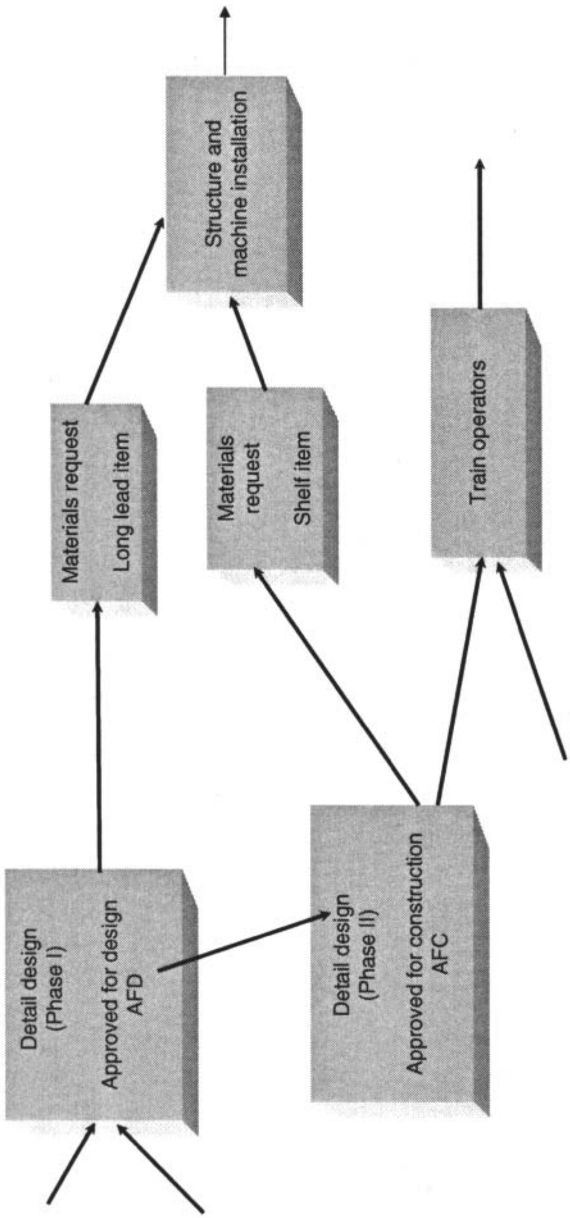

Figure 4.1b Project key stages.

Now you have the information that can be used in the computer software in order to prepare the time schedule for the agreed plan.

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

- The movement of activities should go from the left to the right.
- There is no measure of time.
- There is a place to start in the beginning of the greatest square in the north. Make sure there is an empty place in the page for each major stage in the project.
- Each phase is described by the act of writing in the form of present tense. (Do not try to set the stage for any period of time.)
- The pages are developed in accordance with the logical arrangement.
- There must be communication between the stages of a relationship.
- Identify responsibilities.
- Provide connectivity between the stages.
- Avoid the intersection of the stock as much as possible.
- Identify each key stage by professional codes.

4.1.3 Work Breakdown Structure (WBS)

The work breakdown structure (WBS) is the most important issue in the project plan. The WBS defines the work that has to be done to complete the project. Moreover, the WBS can help determine the cost of the project and its schedule.

As commonly used in projects, as in Figure (4.2), a project consists of three pipelines: a water pipeline to transport water, a pipeline for crude oil production from the plant to storage, and a gas pipeline to transport gas from the production plant to the treatment plant.

The structure of work activities is divided by the project into levels. The first level defines the main stages of the project. Regarding levels two and level three, three pipelines are envisioned. Concrete work includes setting the concrete base, as well as electrical work.

The second level in the WBS will be focus in the Figure (4.2) on stages of the pipeline work. At that level, there will be more than one stage — design drawings must be produced, and appropriate further calculations performed.

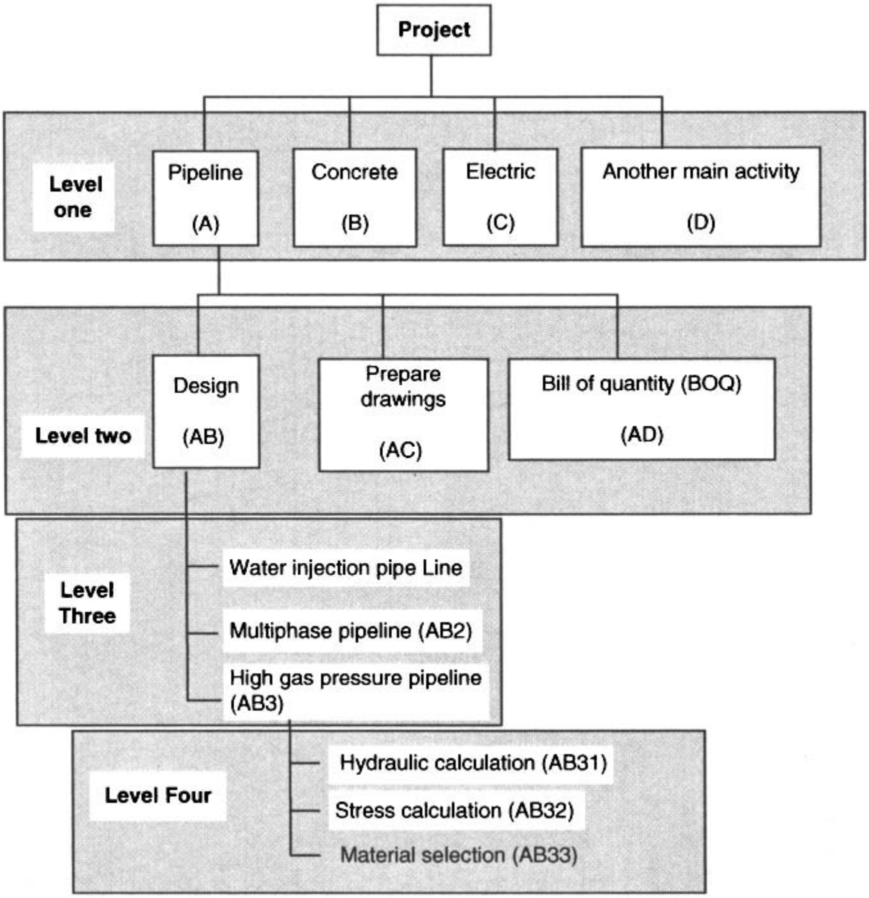

Figure 4.2 Presents work break down structure (WBS).

Level three in this example focuses on the design phase and will be divided for the design of the gas pipeline and oil and water.

In the fourth level, we design a gas pipeline by performing hydraulic design and pipe stress analysis to choose the thickness of the pipe and support locations and to ensure that the subsequent stage is the selection of the required valves. In some projects, it may require several stages depending on the nature of each project.

We note each stage in each level code for ease of use later. The WBS can be completed at any level of description. The WBS does not explain the relations between the activities nor does it show the time or the time period for any activity.

In summary, the WBS is implemented by following the steps as shown in Table (4.1).

Table 4.1 Work breakdown structure

What	The WBS is a high-level breakdown of work scope, a list of main project deliverables, and can be broken down by materials, contracts, area, or defined work packages.
Why	The WBS is used to break jobs into linked tasks. It is the basis for the estimate, the cost report, and the execution plan. Having a common format across all elements of the project results in simpler cost tracking and forecasting.
How	The project team should brainstorm the best way to control and implement the project by assessing the project execution methodology together with the commissioning sequence.
When	The WBS should be included in the project execution plan, early in the select phase, and revised throughout to define and execute.
Who	Project Leader, Planner, SPA, Construction Engineer, Commissioning Engineer, Estimator

After you have selected the main stages and WBS, the next step is to develop a rough period of time on the schedule, but there is an important step prior to that, which is to define responsibilities.

4.2 Responsibilities of the Team

In general, for industrial projects and, specifically, petrochemical projects, there is usually a modification, which will be a minor project such as constructing a new tank, new compressor, pumps, and other mechanical equipment. The team is usually formulated from different disciplines from different project departments for this one project.

The planning team, who is responsible for preparing the schedule at this stage, has a vital role to distribute the main stages of the project to members of the team. Every main stage has a key stage owner (KSO), whose responsibility is to achieve the required targets within a reasonable time. The responsibilities of the KSO include the following:

- Identify the work to the level of small tasks
- Identify relations between activities and tasks and clearly define them

- Estimate time with a high accuracy
- Ensure that business is done in a timely manner in accordance with the required quality
- Ensure that work is proceeding in accordance with the procedures and requirements for quality assurance
- Maintain ongoing follow-up
- Compose periodic accurate reports

As the project or construction manager, you will face problems during a project, and you should resolve them in an accurate time. These problems will be mainly as follows:

- Who/what provides the necessary authority to complete the work
- What tools are needed to complete the work
- Maintaining/ensuring the right atmosphere to achieve the required quality of work
- Ensuring the direct support from the project manager or the official sponsor of the project at all key moments
- Ensuring that staffs and teams understand clearly the performance expectations they are to meet

When choosing the KSO, the following should be considered in the potential KSO:

- Skills
- Depth of information and knowledge
- Previous experience in the same area
- The time which is required to complete the work
- Accuracy in the completion of previous work
- Ability to solve problems
- Ability to manage time
- Ability to work individually and with a team
- The volume of work and the current work of the KSO
- Ability to take and give advice and support
- Ability to work under stressful conditions
- The necessary training required now and in the future

Now the key stages plan is available, and every key stage owner has defined responsibilities. Therefore, it is time to start estimating the time needed for each activity in the key stages.

4.3 Expected Activity Time Period

To define the required time to finish any task, you must know the resource available to perform the work according to the required quality, and to do that you must know the following:

- Know the task volume and if it can be measured. It will be better, for example, to calculate the time required to prepare the wood form to pour 100 m^3 of concrete into the foundation. From that we can figure the task volume.
- Define the work required by hours, days, or weeks to finish this activity, noting that the number of workers should be identified, and consider the capability for each worker to perform the task alone.

Measuring the working capacity for each worker will usually take days. Take care from traps, such as the idea that you should decrease the capacity of work per day by about 50%, as all the hours per day do not focus on the project's activities as there is a lot of time wasted in meetings, special discussions, restroom breaks, eating, and others. Moreover, there is some delay in the work itself.

Now define the time period for each task, but take care from other traps when putting the schedule in the calendar because the total time period will be different due to the following factors:

- Weekends
- Official vacations and holidays
- Annual leave for employees
- Some days the project will stop.

It is worth mentioning that defining the performance rate of each activity depends on a normal rate, which is found in textbooks or standard guidelines for some contractor companies. But it is essential to take any information from others who have extensive experience, work in the same country or the same location, or have experience working on similar, previous projects.

When you need information from individuals or experts, remember that, often, time estimates are very inaccurate. This does not, however, mean that you should, in every case, take someone to task for misjudging their time estimates. For instance, when someone says that the expected time for the activity was 18 days, but he finished it in 10 days, this can be a motivation for him on future jobs.

As a rule of thumb, no one can work 100% of his or her time, because about 20–50% of time is wasted in the following activities:

- Attending meetings that we don't really need to attend
- Spontaneous office visits
- Opening and reading mail and email
- Searching for specific information
- Providing assistance or advice to others
- Equipment failure, such as a computer, printers, and others
- Daily regular activity
- Misunderstanding between team members
- A lack of clear specification or scope of work
- New specification to quality
- Attending a training course or seminar

4.4 Calculating the Activity Time Period

The calculation of the activity period requires taking data from different disciplines, but its accuracy depends on the skill and strong experience of the planner. On the other hand, there is a performance rate for each activity, and in the international contractor companies usually have a standard guide for the performance rate for each activity.

There are many factors that affect the labor productivity:

- Job size and complexity
- Job site accessibility
- Labor availability
- Equipment utilization
- Contractual agreements
- Local climate
- Local cultural characteristics, particularly in foreign operations

There is a method for calculating the time of an activity through the use of performance rates. Below shows the method of calculating the period of time to excavate 15,000 m^3, and this requires, first, determining the method of excavation. In this example, it has been identified by the equipment.

Assume you need to excavate 15,000 m^3 of soil. Using 2 bulldozers and loaders and trucks to transport the disposal will be the method of excavation. The equipment used will be 2 bulldozers, 2 loaders, and 4 trucks. The performance rate for 1 bulldozer is 120 m^3/hour, and the performance rate for 1 loader and 2 trucks is 75m^3/hour.

The rate of excavation = $2 \times 120 = 240$ m^3/hour.
The required time for excavation = 15,000/240 = 62.5 hours = 9 days.
The rate for removing disposal = $2 \times 75 = 150$ m^3/hour.
The time period for removing disposal =15,000/150 = 100 hours = 15 days.

Therefore, the excavation time equals about 9 days, and the transfer of residue is approximately 15 days, taking into consideration that the number of working hours in the day equals only 7 hours in the preparation of the timetable. For the excavation activity, take the largest time period, which is 15 days. But it may be after finishing the excavation is to start pouring the plain concrete, so it will start after 9 days , as there is no need to wait pouring the concrete until transfer all waste from the site.

4.5 Time Schedule Preparation

Now you have a plan for the work and the time period for each activity. The most important thing in preparing the time schedule is to identify the activity and determine the time required for its implementation with the identification of relations between the activities. How to determine the activities and knowledge of time of each activity has been presented, so we must now know how to arrange the activities.

The different common relation between activities is as shown in Figure (4.3).

1. Activity (B) cannot start until the finish of activity (A).
2. Activity (A) and (B) start at the same time.
3. Activity (A) and (B) finish at the same time.

In some cases, activity (A) may begin, and after a certain time period activity (B) begins. This period is called the "lag time."
A computer can perform this task easily, but in general there are two main methods: the arrow diagram and the precedence diagram, as shown in Figure (4.4).

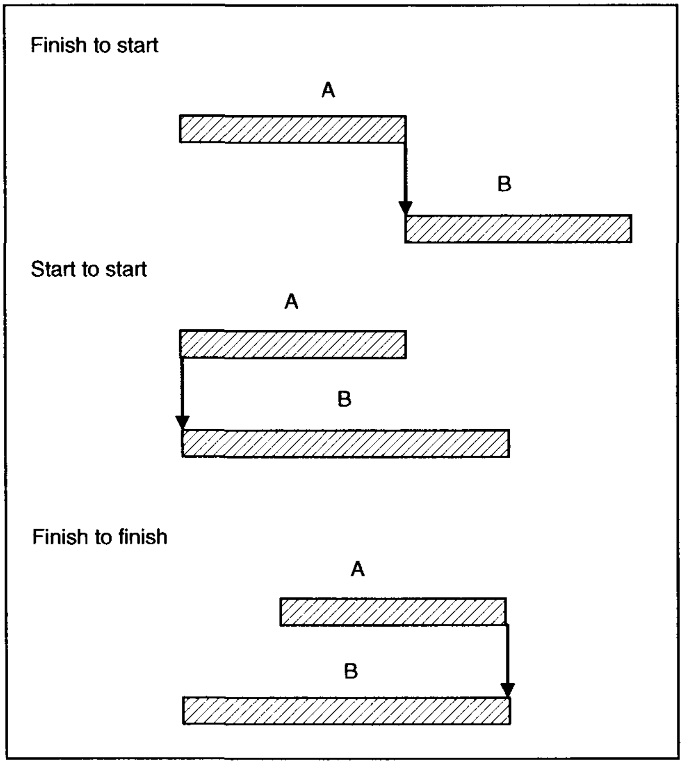

Figure 4.3 Activities order.

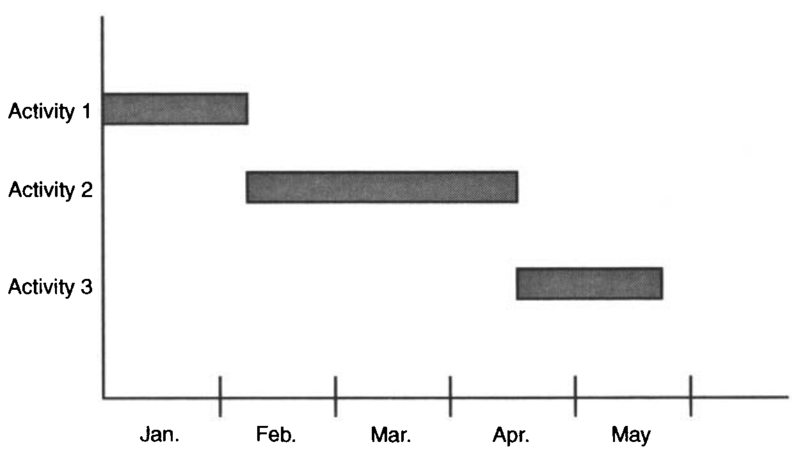

Figure 4.4 Example for a Gantt chart.

4.5.1 Gantt Chart

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

The Gantt chart is the oldest and most traditional method used to present project schedules to this day. But the relations between all the activities are not presented well by this method, and you cannot go through the detailed activity as accurately. Therefore, it would only be useful in presentations for high-level management, as it presents enough information for level one of the schedule, but for more detail another method is needed.

4.5.2 Arrow Diagram Method (ADM)

This diagram depends on the definition of each activity by an arrow, as shown in Figure (4.4), and the point of connecting arrows called nodes, which are drawn as circles. This method is also called Activity on Arrow (AOA).

In Figure (4.5), activity (A) depends on activity (B). However, activity (C) depends on (B) and (D), but there is no activity line between (D) and (C). So, it put a dummy arrow (with dashed line)

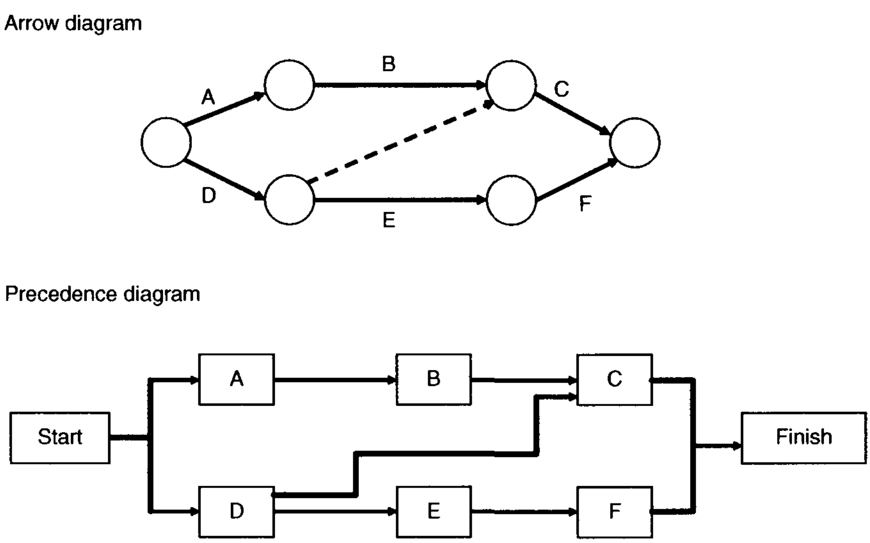

Figure 4.5 Tools to arrange the activities.

with time zero to solve this situation. Dummy activities for large activities can present a problem, so the use of a precedence diagram is preferred.

4.5.3 Precedence Diagram Method (PDM)

This method is the most common one. In this method, every activity is presented by a box or a rectangle, as shown in Figure (4.5), and the detail of the rectangle is shown in Figure (4.6). The rectangles are connected by the arrows, which represent the dependencies between the activities. From this figure, it is clear that activity (C) starts after activity (D) and (B).

Figure (4.6) presents the inside of a rectangle, which will note the duration, early start time (ES), early finish (EF) time, and also the latest start (LS) and latest finish (LF) time.

4.5.4 Critical Path Method (CPM)

The essential technique for using CPM is to establish a model of the project that includes a list of all activities required to complete the

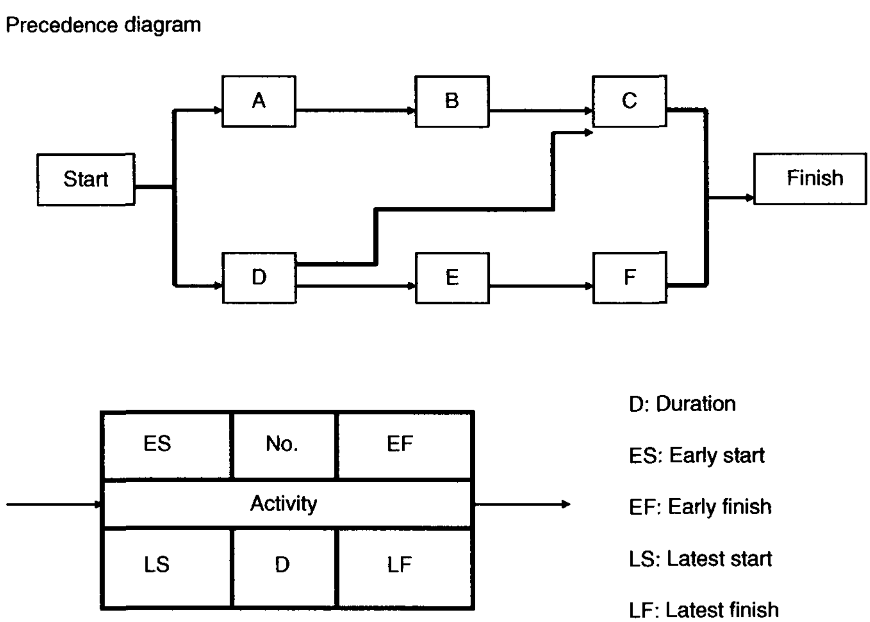

Figure 4.6 Method of preceding diagram.

project, the time duration that each activity will take to completion, and the dependencies between the activities.

By using these values, CPM calculates the longest path of planned activities to the end of the project and the earliest and latest time that each activity can start and finish without making the project take longer time.

This process determines which activities are "critical," which are the activities on the longest path, and which have "total float," as these activities 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 project can have several critical paths. An additional parallel path through the network with the total durations shorter than the critical path is called a sub-critical or non-critical path.

4.5.5 Program Evaluation and Review Technique (PERT)

This is required in any case of special projects or large-scale deliveries with a variety of activities. All activities in the project need to be identified accurately, and all must be completed before the project completion. These activities must be initiated and carried out in a specific sequence and must be completed before the start of the completion of other activities. Some activities may occur in parallel, meaning that two or more could be completed at the same time.

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

One of the operations research methods, which are used to assist the planning team, the coordination, and the control of such projects special in case of the multiplicity and complexity of activities and the large size project is known as method of Program Evaluation and Review Technique known as PERT.

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

This analysis has confirmed its applicability and importance by its application in different projects. Contracting companies can use it successfully because of its role in solving problems of coordination between various activities in a project that has a considerable degree of complexity and its role in planning the time required for implementing each activity. This method has made it possible to complete a project within the time planned and the overall schedule.

PERT was developed primarily to simplify the planning and scheduling of large and complex projects. It was able to incorporate uncertainty by making it possible to schedule a project while not knowing precisely the details and durations of all the activities.

Hence, the PERT method depends on using statistics and probability theory, so it is now the main key for the project risk assessment from the time schedule point of view.

In some cases, it is required to compress the time schedule, for example, in the oil and gas industry, where time is very critical. This can, however, lead to mistakes. For example, we can start to construct the foundation for a petroleum processing plant before finishing 25% of the engineering deliverables, and this sort of fast tracking often results in rework and usually increases risk.

Any dependencies between activities require specification of a lead or lag to accurately define the relationship. An example of lead in a start-to-finish dependency with 10 days lead is when the successor activity starts 10 days before the predecessor has completed. An example of a lag is when there might be a desire to schedule a 2 week delay (lag) between ordering the equipment and using or installing it.

4.5.6 Example

The following example will illustrate the relationships between activities and how can you create them through the precedence diagram.

The example in the following table shows the activities for a cast concrete foundation under machine package and connects the machine with piping to the facilities, which is a simple example of knowing how to arrange activities, account for the overall time of the project, and identify the critical path.

Table 4.2 Example for foundation

Item	Activity	Time (Days)	Precedence Activity
100	Mobilization	3	-
200	Excavation	8	100
300	(Pouring concrete foundation and piping support)	10	200,100
400	Install the piping	4	300,100
500	Install the mechanical package	1	300
600	Put the grouting	1	300,500
700	Connect the piping	5	400,500
800	Commissioning and start-up	2	700

In the above table, the first column contains the item number or the code for that item according to the project and its activities and the sub activities. Also, the main activity code may be 100 and the sub activity may be 110 and so on, but the above example is a simple case.

The second column is the name of the activity, which describes the activity, and the third column is the time period for each activity in days.

The fourth column specifies the relationships between activities.

Figure (4.7) shows the precedence diagram, and in each diagram there is a number with its time duration. Figure (4.8) shows the early start and finish for each activity by using the following equation:

$$EF = ES + D,$$

where EF = early finish, EF = early start, and D = duration.

Start with activity number 100. The early finish (EF) of this activity is 3 days. So transfer this value to activities 200 and 400 in the early start (ES) rectangle zone.

Item number 800 depends on 600 and 700. So it will take the higher value in the early finish (EF), which is 23 days. Put this number as the early start (ES) for activity 800.

For the last activity, which has an early finish at 25 days, transfer this value to the latest finish (LF) rectangular zone.

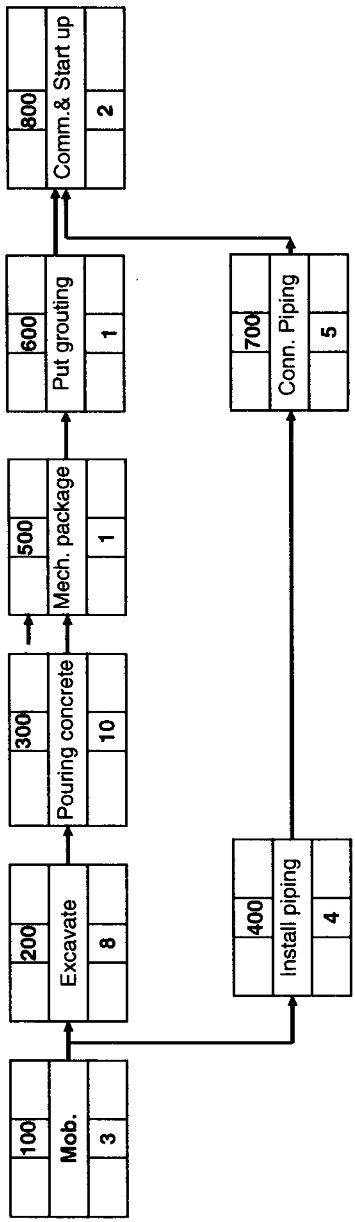

Figure 4.7 Precedence diagram for the example.

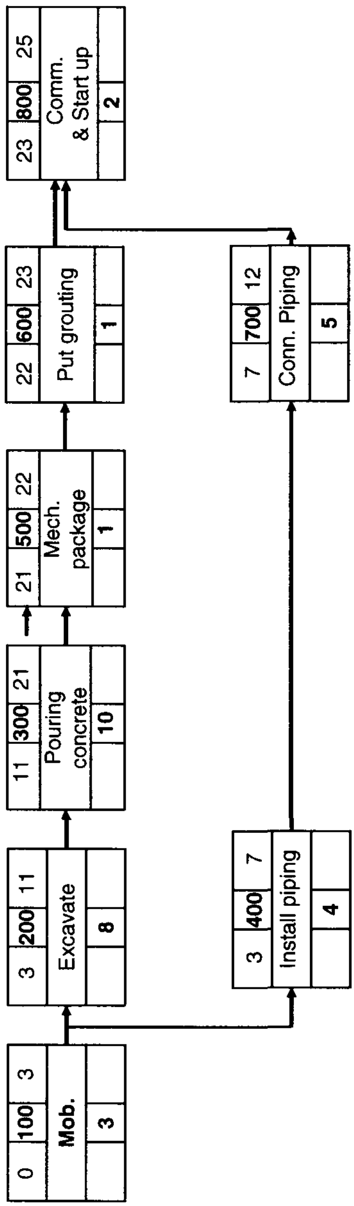

Figure 4.8 Calculate the early times.

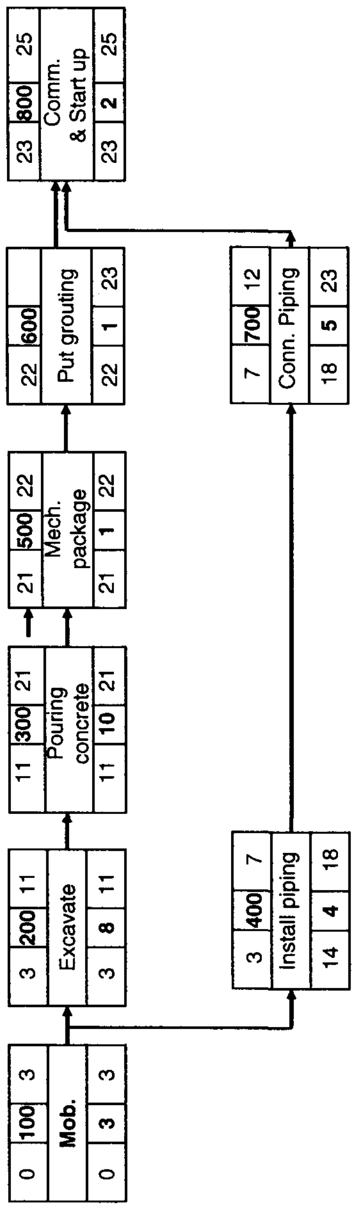

Figure 4.9 Calculating the latest times.

Figure (4.9) shows the latest start and finish for each activity by applying the following equation:

$$LS = LF - D.$$

In Figure (4.9), we can subtract latest start (LS), from latest finish (LF) and subtract early start (ES) from early finish (EF). We get the value of zero, so it means that this activity is on the critical path. But if the difference has a value, it means that this activity can be delayed by this time period without affecting the total project time.

When we calculated the early and late schedule dates for our project, we found that sometimes the early and late schedule dates were the same, and in other activities the dates were different. In these activities there was a difference between the earliest day that we could start an activity and the latest day we could start the activity. The difference between these two dates is called "float," or sometimes "slack." These terms mean exactly the same thing and can be used interchangeably. The float of an activity is the amount of time that the activity can be delayed without causing a delay in the project.

Table 4.3 Float time calculation

No.	Activity	D	Earliest		Latest		Float		Critical
			ES	EF	LS	LF	TF	FF	
100	Mobilization	3	0	3	0	3	0	0	*
200	Excavation	8	3	11	3	11	0	0	*
300	Pouring concrete foundation and piping support	10	11	21	11	21	0	0	*
400	Install piping	4	3	7	14	18	11	0	
500	Install the mechanical package	1	21	22	21	22	0	0	*
600	Put the grouting	1	22	23	22	23	0	0	*
700	Connect the piping	5	7	12	18	23	11	11	
800	Commissioning and start up	2	23	25	23	25	0	0	*

Using computerized project management scheduling software, we can modify the list of activities on the critical path to include activities that are nearly on the critical path. This is important since the critical path method is a management method for managing project schedules. The activities that have zero float are the activities that cannot be delayed without delaying the completion of the project. These are the activities that must be monitored closely if we want our project to finish on time. Conversely, the activities that are not on the critical path, those activities that have something other than zero float, need not be managed quite as closely. In addition, it is important to know which activities in the project may be delayed without delaying the project completion.

Resources from activities having float could be made available to do a "workaround" if the need should arise.

By performing a simple calculation, we can find 11 days as a total float (TF) for installing piping. But installing piping has zero free float (FF), as any delay will affect the connection of the piping. The piping connecting activity has an 11-day FF, as there is no activity after that to delay.

4.5.7 Application of the PERT Method

We previously reported that the implementation of the activity takes time and needs resources. The PERT team may face a problem of how to estimate the time of each activity, as they see that reliance on a single estimate time is a weak assumption and is incompatible with the conditions of uncertainty, even under the best circumstances. The external environmental factors surrounding the project may cause a deviation in the times of the activities planned.

Accordingly, the PERT method has been found to overcome the time uncertainty. By estimating the time of each activity with three estimated time values, they will be gathered together with to reach a statistical probability to estimate time of the project completion. This method will apply as follows.

Optimistic time estimates the minimum possible time in which to do the activity, considering that all the factors affecting this activity are going smoothly. This time is usually low because all the circumstances must be good at the same time.

Pessimistic time estimates the maximum possible time in which to implement the activity. So it considers the worst cases happen to delay this activity. This usually provides a higher time period with low probability.

The "most likely time" presents the time period in which to perform this activity under normal conditions for all the factors affecting this activity. This value has the most probability of occurring.

The PERT method correlates the relation between the above three times by using a beta distribution as in Figure (2.11). The optimistic and pessimistic value precincts the limits of the distribution, but the most likely value present is the frequencies of the event occurring.

To define the activity time period, the activity mean time needs to be calculated, and this is done using the below equation. The summation of all the time periods on the critical path presents the mean time period for the project.

4.5.7.1 Statistics Calculation for Activity Time

From the beta distribution, the expected or average time for each activity is calculated according to the following equation:

$$T_a = \frac{T_O + 4T_m + T_P}{6}, \tag{4.1}$$

where T_a = average time, T_o = optimistic, T_p = pessimistic time, and T_m = most likely time.

4.5.7.2 Example

For the previous example of constructing the concrete foundation, there are three values for time for each activity, as shown in the following table.

Table 4.4 PERT example

Item	Activity	To	Tm	Tp
1	Mobilization	1	3	5
2	Excavation	6	8	11
3	(Pouring concrete foundation and piping support)	8	16	25
4	Install the piping	3	4	5
5	Install the mechanical package	1	1	2
6	Put the grouting	1	1	3
7	Connect the piping	2	5	7
8	Commissioning and start up	1	1	2

After defining the critical path from the previous example, calculate the expected time at each activity as shown in Equation (4.1).

Calculate the standard deviation using the following equation:

$$s = \frac{T_P - T_o}{6}. \tag{4.2}$$

$$\text{Variance, V,} = S^2.$$

From Table (4.5) calculate the Ta, which is the average time and the standard deviation based on Equations (4.1) and (4.2), respectively. The variance is calculated as it is only possible to sum the variance. You cannot perform summation for the standard deviation.

The minimum time to finish the project is 18 days, and the maximum time to finish is 39 days. The average time period to finish the project is in 23.31 days.

What is the probability if you increase the project time over 25 days? This value can be calculated from the following equation:

$$V = 0.44 + 0.694 + 1.36 + 0.028 + 0.11 + 0.11 = 2.74 \text{ days.}$$

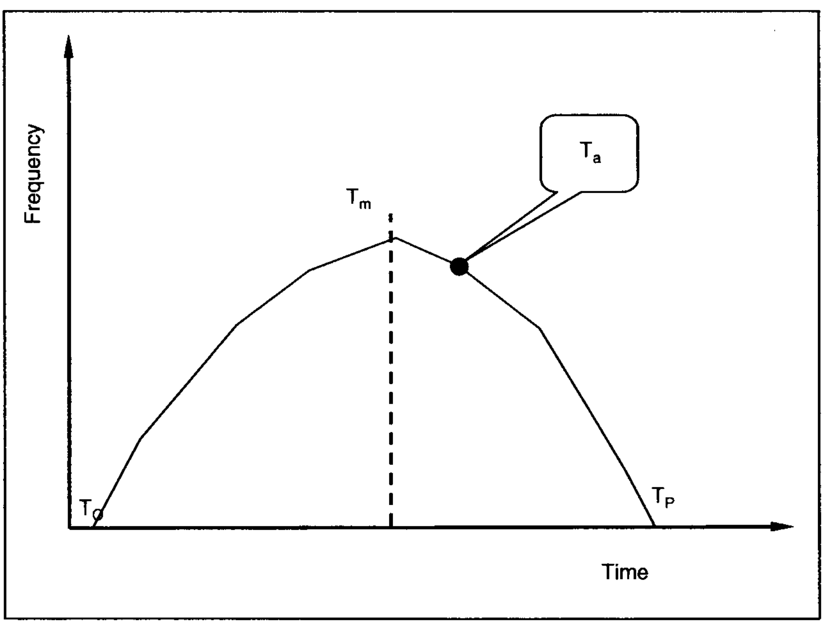

Figure 4.10 Probability distribution for project time.

Table 4.5 PERT calculation

Item	Activity	V	S	C.P.	Ta	To	Tm	Tp
100	Mobilization	0.44	0.67	*	3	1	3	5
200	Excavation	0.694	0.83	*	8.3	6	8	11
300	(Pouring concrete foundation and piping support)	1.36	0.5	*	7.17	8	10	15
400	Install the piping	0.11	0.33		4	3	4	5
500	Install the mechanical package	0.028	0.167	*	1.17	1	1	2
600	Put the grouting	0.11	0.333	*	2.17	1	1	3
700	Connect the piping	0.694	0.833		3	2	5	7
800	Commissioning and start up	0.111	0.333	*	1.5	1	2	3

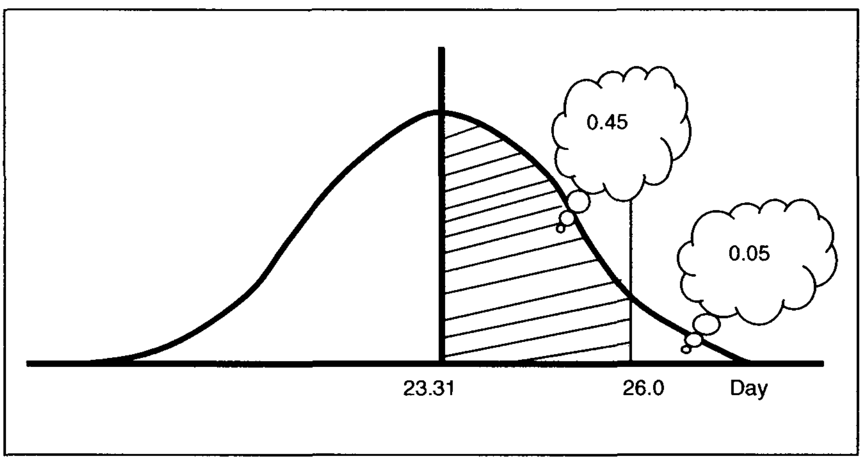

Figure 4.11 Probability distribution.

Standard deviation (S) = 1.66 day.

$$z = \frac{26 - 23.31}{1.66} = 1.62$$

From the probability distribution tables, the probability that the project completion period is more than 26 days is 5%. The probability that the execution time for the project is equal to or less than 26 days is 95%, as shown in Figure (4.13).

4.6 Planning Overview

The following steps are important to obtaining the schedule plan.

- *Create the project definition.* The project manager and the project team develop the statement of requirements (SOR), which identifies the purpose, scope, and deliverables for the project and defines the responsibilities of the project team.
- *Develop a risk management strategy.* The project team evaluates the likely obstacles and constrains and creates a strategy for achieving the required costs, schedule, and quality.
- *Build a work breakdown structure.* The team identifies all the tasks required to build the specified deliverables. The scope statement and project purpose help to define the boundaries of the project.
- *Identify task relationships.* The detailed tasks, known as work packages, are placed in the proper sequences.
- *Estimate work packages.* Each of these detailed tasks is assigned an estimate for the amount of labor and equipment needed and for the duration of the task, which will be explained in Chapter 5.
- *Calculate the initial schedule.* After estimating the duration of each work package and figuring in the sequence of tasks, the team calculates the total duration of the project. This initial schedule, while useful for planning, will probably need to be revised further down the line.
- *Assign and level resources.* The team adjusts the schedule to account for resource constraints. Tasks are rescheduled in order to optimize the use of people and equipment used on the project, which will be discussed in Chapter 5.

These steps provide all the required information to understand how a project will be executed. The steps are systematic, but they don't necessarily come up with the "right answer." It may take several iterations of these steps to find this answer, which is the optimal balance between cost, schedule, and quality.

The planner plays a key role in controlling the project outcome and flagging potential bottlenecks and problems for the project manager. It is expected that the planner set up a weekly review meeting for each of his or her projects with the following deliverables:

- Attendees should consist of the appropriate cost engineer, project manager and senior project engineer, and construction supervisor.
- Review plans, identify issues, and agree on action steps to overcome them.
- Receive hand marked updates from the construction supervisor.
- Review the actual percentage complete versus the planned percentage complete, percentage milestones met, and approximate costs (from the plan) to be passed to the cost engineer.

The planner should be seen as proactive not reactive, predicting the future issues and proposing solutions.

The planner's main skill is in the art of communicating with the project management team, cost engineer, construction supervisor, and contractor. A good planner is a good communicator.

5

Resource Management

5.1 Introduction

The main function of project management — the resources available for management — are manpower and equipment. As project manager on the owner side, the principal resource is usually manpower. As project manager on the contractor side, they are manpower and equipment.This chapter focuses on the management of project resources through strong organization and communication and on best practices for guaranteeing highest-quality output from the workforce, whatever the situation. These principles are also valuable for the individual who is working in a client role with an engineering company or a contractor. Whatever the case, the most widely-used organizational forms within which a project manager can expect to work, both their weaknesses and strengths, are discussed in this chapter.

5.2 Project Organization

There are three commonly used organizational forms. Each has advantages and disadvantages, and it is important to weigh certain factors in making the optimum choice. It may also be possible to "merge" elements of these basic forms into a hybrid form. There may be overlaps to take into account as a result of employing an unincorporated organizational structure. All these considerations have implications for how the project team is organized. The discussion here also illuminates the roles of different project team members and discusses some behavioral problems that a project manager should anticipate in working with the project team.

The project manager usually has little significant impact on the project's organizational form. That form itself appears usually as a prerogative of senior management. A project manager is compelled by these circumstances to work this organizational form as far as it can be worked so that meeting the project's targets is assured. The project or construction manager on site must understand this organizational structure, in all its interactions and relationships. Experienced project managers often re-formulate the organizational structure of the project to fit with their perception of what is best for the development of the project.

5.2.1 Types of Organization

All types of organization have their advantages and disadvantages. The best choice of project organizational form needs to take into consideration the nature of the project, its characteristics, and prior experience for projects undertaken by this company or other similar organizations.

Whether one is a project director, an employee of a client firm engaged in the project or a project team member, a clear understanding of basic organizational types, their advantages and disadvantages is indispensable. In addition, by knowing advantages in every organization, you have the motivation and driving forces, which will be used to control the individuals who work with you. This kind of awareness also strengthens the individual's motivation and driving force working in the project environment, and can be used to bolster the conviction and motivation of other members of the project team, Head Office etc.

The principal types of organization are as follows:

5.2.1.1 Project Organization as Part of the Company

This organizational form is used often for small projects that are within the company itself, such as industrial projects that entail increasing the product line, expanding the plant, or creating a new production line.

In this case, the project manager eeds to define the departments that are responsible for the project. This organization is also used in a type of project that contains new technology, such as buying a new advanced machine in which the supervision of the project rests and operation will be with the engineering management responsibility.

According to this schema, one of the departments will manage the project. This department will have daily work performed by individuals, and the department shall be responsible for the project and report to senior management of the company. Now let us consider what the advantages and disadvantages are to this type of organization.

The most important features can be summarized as follows:

- We can easily transport the personnel to and from the project. This greatly simplifies the processes whereby experiences are exchanged and modern technology is transferred to the largest audience among company employees.
- Being already part of the company, the workforce is readily deployable for project tasks
- Individuals working on the project are operating in the same functions that they normally would, and therefore their presence in the project will enhance the promotion of individuals
- Increasing the experience of individuals who work in the project will increase the benefit to each individual and the company as a whole.

The disadvantages to this type of organization are as follows:

- The department is in charge not only of the project but also of the daily departmental routine, which may have negative impacts on how much time is reserved for implementing the project.
- Although technical problems may be solved relatively easily as personnel are working in their usual job function, but they usually avoid the administrative work as they unfamiliar on it.

- Project lines of accountability and departmental lines of accountability may fail to be adequately distinguished or synchronized. This organization, in most cases, will not be given responsibility for a specific individual, where that work will be responsible from the whole department, so may be two persons work in the same activity in the project. So, may be one of them busy in the department regular activities or in vacation, so the work may be reviewed by more than one person, all that will cause a loss of accountability in the project.
- If or when senior management consider the project just an extension of their usual routine work, the motivation of a working group towards completing project objectives may not be able to play its proper role.

5.2.1.2 *Independent Project Organization*

This organizational structure functions as an independent unit separate from the company.

This form of organization in industrial projects facilitates corporate supervision for enterprises that enterprises that have not large number of projects at any one time.

There are some disadvantages and advantages of this organization. The most important characteristics are:

- The project manager has full authority to manage the project and reports to the Executive Director in the organization.
- Everyone in the team reports directly to the project manager.
- A separate working group is given a sense of independence, which creates a high level of commitment, including commitment to precision, in work.
- In this organization, understanding of work orders and the implementation are direct and not complex.
- There will be powerful, fast decision-making and vitality throughout the project.
- Communication between individuals in the project and the people who work in the company head office will be reduced to minimum or eliminate.

Some disadvantages of this "independence" model include:

- In the case of more than one project in the organization, the teamwork being built into each project may give rise to a certain duplication of effort, thus tending to increased costs of administrative services if these services have to be duplicated for each project.
- In the case of projects that need special technology, the less communication there is between the project and technical divisions, the more difficult it is to transfer expertise from the company organization to the project.
- As a result of the independence from the head office, the staff will be fear about their career in future when they return back to the head office, and they usually have a questions about their promotion.
- Failure to balance properly the independence of operation of individual projects with the overriding authority of Head Office may create unintended clashes among managers working on individual projects and administrators at Head Office.

This kind of organization has defects that can be prevented if an appropriate project manager is selected.

5.2.1.3 Matrix Organization

The matrix organization is commonly used by construction companies or consultancy firms running more than one project at a time. This type of organization is also useful for special projects in the field of advanced technology. One of its most desirable key strengths is its inbuilt tendency to encourage integration of different experiences from multiple projects and its enabling the ready sharing of such experiences across multiple projects.

The main strengths of this organization are as follows:

- At any point in time, while more than one project is being executed, functional departments have expertise available (technical engineers or other specialists).
- Upon completion of the project, no further responsibility for the careers of individuals who work in the project devolves upon the organization.

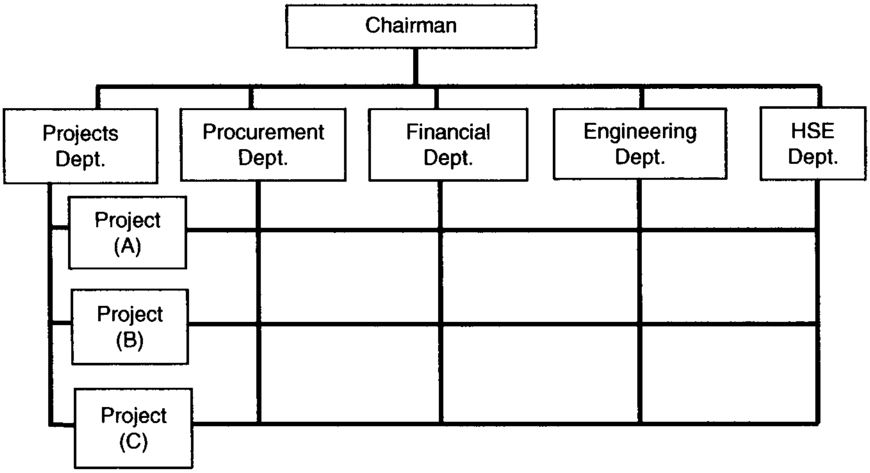

Figure 5.1 Matrix organization.

- There is strong communication between members of the project and between the functional departments in the main office.
- Individual projects enjoy considerable flexibility to operate as separate units. At the same time, expertise not normally attached to some particular project can be engaged from another project currently utilizing that expertise.
- With good planning, and coordination, a balance can be struck over the allocation of the common resources.

The main disadvantages are:

- The individuals in this organization enjoy no employment security at the end of the project, although job security is usually less of a concern than in the independent project organization model.
- The project manager controls the administration, while managers of the departments at the Head Office are managing only the technical aspects. Where a technically-informed decision might have undesired impacts on the project's cost or time targets, this might cause confusion between the project manager and functional department heads.

- Everyone has two managers.
- Potential for conflicts lurks in the overlap between the project manager and directors of different departments.
- A burden rests with the planning department at Head Office in the distribution of resources commensurate with each project's requirements.

Such disadvantages can be minimized or avoided by an experienced project manager, or by selected individuals whose project experience is commensurate with the challenge of achieving the necessary balance between the requirements of the project manager and the functional department at Head Office.

5.2.2 Selecting the Best Organization

The central issue in choosing a project organizational structure is to determine the quality of work to be carried out, according to the initial selection of project objectives and identification of the tasks necessary to implement each goal.

In general, you can follow the following steps in choosing the organizational structure of the project:

1. Identify the goals of the project that need to be achieved.
2. Identify key tasks for each of these goals, and identify functional units in the head office that can perform these tasks.
3. Figure the order of the main tasks, and then configure the work package from them.
4. Determine which parts of the project will perform business groups and which will work with the other.
5. Make a list of the main characteristics of the project, for example the level of technology required, size and execution time is expected. If there is no problem in allocating the resources, this will avoid any political problems that might occur between the different functional departments who will be involved in the project. Finally previous experience of the company will affect the project organization.

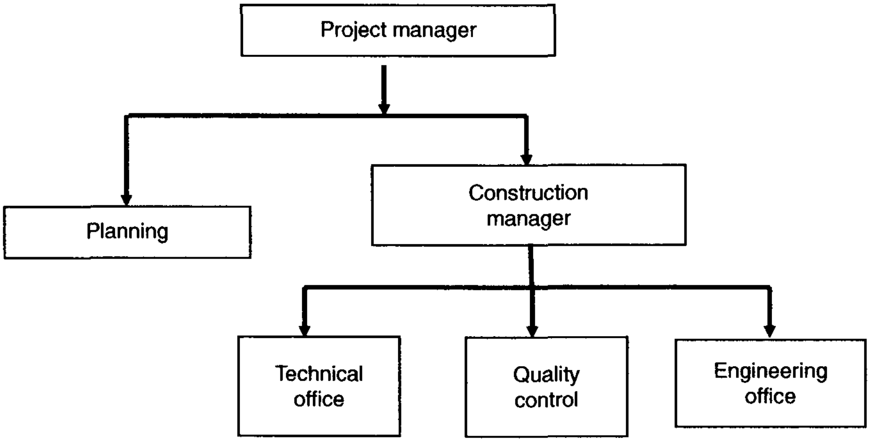

Figure 5.2 Organization chart on site.

6. Based on full knowledge of the disadvantages and advantages of different organizations, one can select the appropriate organizational structure for the project.

The best choice of project-organization type depends ultimately and crucially on actual circumstances. There are no detailed steps that can be considered instructions to determining which type of organization is needed and how to build the project. There is this fundamental rule-of-thumb that should inform an optimal selection, and-or design, of organizational structure: take into account the nature of the project and the characteristics of the available and most relevant organizational types, and carefully weigh the advantages and disadvantages of each.

Single-project organization is most suited to conditions in which a company operates a large number of similar projects, such as construction. Single-project organization is generally appropriate for projects that are unique and where privatization is high. It functions individually, and requires careful control, because it is not necessarily integrated into any department's standard operating procedure within the larger organization.

Matrix-type organization is best-suited to conditions in which a project requires the integration of many functional departments, includes high-tech, but does not require that all the technicians are working full-time professionals. But it does mesh complex and puts the project manager in difficult situations and therefore can be avoided when a structure is simple.

5.3 Roles and Responsibilities of the Project Manager

The project manager is one of the keys to project success. His abilities can lead a team to success on a path that avoids or minimizes performance anomalies. The following are among a project manager's responsibilities:

- supervising the preparation and project plans;
- defining the relations between the different parties involved in the project's execution;
- taking all actions and steps necessary for obtaining project resources;
- organizing supervising and coordinating work between departments;
- following up project activities, and taking appropriate interim decisions to re-form pathways of execution;
- monitoring costs, and making decisions to ensure they match plan costs;
- taking action to ensure the cash flows to and from the project in benefit toward the project;
- ensuring that the professional competence of subcontractors meets the required level, and following up their work;
- preserving the rights of the company, as set out in the contract, and overseeing the administration of the contract;
- sending on the project deliverables in a timely manner and reviewing customer claims (often a source of the truest and most objective judgment of the degree of the project's success);
- establishing a linked system of reports that coordinates the project internally with its functional departments and externally with the project's owners, consultants, local authorities, sub-contractors and suppliers;
- attending the meetings of the project at a strategic level, in general (including executive-level meetings);
- developing a policy to encourage employee initiative within the project;
- testing assistants and subordinates as part of discharging the responsibility for achieving the project plan in

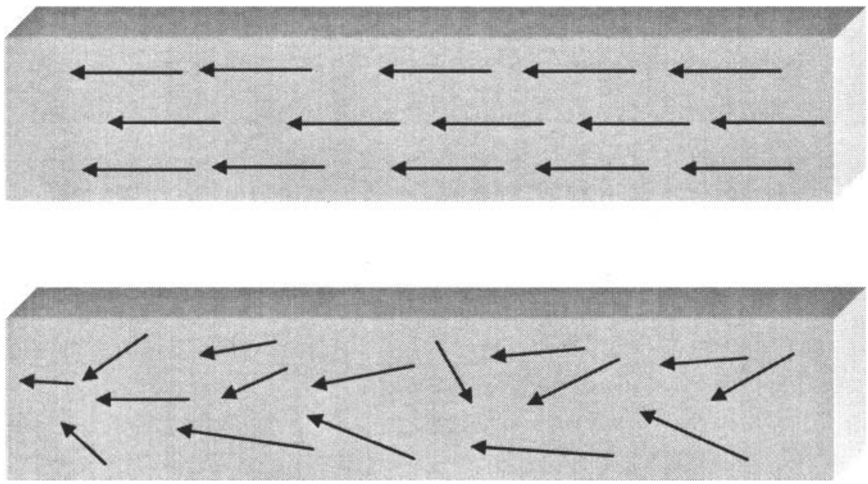

Figure 5.3 Effects of clarity and cloudy for objective, vision and mission to the project team.

terms of time, cost, and quality, and making all other decisions required for completing the project that do not violate existing company policy or practice at Head Office (not to mention governmental statutes and regulations);

- ensuring good onsite management of the project (administration, subsistence, regulating traffic, and securing the site and its employees against risks, etc. In the case of a non-resident manager, regular visits have to be carried out. In the manager's absence otherwise, a second-in-command must be available to take charge and maintain everything according to the regular manager's norms);
- ensuring that equipment works and materials are in compliance with specifications.

The project manager is "the conductor of the band." Failure on the project manager's part to lead execution of the tasks at hand properly will produce a result unsatisfactory to the client. He or she is, and will be held, responsible for clarifying the objectives and requirements of the project before and during its execution.

The following figure illustrates the usefulness of consensus group work, setting goals as the business runs smoothly for the project as a whole. The second figure illustrates what happens with non-compliance and a lack of clarity. Time will be wasted, and that would result in increased costs.

5.3.1 Project Manager as a Leader

A successful project manager has the ability to lead a team composed of individuals with different skillsets, personalities and levels of experience. The team members may have also worked on different projects and in different organizational structures. As a project manager, you must overcome cultural barriers and create a spirit of cooperation and coordination of effort.

The following list attempts to encompass the most desirable combination of qualities and skills in the ideal project manager:

- Excellent communication skills
- Flexibility in work and acceptance of changes
- Training on the tools and techniques of project management
- Potential to direct every member of the project to achieve the objectives of the project
- Respect of senior management
- Ability to make quick decisions
- Ability to identify, analyze, and solve problems
- Entrepreneurial mentality and work ethic, and an attitude that treats general rules of the project as role models and guidelines rather than as either absolutes or matters of indifference
- Self-confidence
- Experienced in procedures and project management tools
- Motivated to achieve success

There are two ways to manage individuals: through direct orders and sharp resolution of a centralized dictatorship, or through democracy, meaning the dialogue and discussion of ideas and analysis as the basis for issuing commands. Each method has its advantages and disadvantages, but the project leader must determine how it will operate, and needs to be ready and able to "shift gears" between these approaches as circumstances may dictate.

Central decision or dictatorship is important in the case of a project that needs speed in implementation. This is a function of the nature of the project as a whole and must take into consideration the people who work with you and the nature of their personalities.

In many instances, this method is very successful with some individuals, but it may fail with others, and how ifar t is used needs to be tempered by the parameters of the project's general atmosphere at various times. For example, when there are good relations between individuals and there is a time for discussion, why not use the other way, a way of democracy to consider the views of individuals and make them reach the solution that you want? Control discussion, but let them feel that they are the owners of the idea. This would reach an amazing result, as the owner of the idea will try to forcefully demonstrate that it is a successful idea, and this is what serves the project as a whole and, thus, matches with the project goal.

5.4 Administrative Organization for Total Quality Management

In each company there must exist a team of Total Quality Management (TQM) such as is demonstrated in the project organization and the company organization as shown in the figures below.

Figure (5.4) shows the administrative organization of onsite construction management. Quality control appears in the administrative organization and in its relations with the project manager and members of the team.

Figure (5.5) shows the administrative organization of the company. This company may be the office of the engineering company or contractor. Of note here is a somewhat specialized quality management system which explicitly identifies executive-level responsibility for maintaining and updating the quality manuals of the organization. The Quality General manager stands at the same administration level with the Projects General manager of the company, and in a direct relationship with the company chairman or Chief Executive Officer (CEO). The idea is to ensure that the Quality Manager has the power needed to follow up recommended improvements to the quality system of the entire organization.

We want to make sure that the company has a system of quality assurance from the outset. Examining the organizational structure and its site quality management of the overall organizational

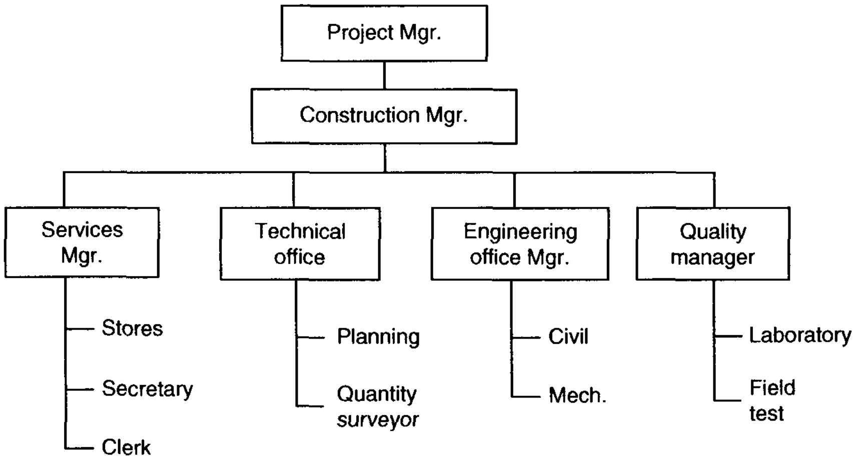

Figure 5.4 Sample of organization.

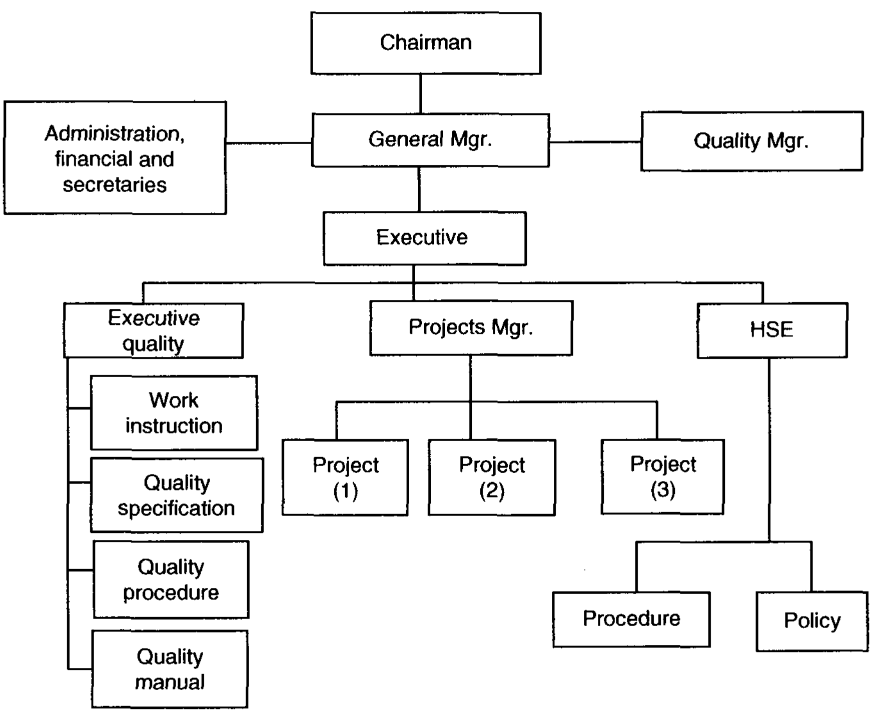

Figure 5.5 The head office organization.

structure of the company, the actual role of the quality system is and its impact within the company can be readily determined. (Here it is worth mentioning that, when reviewing tenders and bids for any company, the organizational structure should be carefully reviewed on the basis of considering carefully the quality of staff and their relationship with various departments, with the aim of determining the location and importance of quality for the company.)

Modern organizations that take quality into account, you must see an existing slot to the quality general director enjoys direct contact with the chairman of the company, giving that company officer he necessary power and speed in decision-making. (These schematic diagrams of organization are just demo as to the size of the quality team, as this number is bound to differs from one organization to another, depending on the size of project and the number of projects they are running.)

5.5 Team Member Selection

Team membership selection is a key responsibility of the project manager, of crucial importance to the initial roll-out phase(s)of a project. As in any human organization, there will be pressures on a project manager to engage this or that individual from the company commissioning the project and-or from the companies contracted to execute the project. From the standpoint of a project manager, actual competence or qualification of these persons for any particular position may be little more than the luck of the draw. A conscientious project manager will anticipate and avoid this trap in favour of retaining sufficient authority and freedom to determine actual competence of a position candidate for himself/herself.

Usually, members of the project team will come from different disciplines and different locations, coming from different organizations with different skills.

In the matrix organization model, the individual will have two direct managers: one whose responsibilities are technical and the other exercising an overall jurisdiction as project manager. In some cases, a team member will be assigned to different projects and work only part-time in your project.

When choosing team members, interview and select every one individually. Team members may have worked together previously or may know each other. Some may have not worked with you previously. Your responsibility is to "break the ice," and your challenge is to enable them to work together as one team.

The choice of individuals should be based on prior study of the experiences and qualifications of each, and not made dependent only or mainly on whether the individual is currently available. When selecting a team, you should ask yourself the following questions and be clear in answering each question:

- What is the experience related to the project?
- Does this individual have special skills suitable for the project?
- Does this individual have experience in similar projects?
- Has this individual ever worked in project teams before?
- Do s/he have technical information applicable to the requirements of the project?
- What is the department responsible for?
- Does he or she have a link with another project?
- When will this individual's association with this project end?
- What is the ratio of currency and participation in the project?
- What is other work load does s/he share with another project?
- Is it possible to reduce the workload by the excess of the project?
- Will he or she work from the beginning of the project until the end?
- Does he or she have a commitment to another project?
- Do this individual deal easily with people?
- Is there a record of his or her performance during another project?
- Is he or she interested to join in teamwork?
- Is this individual orderly, and does he or she know how to manage time?
- Does he or she take responsibilities very seriously?
- Is this individual an excellent player in teamwork?
- Is his or her handling of time commensurate with the tasks?
- What is his or her feeling from the project manager instructions (happy, sad, angry, ...)?

Sometimes the answers to those questions are not easy. To be certain of achieving success, it is necessary, however, that everyone is made aware of each individual's importance for the project.

An individual who has joined the project should be capable of working in a teamwork environment. Also, the project manager should have confidence in good relations between the individuals. Selection should also take into account the targets to be achieved and the capacities required of the team in order that the work is completed properly whatever the time, budget or other constraints and pressures.

5.6 Managing the Team

Difficulties are to be expected at a project's outset, with a team whose ability to work together in the upcoming project is as yet unknown. To assist in anticipating and surmounting the difficulties that can be sensed before they become obstacles, it is crucial that the project manager pay close attention to enhancing the interrelationships in the working group as soon as possible. To overcome conflicts and obtain the highest productivity from the team, the project manager should address the following potential deficiencies at the project's outset:

- Lack of clarity regarding responsibilities
- Lack of equal distribution of work between team members
- Lack of clarity in the allocation of work for each activity
- Lack of understanding of any of the stages of the project
- Overall objectives of the project are not clear.
- Lack of trust between team members
- No continuous and strong contact between the team members
- Lack of guidance for the members
- No interest in the quality of work
- Objectives of individuals differ from the objective of the project.

Paying attention to, and overcoming, the above "negatives" should sustain a high probability of overall success for the team.

5.7 Allocate Resources to Project Plan

The plan for the project as a whole has been finalized, teams have been staffed/selected, and a schedule has been rolled out. The next key stage is the allocating the resources available at different stages of the project. This is illustrated in discussion of the following example.

5.7.1 Example

We will use the same example as discussed previously in Chapter 4 for the time management. The project is to install a mechanical package and connect it with piping as shown in Table (5.1). From this table we can define the relationship between the project activities.

Figure (5.6) shows the critical path of this project through the project plan. Table (5.2) shows the time frame for each activity. This is presented in the table by the total floating time (TF). The resources column indicates the number of personnel required for each activity per day. The last column shows the total number of days required for each activity. Thus, for example, in Table (5.2) excavation needs 7 workers per day, and work will last for 8 days, so this activity needs 56 working days in order to be achieved.

Figure (5.6) shows the distribution of time duration of this project, which is 25 days. Summing the total working days, shown in Table (5.2), the effort will actually consume 173 working days.

Table 5.1 Example for foundation

Item	Activity	Time (Days)	Precedence Activity
100	Mobilization	3	-
200	Excavation	8	100
300	(Pouring concrete foundation and piping support)	10	200,100
400	Install the piping	4	300,100
500	Install the mechanical package	1	300
600	Put the grouting	1	300,500
700	Connect the piping	5	400,500
800	Commissioning and start up	2	700

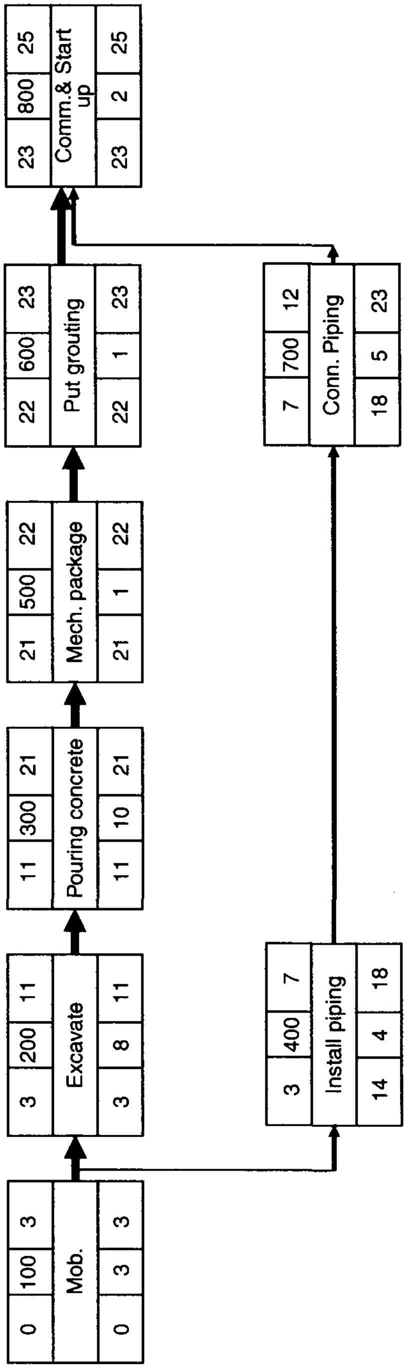

Figure 5.6 Preceding diagram define the critical path.

Table 5.2 Resources allocated to the activities

No.	Activity	D	Earliest		Latest		Float		Resources Per Day	Total Resources
			ES	EF	LS	LF	TF	FF		
100	Mobilization	3	0	3	0	3	0	0	4	12
200	Excavation	8	3	11	3	11	0	0	7	56
300	Pouring concrete foundation and piping support	10	11	21	11	21	0	0	4	40
400	Install piping	4	3	7	14	18	11	11	5	20
500	Install the mechanical package	1	21	22	21	22	0	0	4	4
600	Put the grouting	1	22	23	22	23	0	0	4	4
700	Connect the piping	5	7	12	18	23	11	11	5	25
800	Commissioning and start up	2	23	25	23	25	0	0	6	12
Total projects man days										173

Figure (5.7) presents the time schedule and the number of employees if the plan is presented by the early start (i.e., all activity starts in its first starting time). At the bottom of the schedule another option is presented of launching all the activities which are not on the critical path at the latest starting time. In our example, this is represented by activities 400 (installing the piping) and 700 (connecting the piping).

In the first case, the maximum number men on site will be 12, whereas under the second option, using the latest start, the maximum will be 9 persons. Therefore, a decision needs to be made on whether to use the total float or free float to achieve the project target. In normal cases, it is preferable to keep the number of laborers on site as few as possible consistent with safety standards and project requirements, since, if the number of onsite laborers is increased, the probability of accidents and injury may increase. A similar consideration arises with siting laborers in remote areas such as those in which oil and gas projects are conducted: accommodations have to be provided by the company that may be onsite or nearby but in any case add to the project's ongoing operating costs. If the optimum number of onsite personnel can be minimized, it will help rein to in these costs. (In some cases of this kind, there may be fiurther constraints, e.g., if the client can provides accommodation for only 10 persons per day near or on the site.)

When it comes ot staffing levels in the engineering design office, it is important for maintaining the project's output quality that the work load is distributed so as to maximize the distribution of work and working time to full-time engineering staff, while minimizing the hiring of part-time, or six-month-contracts-at-a-time, engineering staff. Too much part-time work eventually undermines overall project quality, so an appropriate distribution of work loads can be highly beneficial.

Figures (5.8) and (5.9) present the distribution of the resources in two cases, and the harmony of resources distribution is visible if we use the latest start activity as discussed before.

It is worth mentioning here that, in the case of large projects, a meeting be held between a representative of the owner, the consultant, and the contractor. In this meeting, the contractor should define the personnel and equipment that will be found at the site in accordance with the schedule plan. In this meeting all the representative engineers should reach a working agreement about the allocation

Activity	Res.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Mobilization	4																									
Excavation	7																									
Pouring conc.	4																									
Mech. packg	4																									
Grouting	4																									
Comm &start up	6																									
Install piping	5																									
Connect piping	5																									
Sum		4	4	4	12	12	12	12	12	12	12	12	9	4	4	4	4	4	4	4	4	4	4	4	6	6
Install piping	5																									
Connect piping	5																									
Sum		4	4	4	4	7	7	7	7	7	7	7 1	4	4	4	9	9	9	9	9	9	9	9	9	6	6

Figure 5.7

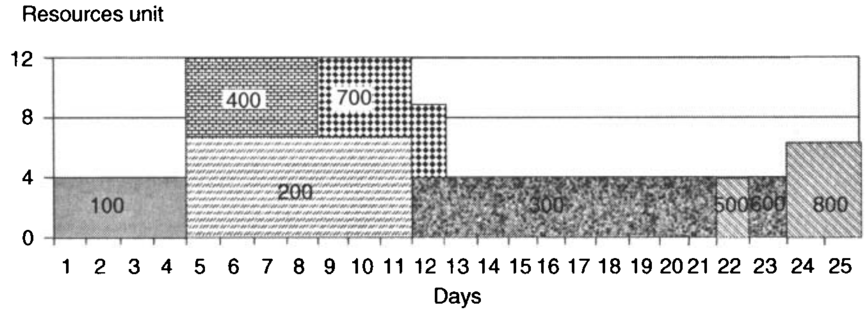

Figure 5.8 Resources distribution in first case.

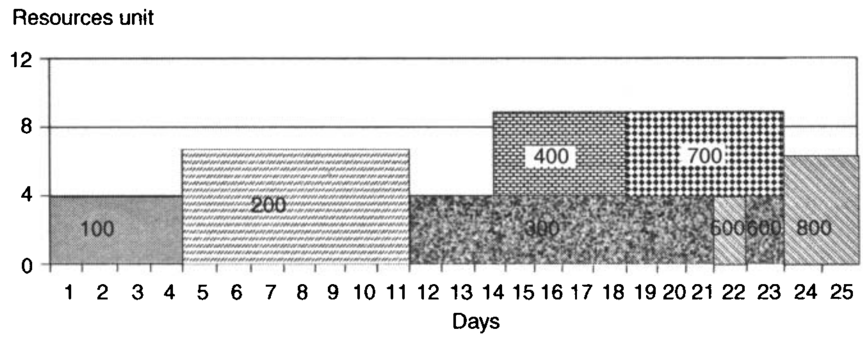

Figure 5.9 Resources distribution by latest plan.

of resources. There are objective conflicts that have to ironed out. For example, the contractor in the negotiation may have his own reasons for supporting a particular distribution of resources, connectd with other plans he has for other projects using some of the same personnel and equipment. This is examined further in the later chapter on costs. From an owner's point of view, not wanting to be exposed to potential liabilities from a project that increase with the time taken for its completion, it is frequently important to complete all the scheduled project tasks as soon as possible. This predisposition, however, leads to favoring a fatter payroll at the project's inception in the hope that the risks of project delays down the road will thereby be minimized.

5.8 Relation Between Project Parties

Any project, large or small, depends on human resources, the ultimate source of any project's success or failure. In every phase of the project, there are teams that work either in parallel or in series. Different teams can work at the same time. Some teams can receive work from other teams. Every team has its own internal organization and may also have specific goals of its own. The project manager is responsible for coordinating all the relationships among the various task forces and agencies that operate within the project.

In the stage of initial studies, FEED engineering action team is in charge of studies. The initial proposal of the idea and the design team change it by hand. Then, the contractor will modify the idea once again according to its requirements or his or her point of view and will finally deliver the product to you.

5.9 Document and Information Transfer

In any project transfer of correspondence, the correspondence between the owner and the engineering office or the contractor is of paramount importance. Speed and accuracy of response from the right person is crucial for customer satisfaction. The movement of documents among the parties is extremely important for each since, as already remarked, all three parties are simultaneously customer and client. The following figures present typical examples of document movement. Figure (5.10) shows an example of the movement of correspondence within one of the companies that generates ISO specifications.

Movement of documents must be integrated.

5.10 Information Transfer

The transfer of information is of great importance, since this is a time of rapid information transfer and information technology in particular with the development of the use of computers. To ensure that information will be transmitted fast and accurately, a strong procedure needs to be established in order to avoid any defect in the information transmission system.

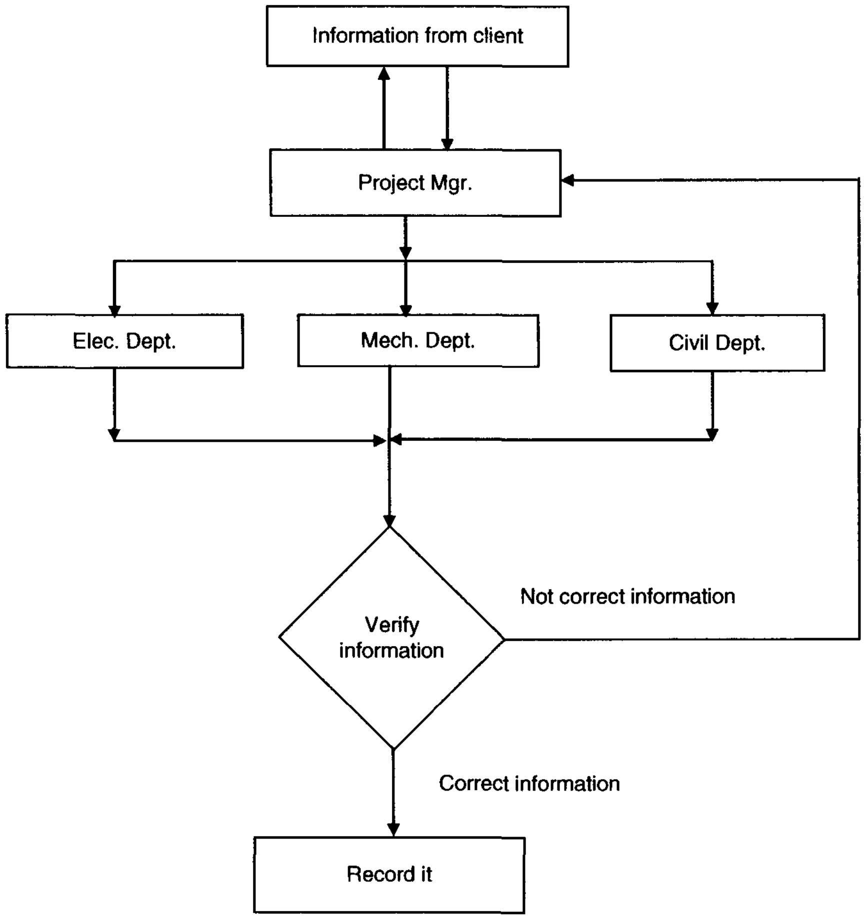

Figure 5.10 Information transfer.

This shows the shape of the movement of information received by the project manager from the owner. The project manager receives information and distributes it to the heads of departments involved. The information will be reviewed and compared with previous projects and it will identify the degree of accuracy of such information.

If, after review, some errors in the information or inaccuracies are found, a report for the project manager is to be prepared. The project manager in turn sends it to the client for review. The information is kept registered in a special list If it is considered sound and the project manager and director of the department are concerned

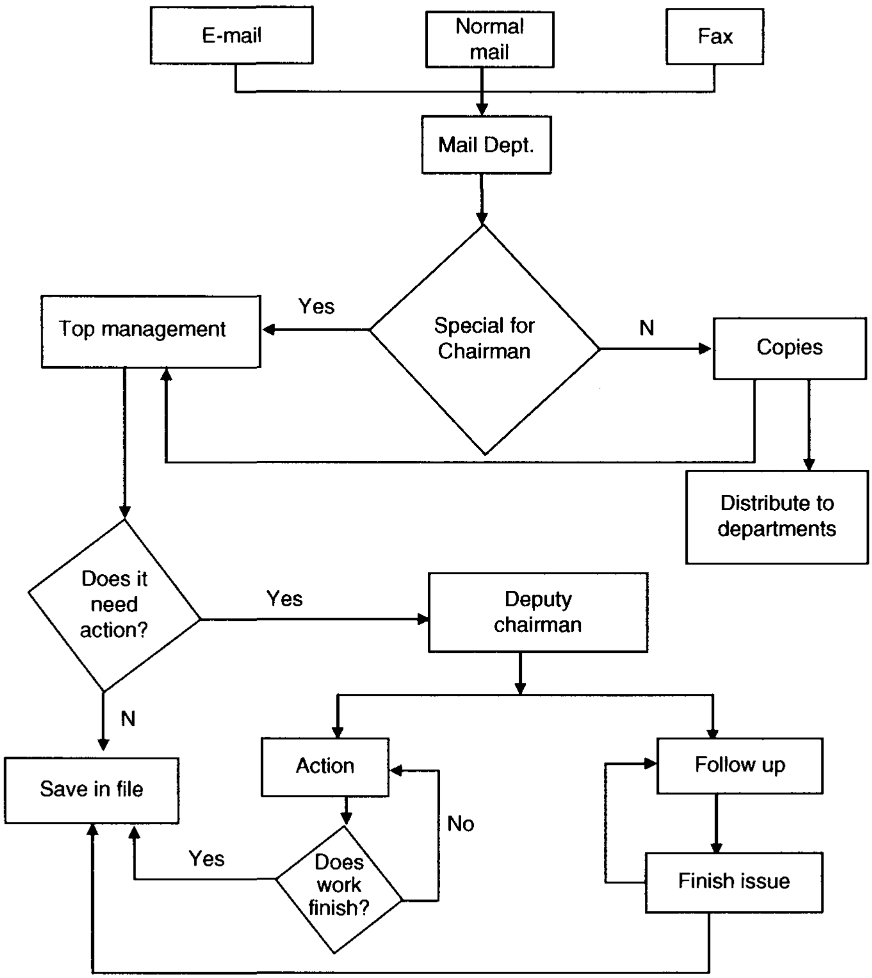

Figure 5.11 Document movement.

to keep such information in such a manner as to insulate them from possible future liability, loss or damage.

5.11 Quality Control in the Design Phase

The purpose of this phase is to develop the procedures required for ensuring that the design will be matched identically with the client's needs.

After the owner and Engineering Office sign the final contract, the head office will select a project manager who will have direct responsibility for the project.

The main role of the office manager or general manager of the company is to verify customer satisfaction and follow up the progress of work. Each project manager and general manager should determine the departments that will plan the work and should send letters to these departments to clarify what the project objectives are.

The project manager and the planning engineer have to specify the number of drawings required, the number of working hours and the work schedule of the project, as determined by Form (2a).

The project manager will submit Form (1a) to the heads of departments. This is the information source for the data to be recorded in Form (7a).

Before starting the design, the department head should determine the work plan using Form (3a). That contains a plan of action and the names of teams and estimates the number of working hours, the number of drawings required, and the foundations of design.

The responsibility of the project manager and planner engineer is to follow up actual performance of the departments involved. The project manager and the planning engineer should start the preparation of the final time schedule after receiving schedules from all of them.

One of the responsibilities of the project manager in the main office and the construction manager on site is to schedule meetings between the relevant departments for discussion or review of all departments and make sure that information is circulated between departments regularly and properly. Management identifies the engineer responsible for design, who gives approval of the drawings. The Director of Administration pursues the design's execution through the timetable that should already have been prepared and sent to the Project Manager in the previous Form (3a).

In the start-up phase, or before the signing of the contract or in tendering phase, the project manager should hold a meeting for all the lead disciplines as, process, civil, mechanical, piping, and others.

In most cases, the client sends information to the engineering office (usually the SOR, original drawings, or scope of work).

Engineering dept.: **Date:** **Doc. No.:**	**1a**	**Engineering Company**

Client: **Phone:** **Fax:** **Email:**	**Project:** **Project No.:** **Project Mgr.:** **Date:**

The required services and document:

Type	Description	Select
Tender evaluation		
Quantity surveying		
General plan		
Types of material		
Facilities work		
Report		
Specification		
Construction drawings		
Others		

Name:

Date:

Signature:

The project manager then distributes a copy of these documents to all the discipline leads. In oil and gas projects, there should be good communication between the main departments, which are usually the civil and piping departments.

However, if the document is read by every discipline separately, every discipline may understand or interpret a paragraph differently.

Engineering dept.: **Date:** **Doc. No.:**	**2a**	**Engineering Company**

Review meeting for client request:	
Client: **Phone:** **Fax:** **Email:**	**Project:** **Project No.:** **Project Mgr.:** **Date:**

Activity	Inquiries	Time schedule	Man hours	No. of drawings	Description	Remarks
Design						
Tender evaluation						
Construction drawings						
Quantity surveying						
General plan						
Roads activity						
Specifications						
Other activity						

Name: **Date:** **Signature:**

This where the project manager has an important role explaining the project to the different disciplines involved, in a manner that clearly conveys the client's requirements and expectations to each of them.

Engineering dept.: Date: Doc. No.:			3a	Engineering Company	
Client: Phone: Fax: Email:			Project: Project No.: Project Mgr.: Date:		
Control design:					
Sign.	**End date**	**Start date**	**Work description**	**Engineering Dept.**	**No.**
Date of first revision:					
Date of second revision:					
Date of final revision:					
Name: **Date:** **Signature:**					

5.11.1 Inputs and Outputs of the Design Phase

Using Form (4a) to clarify what is required from them in the design stage, each department should determine the role of its project team members. This is the form that indicates key input parameters of the project design, including its general specifications, the type of structure, the structural analysis required (i.e., preliminary or detailed design), and types of drawings required (e.g., construction drawings, field sketches, etc.). It determines the size of the final drawing and indicates the sources of its information as set forth by the owner and the engineering office through the SOR and BOD documents, which convey the precise demands of the owner.

Following completion of drawings, the final work is reviewed and team members sign off through Form (5a). A quality assurance team undertakes its review, making sure that each signature is in place in accordance with the responsibility of the person and that each engineer has passed all the steps required without neglecting any step. Drawings are sent to the client only after all these steps are carried out and verified.

This model of project design-phase documentation takes note of any previous versions that had been prepared and recorded earlier in the history of the project. It may also serve to measure the difference between the estimated time to complete the drawings and the actual time spent, thus indirectly indicating the efficiency of the departments concerned in how they manage the use of time.

5.11.2 Design Verification

The department head's responsibility is to ensure that the design conforms with the agreed-upon standards and specifications. In most instances, the department head has to turn to some past projects in order to compare or request from another engineer some calculations to verify / ensure the design. The registration of the design is documented via Form (5a). Vagueness or lack of clarity in any item of the design is registered through Form (6a).

5.11.3 Change in the Design

It may arise that an owner's requirements have changed since the contract was signed. The project manager registers such changes by filing Form (7a). Then all the departments are informed about the change(s) required.

Engineering dept.: **Date:** **Doc. No.:**	**4a**	**Engineering Company**

Client: **Phone:** **Fax:** **Email:**	**Project:** **Project No.:** **Project Mgr.:** **Date:**

Design input:

Option	Define requirement	Work description
ACI, BS, EC		Specifications
Final, preliminary		Structural analysis
Feed, detail		Design
No, summary, detail		Calculation sheet
Steel, concrete, prestress concrete, others		Type of structure
Sketches, construction drawings, as built		Drawings
A0, A1, A4		Drawing size

Start date:

Finish Date::

Name:

Date:

Signature:

Engineering dept.: **Date:** **Doc. No.:**	**5a**	**Engineering Company**

Client: **Phone:** **Fax:** **Email:**	**Project:** **Project No.:** **Project Mgr.:** **Date:**

Review design and approval	
Date of revision 1:	
Notes:	
Date notes completion:	
Date of revision 2:	
Notes:	
Date notes completion:	
Date of final approval	
Remarks:	
Name: **Date:** **Signature:**	

Engineering dept.: **Date:** **Doc. No.:**	**6a**	**Engineering Company**

Client: **Phone:** **Fax:** **Email:**	**Project:** **Project No.:** **Project Mgr.:** **Date:**

Review design document

Item	**Wrong**	**Right**	**Modifications**
Technical data			
Dimensions			
General layout			
Error in Writing			
Other			

Name:

Date:

Signature:

Engineering dept.: Date: Doc. No.:	7a	Engineering Company

Client: Phone: Fax: Email:	Project: Project No.: Project Mgr.: Date:

Register project document

Export				Import				Register Doc.
Date	Review No.	Form	Doc. No.	Date	Review No.	Form	Doc. No.	

Name:

Date:

Signature:

5.11.4 Approval of the Design

After all departments have agreed on the design and sent the drawings to the project, where they are reviewed according to Form (6a), the project manager must sure the design complies with the requirements of the owner and the specifications and standards that were agreed upon before it is sent to the owner through Form (9a).

When there are comments from the owner, the project manager will send the comments to the departments using Form (8a). Each department will review them and send them to the owner again. There is often more than one department responsible for this change which can directly or indirectly affect from the main activity of the work before the amendment.

The cost control department, for example, which would have to negotiate changes in the price of delivering the project according to the amended design, needs to determine any changes in cost resulting from the change in the original design.

In general, the feasibility study may also be affected by this change, and so the department that prepared it has to determine the direct impact on project feasibility — positive or negative — that would ensue as a result of the design change(s). This process is often finalized by a meeting between the owner and all the departments potentially affected by the proposed changes.

All the changes and revisions are finally delivered upon completion of the drawings, which are stamped win red and marked as approved for construction.

Engineering dept.: **Date:** **Doc. No.:**	**8a**	**Engineering Company**

Client: **Phone:** **Fax:** **Email:**	**Project:** **Project No.:** **Project Mgr.:** **Date:**

Design modification
Describe the modification:

Department	**Date**	**Select the department**	**Signature**
Cost control			
Feasibility study			
Architect			
Structural			
Mechanical			
Electrical			
Piping			
Evaluation			
Contract			
Other			

Name: **Date:** **Signature:**

Engineering dept.: **Date:** **Doc. No.:**	**9a**	**Engineering Company**

Client: **Phone:** **Fax:** **Email:**	**Project:** **Project No.:** **Project Mgr.:** **Date:**

Cover transmittal		
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Drawings	Report	Letter
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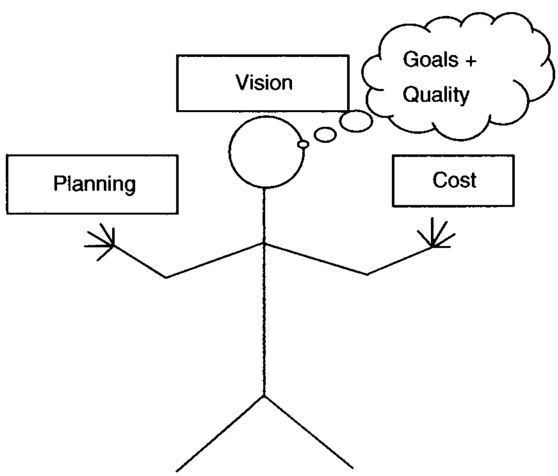
6

Cost Management



6.1 Introduction

The preceding chapter elaborated the significance and discusses the best practices for planning the management of resources available to complete a project. The second key block of information on which the project manager must have a firm handle is project costs. The main goal for the project manager is to manage these costs. The discussion which follows, concerning the costs of a project as a whole from a decision-making point of view, will bring out the many other subjects touched by cost management decisions.

A cost estimate is the main target data to obtain at the outset of any project. It enables management team to define a project budget. During the project's execution, cost control management methods are applied to control and follow up progress of the project.

Usually, cost estimates are calculated and verified in more than one phase of the project. In the initial studies phase, which is called the appraisal phase, costs are calculated according to relatively simplified principles, with the regions and boundaries of "right" and "wrong" widely set. The accuracy of cost estimate calculations increases as the project progresses. Possibilities of increasing, the actual cost more than the estimated cost of the project decreases with time, until the end of the project has been reached and 100% of costs have been issued.

To ensure the best chance of devising an accurate valuation of a project's costs, the feasibility studies phase requires personnel possessing extensive experience in cost-estimating similar projects, hopefully individuals with specialized expertise in the particular type of project at hand. Residential building projects are different than factories and petroleum projects, all of which have distinctive characteristics and needs of their own.

To illustrate the steps in estimating the cost, we will use a traditional example of going to a friend to purchase land for a new villa. Your friend requires a rough budget cost estimate, but this will be very complicated to obtain, as you have no drawings, calculation, or concrete data to calculate cost.

Hence, at the outset, your estimated cost figure will contain high uncertainty. Someone with experience from an engineering office can provide a budget, but he or she at least needs to know the number of floors and the location of the land. Then he will have a cost as per (USD/m^2) for this specific location, the number of floors, and so on.

This is a very preliminary stage, commensurate with small projects such as building a home. In the case of large projects, however, a meaningful budget for this same stage entails conducting surveys and taking soil boreholes and then calculating the cost of the project. The entire project must then be re-examined to compute the likely profit now that there is some realistic data from which to make these and other determinations.

In major projects, such as large-scale and high-cost industrial projects, especially where the equipment and machinery for production are unique, the estimated cost in the initial phase of studies could be within ±50% accuracy.

The difference between the expected and real cost seems initially very large. However, when there is data from a similar project available as a benchmark, then the smaller will be the difference between the actual and estimated costs. This comes about because, with industrial facilities, a large proportion of the project construction cost depends on the equipment and machinery used in manufacturing.

On the other hand, there are some projects such as the replacement and renovation of residential or industrial facilities that have a very low percentage of accuracy and will also operate with an initial error margin of about ±50%. After finishing the front-end engineering design (FEED), the accuracy of the estimated cost will be ±30%. After finishing the detailed construction drawing for the whole project, the estimated cost will be calculated based on the quantity and will provide an approximate cost for each item. At that point, the estimated cost for the project emerges with a predictably small deviation closer to the actual and accepted accuracy, which is about ±15%. Presented this way, such a margin seems like a big improvement. However, proceeding with such a project under these conditions remains a gamble against considerable uncertainty. In a case of this kind, a project manager has to recognize that, even after determining the cost of the project, setting its budget and beginning its implementation for a certain period, a 15% cost overrun may appear and have become irreducible, forcing a full or partial stoppage. If, on the other hand, costs come If, on the other hand, costs come in at less than 15% of the budgeted, it will be a waste of investment to the company as a whole.

As the owner or contractor company could "book" this amount of money, possibly even placing the owner in a position to invest such "savings" in another project.

Based on the above discussion the accuracy of the cost estimate is very critical and vital to project success and becomes more critical over time.

6.2 Cost Types

For the owner, there are different types of costs for construction projects, including the cost of assets and capital costs.Under this rubric we include the cost of the initial composition of project facilities. These elements of capital cost may be broken down as follows:

- Cost of land and property registration procedures
- Planning and feasibility studies
- Engineering activities and studies
- Construction materials and equipment and supervision on site
- Insurance and taxes during the project
- The cost of the owner office
- The cost of other equipment that is not used in construction, such as private cars to transport owner engineers
- Inspections and tests

Maintenance and operating costs for each year of the project's life of the project include the following:

- Leasing land
- Employment and labor wage
- Materials required for maintenance and repairs annual renewal
- Taxes and insurance
- Other costs of the owner

The actual amounts will vary according to the project's type, size, location and organizational structure. With regard to this exercise, it is important to keep in mind the owner's goal of reducing the total cost of the project, consistent with the overall investment objective.

In real estate and building structure projects, the largest component is the cost of construction. However, by contrast, in industrial construction and petrochemical projects, the cost of civil engineering and structural work is small relative to the costs of mechanical and electrical equipment. For example, the cost of the concrete foundation of a power turbine may be in the vicinity of 30,000 USD, while the power turbine itself may cost more than 5 million USD. Similar equipment/construction cost disparities are seen in nuclear-plant and other power generation projects.

When calculating costs from the owner's viewpoint, it is important to calculate the cost of operations and maintenance in each year of the life of the project for each of the alternatives available in the design and the cost of the life cycle of the project as a whole.

The various risks to the project's proceeding and their potential cost must also be estimated. Of importance here is the calculation of the limits within which actual costs may be permitted to deviate from those projected in the project's budget, and the cost of risk or an unexpected event during the execution of the project. The percentage of risk has to be calculated for each item and as a proportion of the total final cost. These calculations rely on past experience with and knowledge of the problems that can normally be anticipated during project implementation. Connected with this are the increased costs of possibly emergency which often occur as a result of the following event.

- Changes in the project design
- Differences in the timing of various phases of the project's work schedule especially those that tend to increase the time it will take to complete the project
- Administrative charges such as salary increases
- Special onsite circumstances, including unexpected obstacles or defects in the soil in some location
- The need of additional or special permits for project construction work

6.2.1 Cost Estimate

Cost estimates predict the likeliest costs of resources required for completing the project, and cost estimation is updated throughout the life of project. At the project's outset, proof-of- concept estimates are done to inform the decision that will need to be taken as to whether to allow the project to proceed. One such estimate is the "order of magnitude" estimate. These can have an accuracy of 50 to 100 percent. As the project progresses, more accurate estimates are required. From company to company, the specified range of values for a given estimate may vary as well as the name used to describe it. For example, "conceptual estimates" are those that have an accuracy of ±30 to 50 percent. "Preliminary estimates" are those with an accuracy of ±20 to 30 percent. "Definitive estimates" are those with an accuracy of ±15 to 20 percent. Finally, the "control estimate," with an accuracy of ±10 to 15 percent, is calculated. As there remains considerable uncertainty at its outset about what work is actually to be done in the project, there is little point in spending more time than necessary to produce an estimate of a higher range of accuracy than required at each particular stage of the project.

Types of estimates are depending on the accuracy required for the cost estimate and amount of effort, there are several methods described in Michel (2005). Several types are in common use, which we now discuss.

6.2.1.1 *Top-Down Estimates*

Top-down estimates are used to estimate costs early in the project, when detailed information about the project is very limited. The term "top-down" indicates that the estimate is made actually at the topmost level of the project, yielding a single overall "ball park" figure. This type of estimate requires little effort and time to produce. However, its accuracy is not as high as it might be with a more detailed effort.

6.2.1.2 *Bottom-Up Estimates*

Bottom-up estimates are used when project baselines, or a cost-control type of estimate, are required. The approach is called "bottom-up" because estimates of this type begin with estimating detailed costs of the project and summarizing these at their appropriate level. The work-breakdown schedule (WBS) can be used for this "roll-up." This kind of estimate is that it produces accurate results. The degree of that accuracy is mainly a function of the level of detail taken into account: as more and more detail is added, the calculations converge statistically towards the most likely cost estimate, or cost range estimate,. Of course: the cost itself of the time required to complete such a relatively detailed estimate is higher, as is the amount of time needed to produce the estimate.

6.2.1.3 *Analogous Estimates*

Analogous estimation is a form of top-down estimate that makes use of the actual cost of previously completed projects to predict the cost of the current project. If the project being used as the analog of the project being estimated is a close match, the estimates could be quite accurate; on the other hand if the purported analogy is more apparent than real, the estimate might not be very accurate at all.

This point is crucial. It frequently happens with software development projects that many analogous previous projects can be found and examined, often sharing an apparently similar design of many of the key code modules. At first it might appear that if the difficulties of the projects are similar, then a 30-per-cent greater size in total program code of the new project should lead to a 30-per-cent greater cost than the analog being taken as the benchmark for comparison. However, if programmers' time-saving code productivity tools have improved in the interim, the new project could cost less even though it uses more code. Alternatively, if the previous project was using some of these newer productivity tools but those tools are not yet part of the planning of the current project, a 30-per-cent increase in coding will actually cost the new project more than an incompletely-informed analogous estimate would predict.

6.2.1.4 *Parametric Estimates*

Parametric estimates are similar to analogous estimates. They are also "top-down," and their inherent accuracy neither better nor worse than analogous estimates. The basis of parametric estimation is some parameter of the project being estimated that changes proportionately with project cost, and a model may be calculated based on one or more such parameters. For most types of estimates, the rated per-unit cost of resources to be consumed in creating the project must be known. With these figures known, adjustments in the parameter will enable revising the estimate without loss of accuracy. Accuracy of the estimate may be improved if there is a close relationship between parameters and costs, and if the parameters are easy to quantify. If there are historical projects that are both more costly and less costly than the project being estimated, and if the parametric relationship holds true for both of those historical projects, the accuracy of

Table 6.1 Cost estimate procedure

What	The function of the estimate is to forecast a cost for a specified scope of work, enabling an accurate budget to be assembled for the business. Cost estimation by definition is uncertain, but different classes of estimation may yield improved levels of accuracy as a project's scope becomes better defined in its details. A work breakdown structure (WBS) should be built from which estimates, schedules, from which cost controls may be derived. Formal documents are produced for all levels of estimate. Appraise: Order of Magnitude (OOM) accuracy range of +/- 50%. Select: Class 3 accuracy range of +/- 30%. Define: Class 2 accuracy range of +/- 15–20%. Class 1 is +/- 10% (rarely used).
Why	This is done to indicate to the business the predicted cost of the project, so that the project is financially viable and can become established.
How	The project leader and the asset development engineer develop a Work Breakdown Schedule. This is then discussed with the project team to allow the relevant discipline engineers input in the estimate. OOM estimate will normally be factored estimates based on the known high-level scope and equipment definition. Class 3 estimates will be factored based on a developed scope and equipment definition including indirect costs. Class 2 estimates will be built up from the developed scope of the project and will be fit for purpose to give the accuracy range.
When	All projects must have a Class 2 at the end of Define for business sanction. An estimate will be produced at the end of each development stage. The accuracy of the estimate will reflect that particular stage.
Who	The project leader is responsible and is supported by the estimator, discipline engineers, SPA, construction engineers, and commissioning engineer.

the estimate and the reliability of the parameter for this project will be better. Multiple-parameter estimates can be produced as well. In a multiple-parameter estimate, various weights are given to each parameter to allow for the calculation of cost by several parameters simultaneously.

"For example, houses cost $150 per square foot, software development cost is $2 per line of code produced, an office building costs $260 per square foot plus $54 per cubic foot plus $2,000 per acre of land, and so on."

Responsibility for monitoring construction and installation costs, which comprise the largest part of the total project costs,is usually shared between the overall project manager and onsite project construction manager. The accuracy of calculating the estimated cost of construction is different from one stage to another. The more accurate the data is, the more accurate the calculation of the cost.

Yet another complexity attending the monitoring, control and updating of construction cost estimates arises from the point-of-view informing the particular calculation method used. From the owner's perspective, the general tendency is to estimate costs on the basis of the project's design and construction drawings. On the other hand, a project contractor's approach to estimating costs will be applied with an eye to entering a tender that will qualify him to win the bidding on the project.

The initial cost estimate is made after preliminary studies of the project have identified industrial facility requirements such as the number of pumps, air pumps, and compressors and the size of pipes and lines in diameter, and so on.

The cost is determined at this stage on the basis of previous experience of similar projects. For example, calculating the cost is as follows:

Example:

Calculate the cost for a project consisting of 3 pumps with 1200 HP, with pipeline 10 inches in diameter and a length of 15 miles.

The pump cost estimate = 700$/HP.

Pump cost = 3 (700) (1200) = 2.52 M$.

Cost estimate for onshore pipeline = 14000 $/inch/mile.

Pipeline cost = 14000 (10) (15) = 2.1 M$.

Total cost = 2.52 M$ + 2.1 M$ = 4.73 M$.

Example:

Calculate the cost of one floor for a building with an area of 300 m^2 from reinforced concrete.

In this case assume slab thickness is 250 mm for a slab beam and column as a practical estimate.

Approximate concrete quantity for slab and floor = 300 × 0.25 = 100 m^3.

Assume the cost of concrete = \$200/m^3

The concrete cost for one floor = \$20,000

The calculation of the concrete price is calculated after determining the type of concrete. The cost of reinforced concrete can be calculated by obtaining the following information:

- Quantity of steel per concrete cubic meter and the price of steel per ton
- Quantity of cement in concrete mix and the price of cement ton
- Quantity of coarse and fine aggregate and the price per cubic meter
- For ready mix, the price of each cubic meter by knowing the concrete grade, which is standardized at 30–25 N/mm^2 for petrochemical projects
- Cost of shattering, bending bars, pouring, and curing per cubic meter of concrete

For ready mix concrete, obtain the following information:

- Quantity of steel in the meter cube of concrete and the price of a ton of steel
- The price of concrete from the nearest ready mix location to the site and the concrete pump
- The cost of wooden form, which is usually a special strong form to the pump concrete
- The cost of steel fabrication
- The cost of the pouring process and curing

Note that in calculating the reinforced concrete cost estimate the main item is the quantity of steel in concrete, and it is different

Calculate the approximate price for one meter cube of reinforced concrete prepared onsite, noting that the approximate quantity of coarse aggregate is 0.8 m^3 and for fine aggregate is 0.4 m^3 and this value is required to provide characteristic cube strength 25 N/mm^2:

Steel cost = \$1000/ton

Cement cost = \$80/ton

Coarse aggregate cost = \$5/m^3

Sand cost = \$1/m^3

Steel quantity = 0.1 t/m3 as shown in Table (6.2)

Steel cost = 0.1×1000 = \$100

Cement cost = $7/20 \times 80$ = \$28

Coarse aggregate cost = 0.8×5 = \$4

Sand cost = 0.4×1 = \$1

Material total cost = \$133/m^3 (as a material only)

Cost of fabrication of wood and steel and pouring = \$30/m^3

Total cost = \$163/m^3

Table 6.2 Guide for estimating steel quantity in reinforced concrete

Structure Element Type	**Approximate Quantity of Steel Reinforcement in Concrete, Kg/m³**
Slab with beam	90–100
Flat slab	250
Hollow block slab	150–180
Columns	90–120
Isolated footing	100–120
Raft foundation	200–300

according to the structure element. The following table is a guide for estimating the quantity of the steel reinforcement.

The data in Table (6.2) is considered a guideline and depends on the concrete characteristics, strength, and the member design, so it is an indicator for the quantity of steel reinforcement.

Table 6.3 Percentage of reinforced concrete building cost

Activity Item	Percentage from the Total Cost, %
Design and site supervision	3
Concrete works	36
Masonry work	6
Sanitary and plumbing	10
Internal and external finishing	45

The percentage cost of the domestic and administration building will be a guide as shown in Table (6.3).

6.2.2 Steel Structure Cost Estimate

The cost estimate for the steel structure is significantly different than the calculation of the estimated cost of the reinforced concrete structure, as it needs a special design the larger the difference in the construction phase.

The most important part of the design and construction of the steel structure is the connection, and it is known that the connection cost is about 50% of the whole building.

The following table defines the cost percentage for each part in a steel structure project.

From Figure (6.1), one can determine the proportions of the cost of main elements for constructing a steel structure. Every item has a percentage of the total cost.

We note from the above table that the connections, either through the use of welds or bolts, have the largest share in the process of preparing detailed drawings, where the most important and most dangerous phase is the accuracy of the details of the connection.

There is no doubt also that they are important in the cost of manufacturing and the installation phase, as the connection cost percentage is 63% and 45%, respectively. The connections are of great importance in the calculation of costs as well as in the preparation of schedules.

6.2.3 Detailed Cost

The detailed cost estimate will be determined from the detailed construction drawings of the project and the completed project

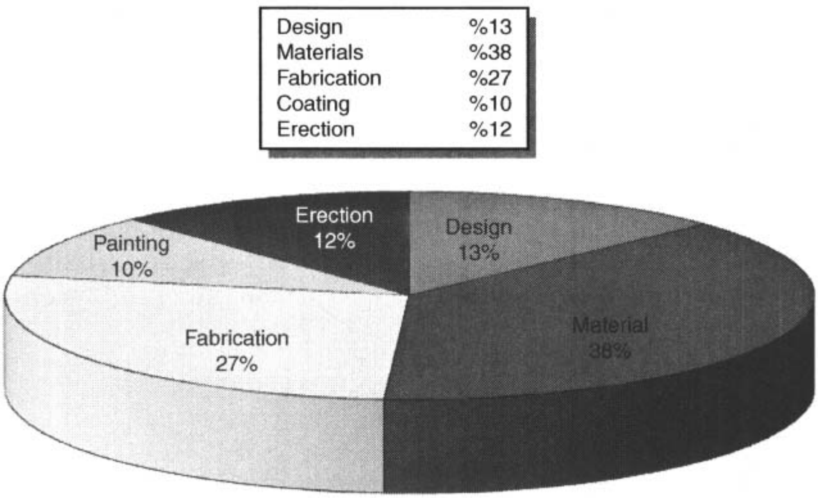


Figure 6.1 Percentage of cost for steel structures.

Table 6.4 Percentage of steel structure costs

Item	Percentage from the Total Cost, %	Percentage of Cost for Connection, %	Percentage of the Connection Cost, %
Preliminary design	2	33	0.7
Final design	3	55	1.7
Detail drawings	8	77	6.2
Total design cost	13		8.6
Material	38	40	15.2
Fabrication	27	63	17
Painting	10	35	3.5
Erection	12	45	5.4
Total percentage	100		49.7

specifications. The engineering office calculates the estimated cost based on the experience of the contractors who carry out the construction of such projects, as well as the expected profit. This depends on the engineering expertise of the office. The costs for supervision borne by the owner should also be included.

The contractor calculates the cost for the tender to be included in the bidding, presenting it to the owner in the form of a bid or offer, or as the starting-point of negotiating his price. Often the contractor arrives at a price estimate of relatively high accuracy, in order to ensure that the work carried is out according to the financial terms governing the project. Most construction companies have a procedure to calculate the cost of construction of the project and to develop appropriate pricing of the tender.

Some work, facilities or equipment will be delivered by subcontractors. The general contractor studies subcontractors' offers and chooses the best price, adding on his percentage of indirect costs and profits.

6.2.4 Cost Estimate to Project Control

The cost estimate is recalculated as part of following up the project's progress during execution. It may be obtained from the following information:

- Approximate budget
- The budget value after contract and before construction
- Estimated cost during construction

Both the owner and the contractor must have a baseline by which to control costs during project execution. The calculation of the detailed cost estimates is often used to determine an estimate of construction where the balance is sufficient to identify the elements of the entire project as a whole.

The contractor's price, which was submitted by the tender with the time schedule, is determined by the estimated budget and used to control costs during the implementation of the project.

The estimated cost of the budget will be updated periodically during the execution of the project to follow-up the cash flows along the project time period in an appropriate manner.

6.3 Economic Analysis of Project Cost

The project cost consists of two parts: direct and indirect. The direct cost is the cost of implementing the activities of the project set forth in the drawings and project documents.

The cost of resources to be provided for the implementation of these activities include employment, raw materials, equipment, contractors fees, and other costs. This cost does not include the expenses related to the supervision of the implementation work.

Indirect costs are expenses that cannot be avoided to supervise the works and facilitate the implementation and can also release the term "administrative and general expenses," which is usually fixed during the period of implementation of the project.

6.3.1 Work Breakdown Structure (WBS)

Most projects aim to achieve a certain specified degree of quality. This objective can be divided into a set of components that reflect the entire project. If the desired goal is to construct a gas plant, five main components can be identified, namely the following:

1. Public works site
2. Concrete structure
3. Mechanical
4. Electrical
5. Finishing works

Each of these components may be subdivided into subsets of components, creating subordinate levels of increasingly specific detail. The resulting "breakdown structure" discloses all the elements of the project to be taken into account during execution.

Although the time spent in preparing and processing the project's WBS may seem like time taken away from getting the job done, it confers a most important benefit of enabling supervisory personnel at all levels to check quickly that nothing is being forgotten or deleted inadvertently from the detailed work involved in implementing the project.

After the WBS has been set, its elements should be coded for ready identification in response to questions at any level about progress in project completion, or requests for information about the specific availability or inavailability or personnel or equipment anywhere within the project.

6.3.2 Organization Breakdown Structure (OBS)

The OBS is compiled of details amassed and ordered in the same way as the details of the WBS. A defined, carefully monitored regularly updated OBS facilitates the ready identification, at every level of project management, of different levels and kinds of responsibilities within the project to facilitate communication between various parts of a project and enable to keep their responsibilities and lines of authority well-defined, the OBS and its updates should be communicated to everyone working in the project.

The project manager along with other members of the management group for the project are expected to keep close tabs on the OBS and any amendments of its content.

6.3.3 OBS/WBS Matrix

The organization breakdown structure and work breakdown structure matrix are shown in Table (6.5). The OBS is in the horizontal row, and the vertical presents the organization.

From this table, every person in the organization has a number of cells that present the work breakdown structure. For example, the project manager will do all the stages, so the cost will be for all these activities, for the mechanical supervisor is allocated for mechanical work only and the civil supervisor is allocated to civil work and foundation work.

6.3.4 Work Packages

The cost is divided into work packages.

For every activity, it is required to define the following in order to calculate the cost:

- Execution time start and finish
- The resources to execute this activity
- The cost to execute the activity

The cost account (CA) records the expenditure of the project's budgeted activity. Covering everyone responsible in the organization, it comprises mostly direct costs for materials and labor.

For example, the concrete supervisor will be responsible for executing the following activities:

- The foundation with cost: $150,000
- The first floor with cost: $60,000
- The other floors: $400,000

Table 6.5 WBS/OBS matrix

	Civil Work	Foundation Work	Mechanical Work	Electrical Works	Design Works	Planning Work
Project manager	×	×	×	×	×	×
Planning supervisor						×
Design supervisor					×	
Electric works supervisor				×		
Mechanical work supervisor			×			
Civil work supervisor	×	×				
Concrete works supervisor		×				

So, in this case, he or she will be responsible for three cost allocations with a total cost of $610,000.

Note that indirect costs, so far, have not been taken into account under this rubric. Not being costs incurred as part of fulfilling the requirements of the WBS, they are charged to the administrative management of the project or elements of project management. For example, the concrete foreman in the previous example has a salary and consumes equipment and other expenses. These expenses cannot be added or charged to the specific activities, as he will supervise the foundation, columns, the slabs, and others. Those expenses must be paid on a regular basis nevertheless during the execution of these activities.

Any other expenses of supervision must similarly be taken into account, as well as related administrative expenses such as offices for the engineers, technicians, computers, cars to transport engineers, and expenses and salaries of engineers and senior management. For example, concrete work might continue for a period of six months. Monthly indirect expenses (the concrete former's salary and miscellaneous expenses) are $10,000. While the cost of concrete materials and manufacturing from mixing until curing it is accounted a direct cost of around $440,000 (calculated based on the quantity of concrete), the concrete former's salary for supervising this activity is included in indirect costs and allocated over the six months allotted for this activity. Thus, the total reinforcing concrete budget comprises:

$$\text{Direct costs} = \$440{,}000;$$

$$\text{Indirect costs} = \$60{,}000;$$

$$\text{Total costs} = \$500{,}000;$$

6.3.5 Cost Control

Cost control is very important in the management of projects. The real-life economics of the project as a whole depend on it.

The objective of cost control is to follow up what has been spent compared to what was already planned to be spent and to identify any deviations, so that appropriate action may be taken at an appropriate time. These matters therefore fall within the domain of the project manager, as the individual directly responsible for defining and deciding who is to execute and who is to supervise.

Calculation of actual cost should consider the different component costs for employment, materials, equipment, and subcontractors, in accordance with the contractual arrangements set out at the start of the project. If the actual costs increase beyond what was estimated, this could be due to any of several reasons:

- the cost estimate was too low;
- the circumstances of the project were not studied well;
- prices of raw materials and labor during the project increased;
- climatic conditions and other circumstances induced unanticipated delays in some project activities;
- there was poor selection of working equipment; and-or
- there was inefficient supervision.

It is difficult to correct for the impact of the first four factors. There is, however, usually some hope of improving the selection of the equipment and ensuring the department is aware and capable of choosing competent supervisors or increasing their capabilities. The cost control process involves more than collecting data on running costs. Cost control should help the project manager to analyze the performance rate for equipment productivities and manpower.

From an auditing standpoint, project costs will fall under one of three possibilities:

1. they were exactly equal to the spending planned in accordance with the implementation plan of the project and estimated budget for this plan.
2. more was spent than was planned, according to the project's plan of implementation, which means an over expenditure "cost overrun."
3. less was spent than planned, generating savings in thr for of a "cost underrun."

In general, over-expenditure is not desirable and must be prevented, whereas savings in spending is desirable. This also requires looking into the causes of increasing costs, a true hallmark of successful project management of a project during its execution phase.

Among the main parameters of cost control accounting management are the following:

- ACWP – actual cost of work performed
- BCWP – budget cost of work performed, also called earning value (EV)

- BCWS – budget cost of work scheduled
- BAC – budget at completion
- EAC – estimation at completion

To illustrate the above factors assume that in the phase of engineering costs, time and resources (CTR) has been planned to be completed in 200 hours. The actual work will take 250 hours. The work already done has reached 200 hours. So one can see that what was done is equal to the plan. Assume the cost of one hour is $100.

The actual cost of work performed (ACWP) = $25,000.
The budgeted cost of work performed (BCWP) = $20,000.
The budgeted cost of work scheduled (BCWS) = $20,000.
Cost variance (CV) = BCWP – ACWP.
Schedule variance (SV) = BCWP – BCWS.

The cost variance (CV) is equal to -$5,000. The minus-sign indicates that, *at this point in the project*, the budget for this component is now "short," i.e., has been overspent, by this amount.

Percentage of cost deviation = (ACWP – BCWP)/BCWP.

Schedule performance index (SI) = BCWP/BCWS; here it equals exactly 1. An SI value higher than 1 representing an acceptable performance, and a value less than 1 representing an unacceptable one, in this example we have reached a borderline, exactly at 1, at this point in the project schedule.

Cost performance index (CI) = BCWP/ACWP. In this example, CI = 0.8. It is less than 1, and this is as expected because the engineering CTR has already used up $25,000 and was budgeted to have consumed only $20,000 to this particular point.

EAC = BAC/CI. Dividing the budgeted actual cost by 0.8 is the equivalent of multiplying it by 1.25. In other words, by the time the project is completed, the estimated actual cost of engineering CTR can be anticipated to run 25 per cent over what was budgeted.

Calculated at regular intervals during project implementation, these factors should be compatible with the date of the month accounted by the company. Monitoring on a monthly basis assists in evaluating the project and approximating final costs of project components while there is enough time left to make any necessary course corrections in management of the remainder of the project's trajectory.

6.3.6 "S" Curve

The cost curve is called the "S" curve. named for the characteristic shape of the curve that plots the distribution of project costs as a function of time. To illustrate the main issues that can be resolved by charting such a curve, we return our previous example of the pouring of concrete foundations. In Figure 6.2 the project-days in which 10 subtasks associated with pouring the concrete foundations were carried out are "Gantt-charted," indicating the days in which this work was completed. The number in the rightmost column, headed "$K", is the amount spent on each subtask for the project-days shown in the chart's main body. (For simplicity's sake, we assume here that every activity cost is rated at $1000 a day.) One of the subtasks was carried out from Day 24 through Day 28, i.e., past the 25-day period (25 workdays at 8 hours per day = 200 hours) originally assigned for completing the pouring of the concrete foundations. This subtask, and another that was undertaken later than planned, have been placed in a second section of the chart, below the main data chart illustrating the completion and budget expenditure on the other subtasks that finished within the originally envisioned 25-day work timeframe.

The (S)-curve is obtained as information from the Gantt chart of Figure 6.2 is graphically represented so as to display project budget expenditure of this set of subtasks as a function of time. In the case of the subtasks completed early, the first curve Figure (6.3) is obtained. In the case of subtasks implemented in the later phases and even past the originally-envisioned 25-day period around which the budget was originally designed, the second curve Figure (6.4) is obtained.

If these data are now taken and placed on the same graph, an envelope appears, bounded above by the curve displaying the data on outlays for the subtasks that finished early and from below by the data on outlays for the subtasks that finished late.

Another example will serve to illustrate cost-control approaches to managing what might happen at the overall level of a project. The following table gives the values of the cost of planning in an engineering project for a period of 12 months. At a point six months into the project, we calculate the position and display the crisis presented in Table (6.6)

From the previous table calculate the cost control parameters after 6 months from start of the project.

Activity	K$	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Mobilization	3																				-	-	-	-	-	-
Excavation	8																									
Pouring conc.	10																									
Mech. package	1																									
Grouting	1																									
Comm & start up	2																									
Install piping	4																									
Connect piping	5																									
Sum		1	2	3	5	7	9	11	13	15	17	19	21	22	23	24	25	26	27	28	29	30	31	32	33	34
Install piping	4																									
Connect piping	5																									
Sum		1	2	3	4	5	6	7	8	9	10	11	12	13	14	16	18	20	22	24	26	28	30	32	33	34

Figure 6.2 Distribution of cost on the activity.

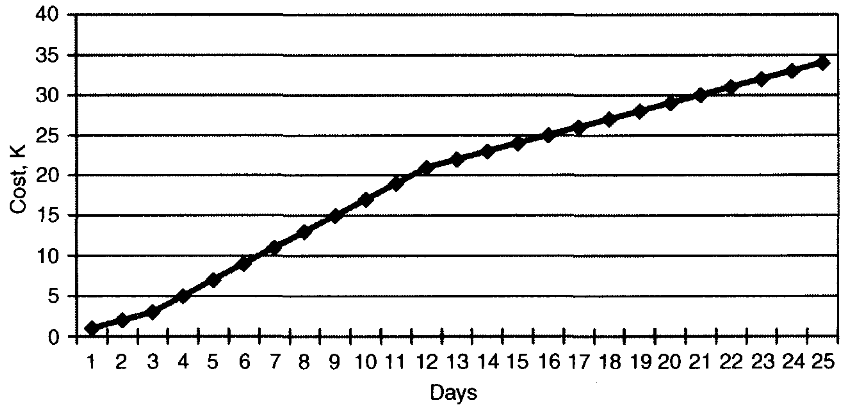


Figure 6.3 Cash flow in case of early dates.

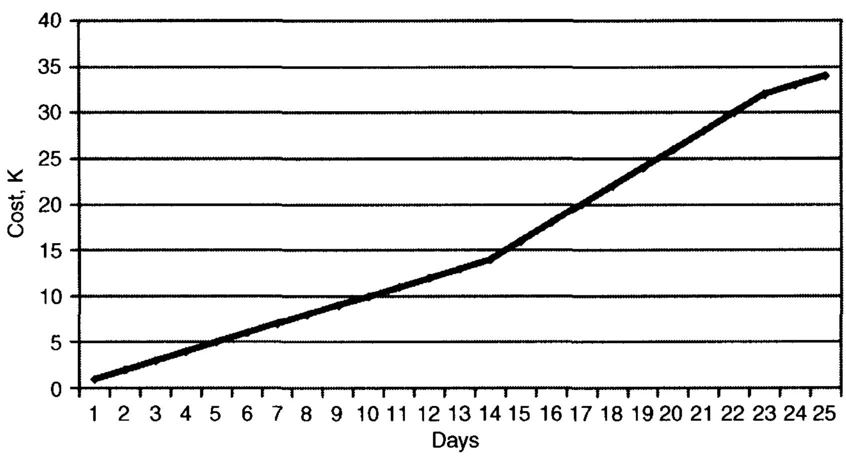


Figure 6.4 Cash flow in case of late date.

From these parameters we have tools to evaluate the project every month as follows:

January
The cost of execution is 300 less than the ACWP in this month, so the work is slow but the cost is acceptable.

The reason for this may be due to late hiring of new laborers.

February
The work is progressing as planned, but work is still slow. Deal with this situation by letting them work on weekends to achieve the required time schedule.

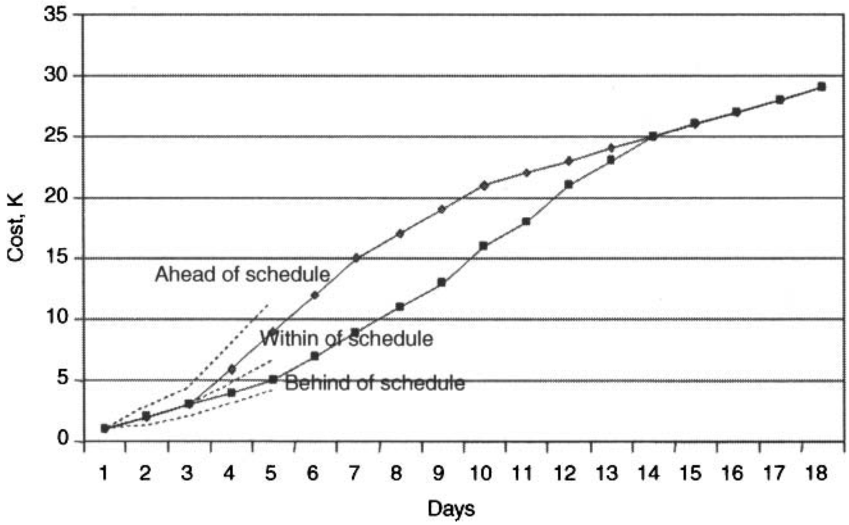


Figure 6.5 Cash flow envelope

Table 6.6 Cost per month

Plan	Jan.	Feb.	March	April	May	June
Work in month	60	140	200	200	200	200
Cumulative	60	200	400	600	800	1000
Cost/month	6000	14000	20000	20000	20000	20000
BCWS	6000	20000	40000	60000	80000	100000
Plan	**July**	**Aug.**	**Sep.**	**Oct.**	**Nov.**	**Dec.**
Work in month	200	200	200	200	100	100
Cumulative	1200	1400	1600	1800	1900	2000
Cost/month	100000	10000	20000	20000	20000	100000
BCWS	120000	14000	16000	18000	19000	200000

March

During this month, the work is close to reaching the plan. Now the time schedule is not the only problem but also the cost increase.

April

This month the work was done more than it was planned. Now the work is going according to schedule and will be back to a normal mode of work, avoiding work on weekends.

Table 6.7 Parameters calculation

	Jan.	Feb.	March	April	May	June
Cost per month	6000	14000	20000	20000	20000	20000
BCWS	6000	20000	40000	60000	80000	100000
BCWP (EV)	4000	14000	20000	20000	20000	20000
ACWP	4000	14000	22000	23000	21000	20000
EV cumulative	4000	18000	38000	88000	78000	98000
ACWP cumulative	4000	18000	40000	63000	84000	104000
CV	0	0	–1000	–1000	–2000	–2000
SV	200	200	–100	0	0	0
Cost index	1	1	0.95	0.921	0.929	0.942
Schedule index	0.66	0.9	0.95	1	1	1
BAC	15000	15000	15000	15000	15000	15000
EAC	15000	15000	16034	16333	16250	16000

May
The activity increased slightly more than planned, so we are going with the time schedule.

June
The work is progressing according to plan after 6 months of project. Work is proceeding according to schedule, but there has been an increase in cost. It is expected that the budget at the end of the project will be about $16,000.

6.4 Cash Flow Calculation

The calculation of cash flow was presented earlier, in Chapter 3. Cash flow is the real movement of money to and from the project. The cash flow is positive if the company receives money. It is negative if the company is paying money out. Net cash flow is the difference between these two amounts.

From a contractor's standpoint, positive cash flow is the money received in invoices or monthly payments. Negative cash flow is the money paid out for wages and salaries, equipment, subcontractors, and other items during the construction. In any project the contractor at some period will have negative cash flow. Money must therefore be available as an investment in the project. In the case of increasing the net cash flow, this contract is self-financed.

In general, construction companies arrange as part of their contract with a project that there is a financial reserve to draw upon in case a project is temporarily lacking funds.

6.4.1 Project Cash Flow

Cash flows and their timing differ depending on the individual's role within the project. The owner pays the contractor and engineering offices throughout the duration of the project's execution. At the start of a project's operation, the owner gains money from the sale of its productive ouputs. Over the project's lifetime, the owner will eventually realize profits

As shown in Figure (6.6), the process of cash flow during the lifetime of a project (planning, construction and operation) has more than one phase. The owner pays the invoices for the preparation of feasibility studies and preliminary engineering studies in select stages during the first period of the project. When the project is in its definition phase of elaborating the detailed design, the

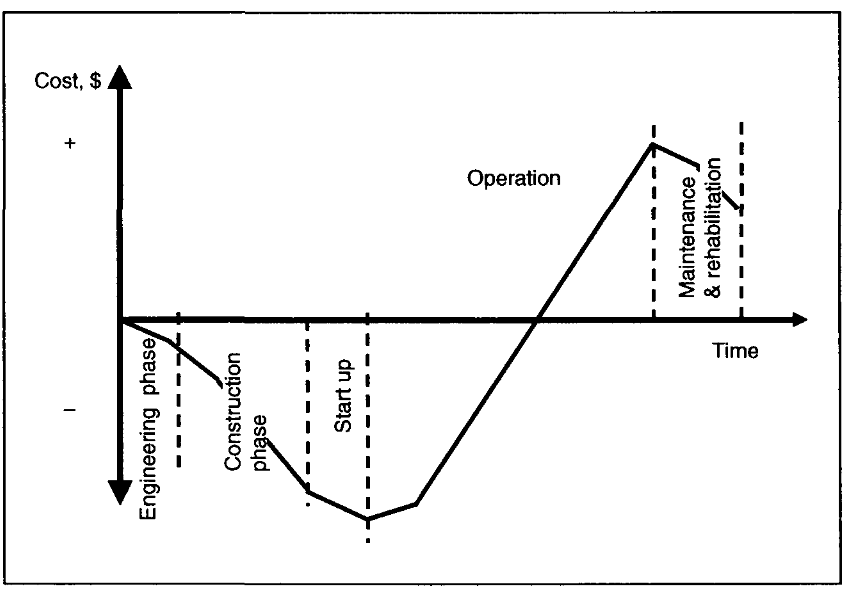


Figure 6.6 Cash flow along project lifetime.

number of team members is increasing, correspondingly increasing the cost.

During the construction phase, construction itself becomes the source of a significant increase in, money being paid out. In construction phase, the spending rate itself of the project's budget increases to cover large payouts for materials, equipment and contractors' invoices. Owner's outlays will peak by the end of the delivery of the completed project facilities, as the project moves into its operational phase.

As operations begin and output is produced and sold, increasingly over time the negative cash flow reverses to positive, becoming "net"-positive after passing through the "break-even" point (represented in Figs 6.6, 6.7, 6.8 and 6.9 below by the first intercept on the horizontal axis after the origin).

As shown in Figure (6.6), after a certain period, and according to the project's designated lifetime, industrial projects require overhauls, maintenance, and rehabilitation that will decrease the profit.

6.4.2 Impact on Increasing Cost

Sometimes costs increase during project execution, and there may be many reasons. The most common culprit is an increase in the price

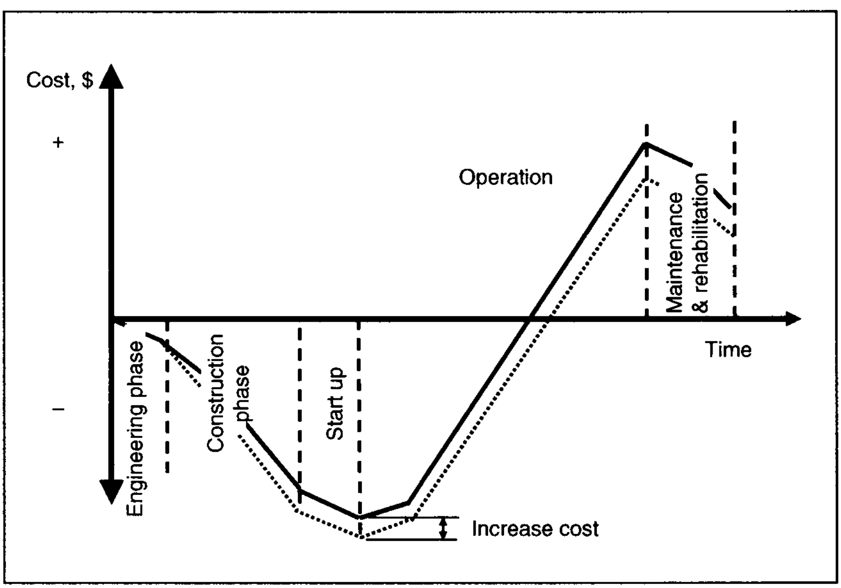


Figure 6.7 Effect of increase cost on the whole project.

of materials over what was estimated during the project's planning stages. There could have been an increase in the foreign exchange rate, hiking the price for machines that have to be imported from abroad. Another potential factor in project cost increases is any difference that arises in practice between in the quantities of inputs estimated in the drawings and design stages and what had to actually be purchased and used to execute the project. A common example arises during excavation: soil characteristics differ from the the soil report, or problems are found in the soil that were not taken into account during the planning stages., requiring renewed study of the soil conditions and foundations and changing the foundations design accordingly. These are all project risks that can be expected to increase project costs.

Figure (6.7) presents the impact of increases in the project cost as seen from the owner's standpoint. In addition to how such increases may shift the break-even point rightwards, i.e., later, in time, the total income from the project at the end of its lifetime will also be less than if the project had been executed within its original budget.

6.4.3 Project Lateness Impact

A delay in final delivery of the project (rather than just some temporary delay somewhere during the time schedule of its construction) can arise from any combination of circumstances, ranging from poor supplier choices to matters beyond anyone's control which result of poor project management. The result is a delay in the cash flow, illustrated below in Figure (6.8), and especially in the time it may take to being obtaining returns from the star-up of the operational phase of the project. Often, projects draw loans from banks as a result of this delay, but as this figure also indicates, this can have impacts on profitability at the end of the project's lifetime that may be greater than the losses accountable to increased costs alone.

6.4.4 Impact of Operational Efficiency

Operational efficiency is the responsibility of the owner. Errors arise during operation either as a result of faulty design, poor reliability or a general failure to meet the owner's requirements. The starting point of these errors usually lies somewhere between the owner and the project's engineering office.

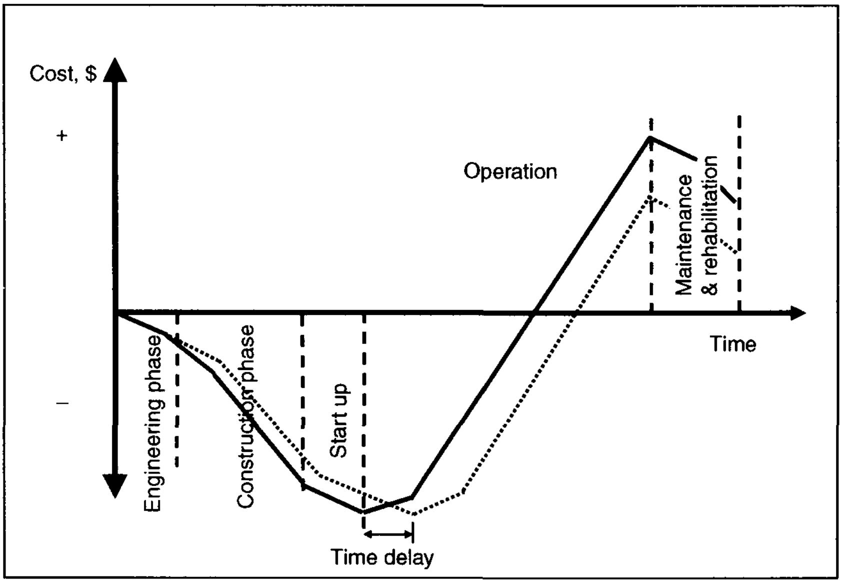


Figure 6.8 Effect of project delay on the whole project.

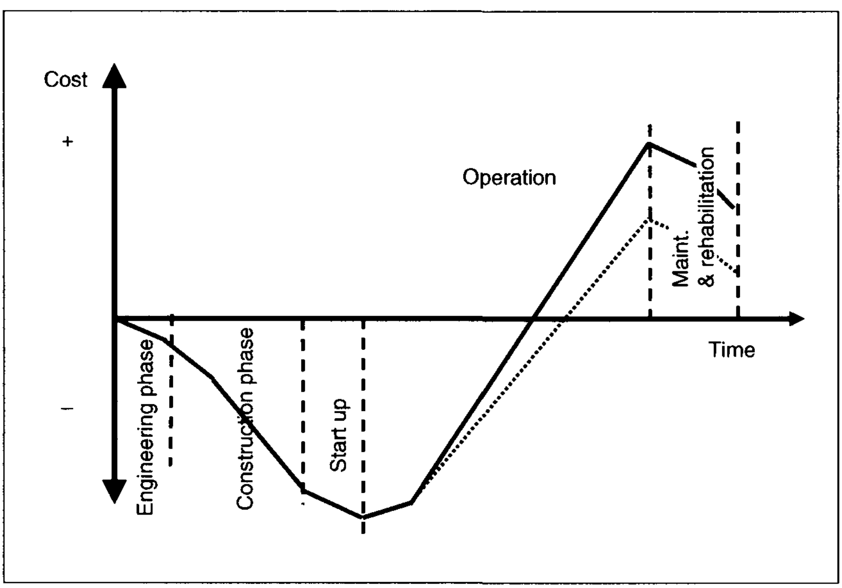


Figure 6.9 Effect of operation performance on the whole investment.

The most common errors in industrial projects are due to the lack of choice of high quality equipment. This is responsible for numerous problems and obstacles besetting operating performance and thereby, affects the overall revenue of the project. This is illustrated by Figure (6.9).

A last but important reason for operational shortcomings may arise from the owner paying insufficient attention to the need for appropriately experienced and adequately trained staff. Slackness on this front is bound to be reflected in the quality of production activities and output of the project, tending eventually to reduce overall revenue.

7

Bidding, Tenders, and Contracts

7.1 Introduction

Notwithstanding its possible impacts on the behavior of a project's service providers, and-or on the ability of the project-management team to overcome any gaps or limitations in its provisions, a contract with any and all parties involved provides the essential and vital backbone to any project. This chapter discusses the types of contracts and tenders in common use and the advantages and disadvantages of each.

It commonly happens that a project managers has worked in the same place for a long time in a company with an established market presence, This in itself may serve to reinforce a certain complacency about tendering and contract procedures already familiar from previous projects. Moving in the footsteps of one's predecessors in preparing another contract, it seems natural enough to expect to arrive at the same point that they did at another time in another set of circumstances.

To avoid unpleasant surprises, however, it behooves the modern a project-management professional to cast a critical eye about the way previous contracts were actually executed, and how their deficiencies and shortcomings were surmounted. This can be determined readily from an examination of the contractors engaged on the current project, reviewing their performance and considering how that performance might be enhanced by introducing certain changes in tendering and-or other contract procedures.

A review of the close-out reports of a previous project, if they embody sufficient clarity and transparency, can quickly enlighten the project-management professional as the relative strengths and weaknesses of past projects. This facilitates the process of revising the strategies to employ in dealing with the various service providers. This can make a contribution to achieving greater success than the company may have previously enjoyed with such counterparties.

In recent times, as a result of easy transportation and communications at the global level, there have emerged unprecedented changes on the development of industry as a result of the easing of communications and speeding-up of the movement between countries and continents.

Internationally, this has fostered an atmosphere of freer — in the sense of less encumbered — movement of goods and services across jurisdictions. At the same time, such apparently "freer trade" between nations and between different continents has brought intensified competition between companies and international organizations in its train, each seeking to maintain current global market share and expand that share. Competition has thus heightened as each actor tries to create or corner new markets with innovative or unique goods and services that edge out rivals. These conditions themselves have served to open up an entire new field of management consulting in the area of market strategies that take into account this intensification of competition on the global scale.

The owner of a project may have offers from different countries. In such an environment, decision-making informed by complete and objective information, including the latest updates about international globally-accepted standards, assumes unprecedented importance. In particular, the potentially large physical distance separating client and a contractor's engineering office or factory has rendered imperative to administer the arrangements of a project according to systems that guarantee the client's confidence in a product or service. One such system is that of the ISO (International standardized organization which a branch of united nations), which will be discussed in chapter eight. Alongside these considerations, the conclusion of a conscientiously designed contract provides a further guarantee of product-quality assurance, at the right price, delivered in a timely manner. Using a device such as a FIDIC contract (a standardized document developed by the International Federation of Consulting Engineers) further assists the project's achieving the desired success.

7.2 Contracts

Projects that entail the creation of one or more physical facilities — factories, offices, workshops, warehouses, oil and gas fields or other energy generation or energy supply projects, etc. — bring project management in contact with the realities of the modern construction industry. Construction contracts are frequently, at least on the surface, an apparently three-way affair as illustrated in Figure 7.1. There are two main contracts between the owner and the engineering services provider on the one hand and between the owner and the main contractor on the other.

Of course, the engineering firm and-or the contractors also have contracts to supply materials or provide services or subcontractors. All these contracts will affect the project as a whole. For example, the services for an engineering firm might come from a company that maintains their computers but with whom there is no binding contract to achieve a fast response or speed performance or ensure quality-of-service in the maintenance of the engineering firm's computer systems and thus extend the overall design time beyond what would be estimated if such a third-party service provider were not part of the picture. So, in other words: a contract between owner and contractor may be fine on its face and all its ramifications perfectly clear to owner and contractors. Other arrangements, however, could turn out to be highly problematic between owner or contractors and others not directly party to the their contractual relationship, or for others whose relationship with them is not strictly regulated by contract. The experienced and alert project management professional makes sure to check for and find ways around such hidden potential minefields.

All contracts are important to the project, and the goal of each should be clear to all.

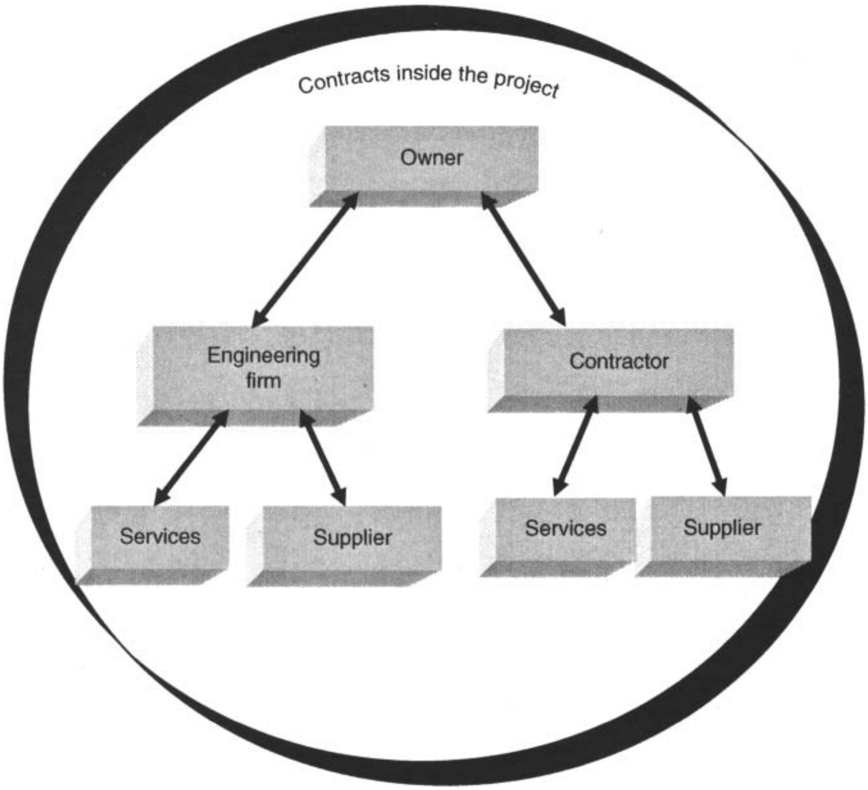


Figure 7.1 Contracts inside the project.

The most risky contracts are often, however, are often the most important, usually entailing the greatest financial commitments of the project, particularly the construction contract between the owner and the construction main contractor. The owner must determine the type of contract, how each contract is different depending on the nature of the project, and its objective. Formal owner – contractor arrangements come in a wide range of contract shapes and sizes. The most widely observed are the following:

- Measured contract
- Lump-sum
- Cost-plus contract

7.2.1 The Measured Contract

This type, one of the most widely used in the construction field, has become well-established from decades of application across a wide range of circumstances, in both stable and unstable social and economic conditions. The contract documents contain quantities of each item, which is accurately described and includes clear specifications. The contractor includes the price of each item, multiplying the price by quantity to determine the total cost of the item. The total project cost is the sum of all these quantities.

The advantage of this method is that a shortage or increase in quantities can be readily determined, along with any impacts on the price of this item which was agreed upon in advance on a basis stipulated in the contract.

Recently, in the wake of rising prices and other ongoing market changes, the presence of a fixed price throughout the project period has come to be seen as a potential source of damage to the interests of the contractor, who enjoys little or no explicit protection under this type of contract. As contractors have accordingly become reluctant, or have even refused, to tender for contracts that have not provided some safeguard against rising costs, there has emerged a widely-followed transnational commercial practice whereby, in the case of a project whose execution exceeds twelve months, a clause in the contract provides for allowing increased prices for labor, materials, or tools.

In European countries, a newsletter is published monthly to define the increase in prices through government institutions such as the Department of Environment.

7.2.2 The Lump-Sum Contract

Traditionally, this type of contract is used in low-cost projects. The contractor in this arrangement will be implementing the project at a fixed rate. Therefore, the drawings and specifications must be clear because this contract does not have a calculation of the quantities. Thus, with any change in the site, the amount of variation cost may become difficult to determine. This is a circumstance that can drag out negotiations between the contractor and the owner, possibly disrupting the entire project.

This form of contract is nowadays elaborated as a turnkey arrangement that outlines the engineering, procurement and construction (known as EPC) all in one place at the same time. It stimulates vigorous competition among contractors particularly in the area of project design. This stems from the fact that this factor by itself can significantly reduce the total cost of a project. The benefits of such a development are bound to redound to the owner, who can hope to start realizing profit from the project's coming into actual operation that much sooner with lowest price.

Another important aspect of the Lump-Sum Contract is the possibility of subdividing major items of expenditure or major mile stones, for example the purchase and-or supply and-or installation of machinery onsite. In this case, a contractor may be interested to partition this cost into one figure representing the cost of providing the concrete base for the machinery, another for performing the mechanical work on the equipment, another for supplying / installing the machine and finally a figure representing the cost of attaching it externally to some source of electric power. By thus breaking down the price of each component item of activity separately in this way, the contractor and project owner may be able to give themselves room to negotiate their way around the effect of some unexpected price increase in any one of these items.

Some contracts also have an appendix that contains the price of labor per day or materials that is known from experience to be likely to cause an increase or decrease in this activity.

7.2.3 The Cost-Plus Contract

In this form of contract, the contractor supplies construction at its actual cost "plus" some fixed ratio for the duration of the project's construction. This latter amount includes the costs of supervision, and profit. So long as price increases do not become a problem, this is fixed for the duration of the project. The main downside of this type of contract is the supervisory effort required, involving daily checking of the plant, labor, and materials.

Cost-plus contracts are normally used in projects that need to be executed quickly and urgently, or that are of particular importance, or that are very small-scale. They usually require delivery of materials in remote areas for urgent purposes. This type of contract is common in oil and gas projects, which often require urgent action to meet some unpredictable contingency or other. The cost of materials is known from the suppliers' invoices, while the contactor obtains his fixed percentage as agreed beforehand.

7.3 Contracts Between an Owner and an Engineering Consultancy Office

This contract relies on various forms of fixed standards, with the Engineering Office supplying the detailed description of the services to be provided. Typically, in businesses of the European countries and in Arab countries, the estimated value is within seven per cent (7%) of the project's total costs for smaller consultancies to within five per cent (5%) for larger corporate entities. The Engineers Association has identified these percentages based on project size. If the contract is for design services only, or design services plus some onsite supervisory activity, there may be additional fees charged for use of facilities, transportation and other supervisory expenses. In some projects, supervision may be charged as a fixed fee rather than as a percentage.

Often in big projects, this type of contract is based on the cost of man-hours employed. The contract specifies the cost per hour of the lead engineer, senior, junior engineers, drafting, and others. In the project as a whole, the overall cost is determined by identifying the number of hours of each group's work. The price is based on an hourly rate in which any administrative, insurance, tax, or other expenses are incorporated.

Table 7.1 Cost, time, and resource estimate sheet

Client		**Project number**	
Project title		**CTR number**	
CTR title		**Start date**	
Revision		**End date**	
Scope:			
In this section the scope of work will be written in summary but should be precise.			
Assumption:			
The assumption that the designer will take into consideration that according to these paper the client will accept and review that.			
Inputs:			
In this item will be the input data which will be the SOR from the client, soil data, survey maps, and other data that the client should deliver to the engineering firm.			

Table 7.1 (cont.) Cost, time, and resource estimate sheet

Deliverables:			
Doc: No.	Doc. title		Doc. type (report/ drawings)
	Define the name of the document, which should be reviewed by the client carefully and should match the requirement of the SOR.		
Resources			
Resource	Hrs	Rate	Total
Lead disciple			
Senior engineer			
Junior engineer			
Senior drafting			
Drafting			
		Sum total	

The benefit for the engineering office from contracting on this basis of man-hours emerges when the owner requests changing any part of the study design or adding some other piece that was not in the scope of work delivered originally to the engineering office. Since the office provides a number of hours for each member, and the rate is already a known quantity, the additional cost can be calculated easily.

7.4 The Importance of Contracts for Project Quality Assurance (QA)

As previously mentioned, there are different types of contracts between the owner and the contractor as well as between the owner and the engineering office, and "bugs" in the contracts can cause problems that may be difficult to resolve, expending valuable time and affecting the project's final cost. To meet this contingency pro-actively, periodic specific reviews provide an important means for maintaining a successful contract that renders every aspect fully and consciously.

In addition to drawings and specifications, including quantity and price, for the materials, labor, and tools; specification of onsite working conditions; and definitions of working relationships to be maintained between the owner, the contractor, supervisory personnel and the engineering facility, there are some other basic items that are frequently overlooked when contracts are being drawn up. Requirements of health, safety and the environment (HSE) to be followed, measures to ensure the security of personnel, how contingent expenses that may arise from injuries or disease at the site are to be managed, the amounts to be reserved to cover tax and other government fees, legal and-or judicial procedures to be followed if a disagreement between contracting parties cannot be settled by mutual consent,, and other administrative items are no less important than those items already mentioned as part of the engineering work details.

One example of a stable regime for international contracts is the instrument known as FIDIC, which incorporates specific forms covering these and other such items. FIDIC is the reference standard for international contracts and is used in major international projects.

7.5 Contracts in ISO

Procedures considered to be best practices for the review of contracts are set forth in ISO 9001 (ISO 9001 Section 4.3). The requirements for preparing and reviewing contracts in ISO cover the following aspects:

- Contracts document
- Review contracts
- Procedures
- Requirements
- Capability of contractors or service provider

The contract documents themselves may contain parts of the ISO standard, or refer to it. The contract document must contain a quality plan from the supplier or contractor as well as plans to review the quality of the deliverables. Before signing, it is strongly recommended that the parties review closely and verify that all requirements are presented in the contract clearly. The supplier or contractor must be able to demonstrate ability to perform the contract in the case of any further requirements in excess of the primary scope. This additional scope must be negotiated and incorporated into the final contract.

7.6 FIDIC Contracts

The FIDIC contract is the most popular form found among international projects. FIDIC is the abbreviation for "Fédération internationale des ingenieurs conseils," the "International Federation of Consulting Engineers.") The FIDIC union comprises assemblies of consulting engineers in different countries, established in 1913 through the participation of three European societies, two architects of the French Society of Consultant Engineers (CICF), the Swiss architects consultant engineers (ASIC) and the Belgian Society of Consultant Engineers (CICB). The first conference was held in 1914 in the Swiss capital city of Berne. The consultant engineer has been defined in the conference as "the engineer who holds the scientific and technological knowledge and professional and scientific expertise, and who practiced law in his own name independent of any commercial enterprise or government for the client and does not receive any money except from his agent." FIDIC's operations were suspended for the duration of World War II, but were re-organized in the 1950s and '60s. FIDIC won international attention, strengthened its relations with the United Nations and World Bank, and penetrated the engineering contract activities of companies beyond Europe such as Japan, America, and some countries of the Third World. Its membership today includes about 65 associations of consulting engineers from around the world, including three Arab countries, Egypt, Tunisia and Morocco.

The Secretariat of the FIDIC is headquartered in Lausanne, Switzerland. From the perspective of the present work, one of its most important activities is its maintenance of contractual standards for international projects. These are encapsulated in a number of volumes distinguished by covers of different colors. A volume with the red cover documents civil engineering services contracts between employer and contractor. Another volume with a yellow cover documents the contract between the owner and the contractor for electrical and mechanical comprehensive installation. The Orange Book covers contracts for turnkey design. The White

Paper presents the standard contractual terms between employer and the consultant engineer.

FIDIC published the first edition of its volume on general conditions for the implementation civil construction work in 1957. Some items were added for the work of dredging in the second edition, which was published in 1969 and 1973. The review of the conditions was set forth in the contract with the World Bank and European Union contractors. After this review, the World Bank approved the use of the terms of this contract in its own projects around the world.

The 1996 edition of FIDIC's standard volume about contracts involving an owner, consulting engineers and contractors sets forth the following outline of contract drafting issues in its Table of Contents as follows:

Contents

Part I - General Conditions

Definitions and Interpretations

1-1 Definitions
1-2 Headings and marginal notes
1-3 Interpretation
1-4 Singular and plural
1-5 Notices, consents, approvals, certificates and determination

Engineer and Engineer's Representative

2-1 Duties of the engineer and authority
2-2 Representative of the engineer
2-3 The engineer's authority to delegate
2-4 The appointment of assistant
2-5 Written instructions
2-6 Engineer to act impartially

Assignment and Subcontracting

3-1 Assignment of contract
4-1 Subcontracting
4-2 Assignment of subcontractor's obligation

Contract Documents

5-1 Language and law
5-2 Priority of contract documents
6-1 Custody and supply of drawings and documents
6-2 One copy of drawings to be kept on site
6-3 Disruption of progress (delay)

6-4 Delays and the cost of delay of drawings
6-5 Failure of the contractor to submit drawings
7-1 Supplementary drawings and instructions
7-2 Permanent works designed contractor
7-3 Responsibility unaffected by approvals

General Obligations

8-1 Contractor's general responsibilities
8-2 Site operations and methods of construction
9-1 Contract agreement
10-1 Performance security
10-2 Period of validity of performance security
10-3 Claims under the performance security
11-1 Inspection of site
12-1 Adverse physical obstructions or conditions
13-1 Carry out the works in accordance with the contract
14-1 Program to be submitted
14-2 Revised program
14-3 Submission of cash flow estimates
14-4 Contractor nor relived of his duties or responsibilities
15-1 Contractor's superintendence
16-1 Contractor's employees
16-2 Engineer at liberty to object
17-1 Setting-out
18-1 Borings and exploratory excavation
19-1 Safety and security and protection of the environment
19-2 Responsibilities of the employer
20-1 Care of work
20-2 Responsibility to rectify loss and damage
20-3 Loss or damage arising from risk employer
20-4 Employer's risk
21-1 Insurance of works and the contractor equipment
21-3 Liability for the amounts not recovered
21-4 Exclusions
22-1 Damage to persons and property
22-2 Exceptions
22-3 Indemnity by the employer
23-1 Third party insurance (including the employer's property)
23-2 Minimum value for insurance
23-3 Cross liabilities
24-1 Accident or injuries to workmen

24-2 Insurance against accidents to workers
25-1 Evidence and terms of insurances
25-2 Adequacy of insurance
25-3 Remedy on contractor's failure to insure
26-1 Compliance with statues, regulations
27-1 Fossils
28-1 Patent rights
28-2 Royalties
29-1 Interference with traffic and adjoining properties
30-1 Avoidance of damage to roads
30-2 Transport of equipment by the contractor or temporary works
30-3 Transport of materials or plant
30-4 Waterborne traffic
31-1 Opportunities for other contractors
31-2 Facilities for other contractors
32-1 The contractor to keep site clear
33-1 Clearance of site on completion

Labor

34-1 Engagement staff and workers
35-1 Returns of labor and the contractor equipment

Materials, Plant, and Workmanship

36-1 Quality of materials, plant, and workmanship
36-2 Cost of the samples
36-3 Cost of tests
36-4 Cost of tests not provided for
36-5 Engineer's determination where tests not provided for
37-1 Inspection of operations
37-2 Inspection and testing
37-3 Inspection and test dates
37-4 Rejection
37-5 Independent inspection
38-1 Examination of work before covering up
38-2 Uncovering and making opening
39-1 Removal of improper work materials or plant
39-2 Default of contractor in compliance

Suspension

40-1 Suspension of work
40-2 Engineer's determination following suspension
40-3 Suspension lasting more than 84 days

Commencement and Delay

41-1 Commencement of works
42-1 Possession of site and access thereto
42-2 Failure to give possession
42-3 Rights of roads and facilities
43-1 Time for completion
44-1 Extension of time to the end the project
44-2 Contractor to provide notifications and detailed particulars
44-3 Interim determination of extension
45-1 Restrictions on working hours
46-1 Rate of progress
47-1 Liquidated damages for delay
47-2 Reduction of liquidated damage
48-1 Taking over certificate
48-2 Taking over of sections or parts
48-3 Substantial completion of parts
48-4 Surfaces requiring reinstatement

Liability for Defects

49-1 Defects liability period
49-2 Completion of the outstanding work and remedying defects
49-3 Costs of remedying defects
49-4 Contractor's failure to carry out instructions
50-1 Contractors to search

Alteration, Additions, and Omissions

51-1 Variations
51-2 Instructions for variation
52-1 Valuation of variation
52-2 Power of engineer to fix rate
52-3 Variations exceeding 15%
52-4 Workday

Procedure for Claims

53-1 Notice of claims
53-2 Contemporary records
53-3 Substantiation of claims
53-4 Failure to comply
53-5 Payment of claims

Contractor's Equipment, Materials, and Temporary Works

54-1 Contractor equipment, temporary works, and materials exclusive use for the works
54-2 Employer not liable for damage
54-3 Customs clearance
54-4 Re-export of contractor equipment
54-5 Conditions of hire of contractor's equipment
54-6 Costs for the proposed of clause 63
54-7 Incorporation of clause in the subcontracts
54-8 Approval of materials not applied

Measurements

55-1 Quantities
56-1 Works to be measured
57-1 Methods of measurement
57-2 Break down of lump sum items

Provisional Sums

58-1 Definition of provisional sums
58-2 Use of provisional sums
58-3 Production of voucher

Nominated Subcontractors

59-1 Definition of nominated subcontractor
59-2 Nominated sub-contractor objection to nomination
59-3 Design requirements to be expressly stated
59-4 Payments to payment to be nominated to subcontractors
59-5 Certification of payments to be nominated to subcontractors

Certificates and Payments

60-1 Monthly statements
60-2 Monthly payments
60-3 Payment of retention money
60-4 Correction of certificates
60-5 Statement at completion
60-6 Final statement
60-7 Discharge
60-8 The final certificate
60-9 Cessation of employer's liability
60-10 Time for payment
61-1 Approval only by defects liability certificate

62-1 Defects liability certificate
62-2 Unfulfilled obligation

Remedies

63-1 Default of the contractors
63-2 Valuation at date of termination
63-3 Payment after termination
63-4 Waive the agreement gains
64-1 Urgent remedial work

Special Risks

65-1 No liability for special risks
65-2 Special Risks
65-3 Damage to works by special risks
65-4 Projectile, missile
65-5 Increased costs arising from special risks
65-6 Outbreak of war
65-7 Removal of contractors equipment on termination
65-8 Payment if contract is terminated

Release from Performance

66-1 Payment in event of release from performance

Settlement of Disputes

67-1 Engineer's decision
67-2 Amicable settlement
67-3 Arbitration
67-4 Failure to comply with engineer's decision

Notices

68-1 Notice to contractor
68-2 Notice to employer and engineer
68-3 Change of address

Default of Employer

69-1 Default of employer
69-2 Removal of contractor's equipment
69-3 Payments on termination
69-4 Contractor's entitlement
69-5 Resumption of work

Changes in Cost Legislation

70-1 Increase or decrease of cost
70-2 Subsequent legislation

Currency and Rates of Exchange

71-1 Currency restrictions
72-1 Rates of exchange
72-2 Currency proportions
72-3 Currencies of payment for provisional sums

7.7 General Conditions in Contracts

General requirements in contracts are defined these days very precisely by individuals with extensive legal or adminittrative experience. In the end, however, the project manager is responsible for any contractual problem or error during project execution, and the onus falls on that individual to review the contract and general conditions carefully. The following list must be reviewed, and all items that have been drafted by the contract should be confirmed. This list is also used to terminate the contract, to make sure that the contract contains all the essential items, and to ensure that nothing has been forgotten.

List of General Conditions

Contract

- ☐ Definitions
- ☐ Agreement document
- ☐ Laws and language
- ☐ Clarification

Owner

- ☐ Owner responsibilities
- ☐ Deliver information and document
- ☐ Reach the site

Owner Representative

- ☐ Engineer
- ☐ Roles and responsibility
- ☐ Engineer representative
- ☐ Requirements and conditions

Contractor

- ☐ General responsibilities
- ☐ Contractor Representative
- ☐ Guarantee
- ☐ Subcontractor

Engineering Design

- ☐ General responsibilities
- ☐ Drawings
- ☐ Project specification

Supervision and Labors

☐ Labor rules
☐ Labor salary
☐ Health and safety

Equipment and Materials

☐ Construction procedure
☐ Tests

Time Plan

☐ Start time
☐ End time
☐ Performance rate
☐ Penalty

Tests

☐ Contractor responsibilities
☐ Testing procedure and condition

Receive Projects

☐ Receiving certificate
☐ Operations manual to the owner

Fault Responsibility

☐ Cost of repair
☐ Tests after repair

Contract Value and Payment

☐ Contract value
☐ Down payment
☐ Payment schedule

Change Order

☐ Right to change
☐ Methods of change
☐ Present change
☐ Value of change

Contractor Fault

☐ Excuse
☐ Contract termination
☐ Pay at completion

Insurance

☐ On design
☐ Equipment
☐ Labours
☐ Others

Force Major

☐ Definition
☐ Effects
☐ Exemption from the delay and performance

Disputes and Arbitration

☐ Method claim
☐ Payment of the claim
☐ Arbitration
☐ Determine the courts in case of conflict
☐ The laws governing the conflict

7.8 Arbitration and the Arbitrator

Arbitration is a process for resolving disputes that arise between two parties — usually the project owner and one or more contractors— in front of some third party mutually accepted by the disputing parties as final judge. The idea is to resolve disputes relatively quickly and far less expensively than going through the civil courts.

In managing disputes arising in the course of engineering projects, an arbitrator in addition to being unbiased in the eyes of the disputing parties must also possess or be able to summon the advice of technical engineering expertise, including perhaps legal expertise as well, pertaining to the particular technical area involved. This role is usually filled by a consulting engineer, who conducts both the technical and administrative phases of an arbitration.

FIDIC contracts play a vital role and give power to the consultant engineer when there is a requirement for the contractor. The idea here is to take the first and important step of attempting to resolve the problem before it goes to arbitration.

According to FIDIC's standards, a contract must provide for an arbitration process of some kind. Typically, arbitrations are concluded by an adjudicating body consisting of three arbitrators chosen by each party. These two select the third arbitrator, who conventionally serves as president of the commission. International contracts must define the nationality of the third arbitrator as the decision will be crucial in the case of a deadlocked vote of the rest of the arbitral tribunal. Additionally, in the case of disputes in international contracts, the contract must define who will be the third arbitrator, in case the parties fail to select one. Appointment authority comes from the management of arbitration in private institutions such as the International Chamber of Commerce.

Within 84 days [12 calendar weeks] from the date for receiving a request from either an owner or contractor, a consultant engineer should be appointed to initiate arbitration of their dispute. The owner and the contractor are to submit their acceptance or rejection of the consulting engineer's decision in writing. If neither party submits an appeal from the decision within 70 days [10 calendar weeks], it is considered final and an arbitral tribunal is to take the decision of the consultant engineer into account.

7.9 Bids and Tenders

Having defined the project and its work volume, collected all drawings and specifications, selected the type of contract, and determined the final form of the contract, the next phase of complex administrative work dawns. In this phase, the project manager becomes familiar with the laws of each country governing contracts and bids for projects. In this sphere, various solutions can be sought to reduce undue or unfair manipulation of the project and-or of its contractual arrangements. This is the sphere as well in which sources of possible or actual corruption can be challenged and exposed or blocked, so that fair competition between contractors is maintained and guaranteed.

Most countries have laws that enable access for foreign construction companies to their markets while also encouraging local construction companies. As part of mastering this sphere of a project manager's responsibilities, it is important to understand the laws governing tendering and bidding procedures. This affects the project's primary objective of contracting with a service provider who can accomplish the project's aims, delivering the required quality at the lowest price. Although the general principles and practices of commercial law are broadly the same across many countries, every country's legal system has its own peculiar features and usages. Thus, it is not surprising to see international companies doing business in more than one country relying on a contracts department that can manage contracts and tenders according to the specific legal norms of contract law and tendering procedures of each country.

The general framework of the different types of tender is well-established, as are the conditions to be followed and the characteristics of each type of bid. There are certain differences in the financial limits and operational requirements among the main types of tender.

The four main types discussed below are:

- Public (open) tender
- Limited tender
- Negotiated tender
- Direct order

7.9.1 Public (Open) Tender

The owner prepares the service terms and conditions booklet, and lists of works and accessories. These documents need to be prepared with special care. A copy must be kept of the contract and its specifications; financial, administrative, tax, insurance; and succession requirements. Contractual language is standardized on and drafted in English. Translated brochures list the contract's main requirements and specifications and, in the case of external tenders, they indicate whether, in the event of any disagreement or confusion about the content, Arab, French, Chinese or other texts apply.

Open bidding is advertised in newspapers. This advertisement should make its appearance in a timely manner, disclosing the declaration submitted to tender, the last date for submission, the work required, the value of the primary and final bond, the price of a copy of the tender conditions, whether external tenders must be advertised in the owner country and abroad, and any other data the administration deems necessary for the work.

Usually, from the date of the first announcement of the auction a period of at least thirty days for submission of bids is opened for public tender. If necessary, a licensed competent authority may choose to shorten the period, but to not less than fifteen days. (Except in cases of extreme necessity dictated by the circumstances of the subject of the tender and with the consent of the competent supreme authority, such conditions are not applied to public tenders relating to provision of annual supplies). Except when the body administering the tenders auction requests, in a timely manner, that bidders accept some extension, the duration of a tender's validity usually runs from the date fixed for the opening of the envelopes at auction until notification of acceptance before the expiry of the tendering submission deadline.

A company planning to enter a bid designates an employee to keep tabs on the chain of custody of its tendering documents from the point at which the documents receive final approval from the relevant department to go forward until the documents are delivered to the office where the tendering auction will convene. This delivery will usually be timed for the afternoon or morning before the bids are scheduled to be opened, but this critical responsibility might also entail having to inform some designated responsible party from the auction-managing authority of imminent delivery of his company's bid very close to the time officially set for opening the envelopes.

On the day appointed for opening the submitted bids, the chairman of the committee administering the formalities of the auction is tasked with the following:

- verify the integrity of the seals on the bidding documents received;
- establish in the minutes of the meeting the number of envelopes received;
- open the bids sequentially, assigning each opened envelope its uniquely-identifying serial number;
- enumerate the components of the tender;
- read aloud the name of each bidder and title of their tendering document to the audience of bidders or their representatives; and
- announce the amounts of each bid.

Bidders deposit an initial bond of not less than 1% of the tender value of construction work. Upon acknowledging acceptance of the tender award, a successful bidder deposits a bond equal to 5% of the value of the project's construction costs. These actions are usually to be concluded over a period not exceeding 10 days, counted from the day following the auction. (For successful bidders from outside the country, the time allowed for submitting this bond is usually not more than twenty days. The authority concerned may extend by not more than 10 days the deadline for the filing of the final deposit.)

Public tenders are particularly favored by government authorities as an instrument for strengthening the general business environment. The public-policy aim is to encourage the development of new contractors on the basis of maintaining an orderly rules-based system complete with internationally-accepted standards from which domestic contractors may raise their overall performance and competitiveness in domestic and foreign markets.

7.9.2 Limited Tender

The limited tender is usually used in most special industrial projects, where the number of contractors or vendors, being more specialized, may be limited. Before registering the contractors on the company bidder list a pre-qualification assessment and audit for these companies should be performed as per ISO procedures and requirements.

Unlike the public-tendering case, the owner already has a record of potential suppliers and contractors. The limited tender is directed to a specific registered number of contractors known to already have previous relevant experience. Such a tendering process is used by most private companies as well as by some government departments to limit participation in the bidding to a relatively small number of suppliers and contractors of established reputation, from within and-or outside the country.

The aim is to save both time and money in launching the project. The procedural steps followed for the calling the tender, preparing a bid and selecting a winner follow the methods already discussed regarding public tenders. With the ubiquitous spread of secure corporate websites over the Internet, which electronically enable the confidential submission of bids, however, one significant new wrinkle in limited-tendering has emerged. With sophisticated software that takes care online of many of the background functions of securing the provenance and chain of custody of tendering documents, the processes of generating, filing and amending limited tenders has been rendered less costly and in most cases just as reliable as the work that previously required many more human agents.

Typically, an owner will prepare a website on the Internet, where bidders may to enter the page and proffer or change their prices. By enabling the bidders to see the prices of the competitors, there is a high level of transparency in the data. All parties know why a company wins the bidding without getting into rumors and excitement. Of course, all this is contingent on precise descriptions of each project component and what the work to deliver it will actually entail.

This tender is commonly used in oil and gas companies, specifically for chemical tenders. The specifications are very precise, and well-defined, and can be delivered by only a very limited number of famous suppliers in the world market — facilitating the owner's need to obtain the best price.

7.9.3 Negotiated Tender

A negotiated tender may be accomplished by an individual or group designated by the owner and usually comprising technical, financial, and legal personnel, meeting with contractors that have submitted bids on the restricted "pre-qualifying" basis described above in section 7.9.2. The purpose of meeting is to bring down the prices submitted in their bids by means of a process of having them bid amongst themselves. Amended price offers may be submitted in one-on-one meetings with the negotiating committee by all the final bidders together in the same room with the committee. The process concludes with the owner receiving and accepting the commmittee's recommendation.

This type of tender expedites the launch of projects whose major costs are centered on a small set of essential goods or services; or whose award has come down to choosing between two final-bid contenders charging more-or-less the same price in a circumstance where they and-or the owner cannot commit any more time or money to redoing the tender:

- Consultancy work, which requires technicians, specialists, or experts
- Things that only exist for one contractor
- Things monopolists manufacture or import
- Things that cannot be identified exactly
- Procurement, general contracting, and transportation services and the delivery of services, which are characterized by urgency

The negotiated tender procedure itself is most often used to overcome a restricted tendering process, by empowering a designated negotiating committee to proceed to negotiate the actual terms of the contract within strict guidelines prior to its being awarding the contract. The negotiation may also be advertised, and the committee of negotiations will do the negotiation with all suppliers and contractors, and their discussion in public meetings is open to suppliers, contractors, or their representatives. The committee will then submit its recommendations to senior management, depending on what the committee result for direct award to successful contractor.

7.9.4 The Direct-Order Tender

This type is usually rolled out to deal with one of two situations:

- the emergence of very urgent issues that cannot wait for completion of a more normal bidding procedure; or
- the circumstance of being compelled to fulfil a requirement through a sole vendor. This arises

frequently within industrial projects, when a specialized engineering study is required that only one company may be in a position to provide. An agreement is made directly with the monopoly service provider, and further price negotiation is rare.

7.9.5 Tender Technical Evaluation

This is a modification of tendering procedure to enable an independent evaluation of how a bidder proposes to meet the owner's technical requirements. Two envelopes are submitted — one containing technical details on which an owner would appreciate an independent evaluation, the other containing financial details of the bid. The committee opens the "technical" envelopes of the various bids; their engineering technical packages go to a technical committee for separate evaluation. This process eliminates the technically unacceptable offers from further consideration. After narrowing down the final selection of technically acceptable offers, the financial envelopes will be opened and evaluated. This is the stage in which the lowest price and successful bidder are determined.

Bids accepted into the first technical-evaluation stage are examined according to specific criteria. These considerations include the following:

- Management system of the contractor's company and its size
- Form of administrative organization onsite
- Previous general experience
- Quality standards criteria followed by the contractor
- Health, safety, and the environment (HSE) policy followed by the contractor, and records of the latest reported incidents
- Previous experience in the same project
- Equipment available
- Time schedule and the overall duration of the project completion

The above criteria are more or less important depending on the size and type of the project. Some projects have a specific nature. For example, for some projects the time factor is very important and an increase in time may affect the project. In hotel projects, any delay reduces the number of days before a hotel is open, a period in which no profits are realized by the owner. For oil companies, each day represents a loss of the number of barrels of oil produced. In such projects, considerable attention and weight is given to the schedule and time. In other projects, safety requirements may be the most important

A points system is commonly used to weigh the best technical offer. Each element is assigned its weight, e.g., 20 degrees for the duration of the project. That is the technical offer which gives the minimum period of time garners 20 points, whereas contract proposals providing a longer execution time are allocated fewer points. The company obtaining the highest total is the technical winner. Many companies and government departments that frequently resort to putting technically complex projects out to tender maintain their own points system criteria, requiring the technical offerings of a bid to pass thresholds of as low as 50 to as high as 70 per cent in order to make the final cut. The points-table and the relative weighting of each technically significant item is set out in the tendering process documents.

The following example illustrates the technical points-system to be applied to evaluating tendered offers to construct a nuclear plant,

A. Experience

Table 7.2 Experience score

Item	No. of Points
1. General activity/standing of firm (year of establishment, number of employees, etc.) 2. Tender's past and recent experience and the consortium members (if any); they have participated in two nuclear power projects of 500 MW and above using water cooled reactor technology in the last five years as a minimum in two different locations. In addition, they have successfully completed three similar projects in the last 30 years, one of which is outside of home country. Tender and all the consortium members (if any) shall provide details of the required experience as well as its current workload.	50

Table 7.2 (cont.) Experience score

Item	No. of Points
Site studies and evaluation	100
Preparation of bid documents, invitation of bidding, bid evaluation and negotiation, and preparation of contract documents	50
Project management and implementation includes commissioning	100
Technology transfer and personnel training	50
Sub total	350

B. The Work Plan

Table 7.3 Work plan score

Item	No. of Points
Submittal of the tender in compliance with the terms and conditions listed in the tender document	50
Submittal of the tender in compliance with the technical requirement described in the tender document	50
Adequacy of the man months indicated in the proposal to execute the required services	75
Tender's proposed project time schedule and description of the approach to completeness of the work	50
Tender's localization plan to submit a complete program describing the components of the equipment that would be manufactured locally	25
Adequacy of the quality assurance program	50
Tender's organization chart and adequate manpower data of tender's personnel to be assigned during the execution of the work to meet the tender's schedule	100
Sub total	400

C. Financial Capability and Experience

Table 7.4 Score for financial capability and experience

Item	No. of Points
Tender's financial capability and audited financial data for the last three years	75
Tender to demonstrate its knowledge of the project international co-financing institutions procurement processes	75
Sub total	150

D. Industrial Safety

Table 7.5 HSE score

Item	No. of Points
Tender understands generally recognized industrial safety standards	20
Tender's industrial safety and health performance has progressively improved over the last 3 (three) years	40
Tender has submitted an acceptable industrial safety plan	40
Sub total	100
Total technical score	1000

7.9.6 Commercial Evaluation

This is the second stage after the technical evaluation. Commercial evaluation varies from one country to another due to special laws in government projects. In private-sector projects, the owner has the right to employ whatever evaluation system he feels best matches his requirement. In some countries, on government projects, a contractor-bidder can choose the system of evaluation. The system being followed should be stated on the tender package.

While cost always remains an important factor, other factors such as time and quality also need to be taken into account. Choosing the bidder who provides the lowest price may not be the best criterion if that price has emerged from a mistake in calculation or from the scope of what the contractor is proposing to cover not being made sufficiently clear. The impacts on the project will be felt in the time taken for completion or in the quality of the final result. Although the experience and capability of the contractor will be covered by the technical evaluation, that technical evaluation may have been accepted on the basis of the bidder's proposals only just passing the 70-per cent threshold mentioned earlier.

7.9.6.1 Commercial Evaluation Methods

This phase, which follows the technical evaluation stage, is the most important stage in the evaluation process because it is the last stage after which the project is immediately assigned to the winning contractor.

Commercial evaluation methodology varies from one country to another, and possibly also even from project to project. Every system of public commercial law aims to ensure that the best price is taken whatever the value of the tender, which is why in most countries' commercial legal practice, the winner is the contractor who provides the lowest price.

On the other hand, there may be significant differences between the bidders which cannot be accounted for from purely rational or logical considerations, and which can cause problems during execution when a project has been awarded on the basis of the bidder offering the lowest price. One of the purposes of having the technical offerings of a tendered bid evaluated before finally selecting any particular proposal is to avoid this trap. The lowest-price criterion works pretty well for limited tenders, but with open tender, the risk of an improper estimation of costs by the contractor can have seriously negatively impacts on project performance.

In Japan and some countries, another method of commercial evaluation is applied in which, after deleting the very highest bid and very lowest bid, an average is taken of the final-cost numbers of remaining bids and the bid that comes closest to that average is selected. Thus for example, in the following collection of bids — 1000 million, 700 million, 600 million, 500 million, and 100 million, then omitting the very highest and lowest values. The average of 500 million, 600 million and 700 million, is 600 million and the winning company with offer 500 million.

For some military projects in some countries in the Arabian Gulf area, in the tender conditions stated that the winner will be next above the lowest price bid. For example, in the case of bids will be 1000 million, 700 million, 600 million, 500 million, and 100 million, the winner will be the $500 million bid. This method compels a bidder to recognize that he will not be successful if the tender price is too low, implying excessive sacrifice of quality standards. Hence, he will be very careful in the pricing the items as to be match with the right number without sacrificing quality attain the lowest price.

Some countries and professional companies provide a relation between the technical evaluation point and the commercial value, and this can be achieved by applying the following equation in which the tender will be ranked using the following criteria:

(Total estimated price)/(Tender's technical evaluation score × 1000). The lowest value for this quotient will be the winner. For example, two companies have the same price, say: $1000K. The first scores 1000 and the second 700. The rank for the first one is (1,000,000.00)/(1,000 × 1000) = 1.0. The other is 1,000,000.00/(700 × 1,000) = 1.4. The winner will be the first one because although the price was the same, the technical evaluation, and hence the denominator of the equation, was higher, yielding a lower value for the first compared to the second.

Another example shows what happens if the projected costs are different: let the first contractor's price be $800,000, and technical evaluation of 700 points, while the second contractor's price is $900,000, and the technical evaluation 1000 points.

For the lowest price technique, I will take the first contractor's bid, which scores lower technically. The ratio is 800,000/700,000 = 1.14. The second ratio = 900,000/1000,000 = 0.9. Here the second contractor will be the winner. In this case, the owner will pay less for higher technical value.

7.10 Closeout Report

The closeout report marks the project's final stage. It is prepared internally by the owner's project team, the contractor and engineering firm should be involved as well. This report is very important and critical for future projects. It enables a cycle of continuous improvement of the project beyond the turnkey moment. In most owner companies, after commissioning and project start-up, the complete team membership assembles for a light workshop that brings forth the advantages and disadvantages that emerged in any part of the project —construction, engineering, procurement, HSE, contracts, planning, etc. After this "brainstorming session," all the data are collected in a final "closeout" report.

Principal characteristics of such a report include:

- preparation at the end of the project.
- preparation by the technical office, the planner, and costs control engineers.
- review is done by the various departments concerned, with a final audit by the project manager.

Basic elements of the report include the following:

1. Introduction
2. Background on the project and its objectives
3. The budget allocated for the project and the actual cost
4. The difference between the estimated and actual cost allowed
5. Evaluation of the performance of contractors and suppliers

Table 7.6 Project closeout report preparation procedure

What	This is a critical review of a project to assess both highlights and lowlights of project performance. This review should be used to ensure that lessons are learned and shared.
Why	To critically review project performance in all areas, i.e., schedule, cost, quality, etc. Good practices and outcomes should not be lost but should be shared with others. Less effective practices must be prevented.
How	For minor projects, the project leader should collate the report from core project members. For small/medium sized projects, a facilitated wash up session should be held to capture all aspects of project performance.
When	The report should be done in early operations to capture both good and bad issues.
Who	The project leader is responsible for the generation and communication of the report.

6. The final drawings correspond to the final situation on site (as built drawings)
7. Planning time at the beginning of the project and has been modified in the time schedule
8. The reasons for completion of the project before or after the plan schedule
9. The change in the quantity rather than in the contracts and their impact on the time and costs
10. Recommendations:
    - Amendment to calculate the estimated cost
    - Modified schedule plan
    - Recommendations for the performance of contractors and suppliers
    - Recommendations for the operator

8

Quality — From Theory to Reality

8.1 Introduction

In organizations seeking to develop a privileged position at the local and global levels, the processes involved in controlling and assuring the quality of a product have become matters of critical importance to business survival. This is the impetus behind the increasing demand for, and interest in the most effecive methods for achieving, Total Quality Management (TQM). This chapter's focus is on quality management systems in construction projects, and the the responsibilities of various parties for their share in ensuring achievement and maintenance of project-wide TQM. Any organization aiming to to grow its business in today's open markets, competing and cooperating with other organizations in sharing local and international markets, has a stake in ensuring TQM throughout their work.

8.2 Quality Management Systems

With globalization, any machinery may be purchased from anywhere. How is the buyer to be assured that it has the required quality, capable of delivering the client whatever the project requires in the time set out in the terms of a mutually-agreed contract? The client needs a quality management system in which confidence may justifiably be reposed and project risks minimized.

Owner-contractor, engineering, and vendor companies in today's business environment are multinational. A head office may be in the United States, with branch offices in the Middle East, Asia, or Europe. If current or prospective clients are to be assured of what they're getting from an office perhaps thousands of miles from a project site, quality management issues have to be addressed so that the company's reputation is maintained. In these circumstances, there has evolved increasing reliance and insistence on universally accepted standards as the principal objective criteria underpinning a provider's promise to deliver the quality expected by a client. This is embodied today in the criteria developed and maintained by the International Standards Organization (ISO), a branch of the United Nations.

As recently as a generation following the end of the Second World War, however, there was no widely-accepted third party developing or standing behind objective yet broadly acceptable engineering quality standards criteria. Today this trend has advanced to the stage where universally-accepted specifications have been developed for the building and deployment of manufacturing equipment and facilities of all kinds, incorporating the highest possible levels of quality assurance consistent with generally manageable levels of capital investment.

Work on these specifications began in the United Kingdom through the British Standards Institute, which had been publishing a number of instructions on how to achieve the BS4891 quality assurance. After some time, a number of acceptable documents were created, designed to meet the needs of the manufacturer or supplier.

Thus did the BS5750 specification begin to emerge, and was published in 1979 as a series. It provided guidance for internal quality management in a provider company as well as quality assurance of the product for clients of such a manufacturer. Soon this standard came to be accepted as a benchmark throughout the United Kingdom by manufacturers, suppliers and customers. In this same period, the American National Standards Institute began working on something similar, the "ANSI 90" standard, for businesses in the United States, the British specifications are considered to be the base point for any European specifications.

8.3 The ISO 9000 Standard

The International Organization for Standardization (ISO), established in 1947 as an agency of the United Nations, entered the picture as the one authority that could be trusted to publish everyone else's standards and maintain comprehensive translations them among the key languages of the United Nations. The activities of the ISO increase with time, and there are many specifications published through the ISO. The specifications have widely spread due to the interest from manufacturers, their international agents, and customers. The manufacturer provides a product to give the customer satisfaction, which increases the production and sales. The ISO comprises representatives from 163 countries; most of whom already share the use of BSI and ANSI standards. By lifting the translation burden off the backs of other countries, the activities of the ISO have increased with time, with many specialized specifications also coming to be published under their aegis.

The ISO 9000 specification released in 1987 closely followed British standards BS5750, parts 1, 2, and 3. The same general arrangement of the parts and the ISO increased as a general guide to illustrate the basic concepts and some applications that can be used in a series of ISO 9000. On December 10 of that year, the board of the European committee for standardization agreed to align its work on standards specification to the provisions published in ISO 9000. Accepted without further amendment or modifications as a standards specification for European countries, it was published under the rubric "EN29000 1987." The official languages of these European standards are English, French, and German. This group subsequently agreed to publish and translate these specifications for every country based on its language.

The next major further development for this standard came in 1994, when about 250 articles were modified. These modified articles clarify the specifications and are easier to read than the original versions.

To clearly elaborate quality assurance specifics regarding the design, the manufacture, and the acceptance of a final product, ISO 9000 is divided into parts 9001, 9002, and 9003 respectively. ISO 9004 contains the basic rules for the development of the Total Quality Management system according to current conditions most likely to be encountered with current technologies, market demand for the main lines of available products, factory conditions and available technology.

8.4 Quality Management Requirements

The quality management regime elaborated in ISO 9000 is a structure of linked resources, activities and responsibilities that provide procedures and means for fostering or maintaining trust in the capacities of any provider following its requirements to deliver acceptable standards of quality in the marketplace.

8.4.1 Quality Manual

A company's quality manual is the formal record of its quality management system. It may contain the following:

- A rule book by which an organization functions
- A source of information from which the client derives confidence
- A vehicle for auditing, reviewing, and evaluating the company's Quality Management System (QMS)
- A firm statement of the company policy towards quality control (QC)
- A quality assurance (QA) section and description of responsibilities

As commander of the process, review, and evaluation of the quality system within an institution, the Quality Manual must contain:

- Models of documents as well as models for the registration of the test results
- The necessary documents to determine how to follow up on quality

8.4.2 Quality Plan

The quality plan contains steps to achieve quality in a practical way according to a predefined order of action steps to be taken in order to reach the required quality in the project.

The quality plan varies from one project to another according to the particular requirements of the contract with the owner or the client. It should enumerate the resources to be employed, the types of personnel and the equipment required to achieve the quality goals of the contract. All this is specified in full detail, including a program for testing and examination of the progress achieved during execution of the contract towards attaining these goals. The quality plan is inflexible and cannot be edited before the end of the project.

In the case of contracts requiring that a buyer, client, or owner to include special requirements needed for achieving the final product, the quality plan must clarify the detailed steps to be taken to reach the goal. This plan is presented to the client to boost trust in the ability of the provider to achieve the quality of the desired product. The quality plan includes:

- all controls, processes, inspection equipment, manpower sources, and skills that a company must have to achieve the required quality
- QC inspection and testing techniques that have been updated
- any new measurement technique required to inspect the product
- measures that remove potential sources of conflict between inspection and operation
- standards of acceptability for all features and requirement that have been clearly recorded
- compatibility of the design, manufacturing process, installation, inspection procedures, including all applicable documentation readied before before production begins.

8.4.3 Quality Control

ISO defines as a group of operations, activities, or tests that should be done in a definite way to achieve the required quality for the final products.

In construction projects, the final product is a properly-functioning building or structures. The first step in quality control is to define the level of supervision in all the project phases, ensuring *every part of the project is performed properly* according to the required specifications. The design, execution and the use of the buildings and structures are to be rendered as compatible as possible with the project specifications.

Note that quality control is a responsibility of the project-delivering organization ast all levels, from the manager on down. In practice, the construction managers and the department head have the designated responsibility for quality control.

8.4.3.1 *Why Is Quality Control Important?*

The improvement of quality confers many benefits. Ensuring that work is being performed correctly reduces mistakes, thus reducing the need to redo tasks, reducing waste and thus keeping project costs under control. Higher productivity and increased worker morale resulting from such an atmosphere can help improve the competitive position of the company.

Consider two crews of the same size, skill level, and work activity. The first crew, but not the second, enjoys the benefit of having someone performing quality control duties. Any defective work can be corrected before work proceeds any further. On the other hand, any defect in the work made by the second crew will probably be discovered only after the work is completed. This defect in the work will be torn down and corrected or ignored and left in place. All this will cause problems as construction progresses, providing the owner with a degree of dissatisfaction. Customer dissatisfaction may even lead to the company being removed from consideration for future construction projects, or require costly corrective actions. Defects are not without their cost: the individual who made the mistake has accepted payment, while the person who fixes it will also be accepting payment, and expenditures for additional material and equipment will be required.

Consider the well-known case of the partial collapse of a parking garage in New York City. The absence of reinforcing steel in three out of six of the cast-in-place column haunches, which supported the main precast girders, caused this accident. The project plans and the rebar shop drawings showed that reinforcing steel was to be installed at these locations but was accidentally left out. As a result, extra work had to be performed at the contractor's expense to correct the work and repair the damage post.

Another major quality blunder occurred when constructing a shopping mall in Qatar. After pouring the concrete for the columns and the slab, they found around 40% of the columns had a strength lower than the allowable strength. So due to the lack of concrete quality control on site and experience of the staff, this cost a lot of money to repair and also delayed the whole project.

Quality is often sacrificed to save time and cut costs. However, quality does indeed save time and money. Nothing saves time and money more than doing the work the right way from the first time, eliminating costly processes of correction from the outset.

8.4.3.2 Submittal Data

The review of submittal data for the project, such as shop drawings, work samples, test and other performance data about the materials to be used, Letters of Certification etc., is one of the first steps of the quality control process. Whether the information received from subcontractors and suppliers for items to be installed into the project meets the standards set forth in the contract documents has to be verified. Items such as dimensions (thickness, length, shape), ASTM (American Society for Testing Materials) standards, test reports, performance requirements, color, and coordination with other trades should be reviewed and verified. Particularly crucial is the checking of shop drawings, which fill in information concerning requirements for concrete reinforcement, structural steel, cabinets/millwork, and elevators that may be missing from contract drawings This caveat applies especially for projects using items originally fabricated off-site: the information provided on the approved shop drawings ia what the fabricators use to "custom-make" their materials. Each item on the shop drawings must be verified against the contract plans and specifications. Following meticulous review of the submittal data, a determination is made on whether the project meets the required quality control standard.

Submittals are reviewed by the General Contractor, then given to the consultant engineer for further review. If the data is "disapproved" or incomplete, the originator of the submittal data must resubmit corrected or additional information. A submittal that completes the review process provides the "template" on which additionally-required materials will be fabricated. Any mistakes not discovered in the submittal review process could potentially cause problems involving extra cost and additional time for correction.

The Kansas City Hyatt Regency walkway collapse in 1981 illustrates how a poor shop drawing review can lead to disastrous consequences. A change in the details of structural connections, left unchecked during the submittal process, doubled the load on the fourth floor walkway connections. This led to the collapse of the fourth floor suspended walkway onto the second floor walkway and then onto the ground floor below. This disaster killed 114 and inflicted a further 200 injuries.

8.4.3.3 How to Check Incoming Materials

Once submittal information is checked against the contract requirements and approved, it is filed for future reference. Many companies file submittals with a reference number.

By comparing information found on the delivery tickets, or manufacturer's information provided in the shipment, with data from the submittal, incoming materials can be readily verified against contract requirements and off-loaded at the storage site once everything matches up. At the same time, care must also be taken to ensure that any "unapproved" material stored on-site is not included in the construction process — something that could leads to redoing work or taking other corrective action.

8.4.3.4 Methods of Laying Out and Checking Work

The layout of work and the verification of correct placement, orientation, and elevation of work are also important for maintaining project output quality. Work that is not placed correctly — misplacement of anchor bolts for the foundation, for example — will lead to an extra cost for rework and delays.

In addition to checking work, the proper layout of work is also required. The required tools needed to place anchor bolts in a foundation, for example, include a tape measure, plumb bob, carpenter's level, and a chalk box. Topics to discuss for the proper layout and checking of work include checking elevations at the height of concrete footing during placement and finishing the grade and floor. Methods to check for proper alignment of work in the field manufacturer's recommendations for the layout of certain items are windows, overhead door, and air-handling units.

Since quality control is the responsibility of everyone involved in the construction process, most of the engineers in construction positions will help to manage QC functions. Since it is not always clear what one needs to find in order to ensure a proper inspection, engineers should be instructed to watch for "key items" during inspection.

Another Example - QC for Steel Door and Frame Installation

1. When delivered to the site, each door and frame should be checked for damage.
2. Ensure proper size and gauge of doors.
3. Doors and frames must be stored off the ground somewhere in a place that protects them from the weather.
4. Do not stack doors or lay doors flat. This will cause doors to warp. Doors must be stacked on end of a carpet-covered racks or using other appropriate methods.
5. Check doors and frames for proper material, size, gauge, finish (satin, aluminum, milled), and anchorage requirements.
6. Verify door installation according to the schedule shown in contract documents.
7. Fire-rated doors or frames must be used in fire-rated wall assemblies.
8. Fire-rated doors and frames must have a label attached or a certificate stating the fire-resistance rating.
9. Check for the proper location of the hinge side of the door and for proper swing of the door. (For example, fire codes require the door swing for stairwells and other egress openings must open out, not into the stairwell.)
10. Door frames in masonry walls must be installed prior to starting masonry work (masonry must not be stepped back for future installation of door frame).
11. Is the doorframe installation straight and plumb?
12. If wood blocking is required for doorframe installation, make sure this activity is completed during the construction of the wall.
13. There is a uniform clearance between the door and doorframe (usually 1/8″ or 3.2 mm).
14. Has adequate clearance been provided between the bottom of the door and the floor finish (carpet, tile) that will be installed?
15. Touch-up scratches and rust spots with approved paint primer.
16. Exterior doors must be insulated.

17. Check for weather-stripping requirements on exterior doors.
18. The intersection between the doorframe and wall should be caulked – check for missing caulking in hard-to-reach areas (for example, hinge-side of doorframe).

8.4.3.5 *Material/Equipment Compliance Tests*

Every project owner requires testing of materials and equipment prior to placement and after installation. Engineers should be familiar with testing methods, whether or not they will be performing the actual tests. Prior to beginning construction operations, a listing of each test that will be required should be set out.

This will serve as a checklist to be used by QC personnel. This testing checklist should list the type and frequency of testing required per each segment of work. Once tests have been performed, a test report documenting the results of the test should be kept on file or put into a «test report» folder for future reference. The following tests are typical tests that will be performed on the jobsite to ensure the quality of work is placed or completed.

8.4.3.5.1 Soils Testing

The foundation of a structure is responsible for transferring the loads from that structure into the ground below. The soil in this ground must be strong (dense) enough to stand with the loads that will be imposed. Additionally, the strength of soil must also be uniform to avoid any differential settlement in the structure, which can possibly cause structural and weatherproofing problems. In order to ensure that minimal settlement takes place in the building structure, the compaction of the soil must be verified. Each excavation or soil backfill operation must be checked to ensure compliance with the compaction requirements listed in the project specifications. These tests take place prior to starting any additional work, such as rebar placement.

8.4.3.5.2 Concrete Tests

There are two types of concrete tests that are used to evaluate concrete on the jobsite: the slump test and the concrete cylinder, or cube test. The slump test, per ASTM C 143, determines whether the desired workability of the concrete has been achieved without making the concrete too wet.

8.4.3.5.3 Mortar Testing

The project specifications for mortar provide that mortar must comply with either an ASTM C270 or ASTM C780 standard.

ASTM C270 states the required proportions of mortar ingredients (1 part Type S masonry cement to 3 parts masonry sand), while ASTM C780 states the method of obtaining samples for compressive testing and the strength required for the mortar. Copies of these ASTM standards must be obtained to ensure full compliance with both the project specifications and industry standards.

8.4.3.5.4 Heating, Ventilation, and Air-Conditioning Testing

Although HVAC testing is performed by a professional testing agency, quality control personnel need to understand how and why these tests are performed so they can be performed at the appropriate times. The ductwork joint leakage test is performed after the ductwork is completed, prior to the insulation being installed on the outside of the ductwork. Performing the leakage test requires that all openings in the ductwork are sealed up. A high-powered fan is then used to "pressurize" the ductwork to a specified level. The project specifications will either state this pressure level or will refer to the SMACNA (Sheet Metal and Air-conditioning Contractors National Association) HVAC Air Duct Leakage Test Manual. Once the proper test pressure is reached, it will be watched for a drop in pressure. Any drop in pressure indicates the existence of a leaky joint in the ductwork. If this occurs, each joint must be corrected and retested until the proper pressure is maintained. HVAC system balancing adjusts the system to work properly. This ensures that the measurement of actual air volume meets the designed air volume.

8.4.3.5.5 Plumbing Tests

All pipes in the building must be checked for leaks. Testing for leaks involves subjecting all pressurized (supply/return/fire sprinkler) pipes to hydrostatic pressure testing, which is measured by a water pressure gauge. Usually, the test requires the pipes to hold 150% of the normal operating pressure for 2 hours. Any drop in pressure indicates the presence of a leak in the line. Once this leak is found and repaired, the test is restarted for two hours. It should be noted that leaky joints must be tightened or taken apart and corrected. The application of pipe sealant to the outside of the pipe is not an approved correction method.

8.4.3.5.6 Performance Tests

Performance tests are required for many of the complicated systems that are installed in the building. A few of these systems include the fire alarm system, elevators, and water chillers/air-handlers. These types of tests are performed by the installer of the system and are only witnessed and verified by QC personnel. Once again, it is important for QC personnel to have some knowledge of what is involved with testing these systems. The project specifications will state industry standards, which must be followed for proper testing.

8.4.3.6 When to Inspect Work

Knowing when to inspect work-in-progress is beneficial to the QC person. The following list is a summary of when and what to inspect on the jobsite:

8.4.3.6.1 Inspection before the Commencement of Work

In some specific cases, as in the U.S. Army Corps of Engineers, this portion of inspection is called the "preparatory inspection phase." This inspection is made for each major work activity and is used to "verbally build" the item of work. A majority of the time, a preparatory inspection is held for each section. This involves holding a meeting to perform the pre-inspection of materials, methods, and personnel that are used to perform the work. Submittals and industry standards are used to verify that the work to be performed will be completed in compliance with the project documents. The use of sample panels for work such as masonry or stucco finishes is a prime example of this type of inspection. The workmanship and materials of the sample panel are inspected and approved prior to its implementation into the construction process. Corrections made at this level of inspection will cost less and will not impact the project schedule as much as if work was started before problems were discovered.

8.4.3.6.2 Inspection During Work-in-Progress

In some cases, the inspection of work-in-progress must be performed on a continual basis. QC personnel must maintain constant watch on work as it begins and heads toward completion. It is very important to verify that work starts out correctly; otherwise, rework to correct the problem will occur. It is easier, and less expensive, to correct work as the work progresses instead of discovering defects after the work is completed. No one likes to perform the same item of work more than once.

8.4.3.6.3 Inspection of Work after Completion
Each work activity must also be inspected upon completion. This action is necessary to detect any deficient work prior to the next work activity to be performed. A "punchlist" consisting of the list of deficiencies discovered should be made and given to the parties responsible for the defective work. Verification that each deficiency has been corrected must be made to ensure that there are not any outstanding deficiencies. This stage of inspection will also require the performance testing of installed materials or equipment.

8.4.3.7 Paperwork/Documentation

Keeping track of quality control activities is an important duty of quality control personnel. Quality control paperwork is comprised of three types: recording logs, pre-installation inspection reports, and punch lists.

8.4.3.7.1 Recording Logs
Recording logs are used to keep track of items that either have been performed or are not completed as of yet. Submittal logs are used to keep track of the submittal flow throughout the course of construction. As each submittal is reviewed, a number is given to that submittal for tracking purposes. Depending on the submittal numbering system used, this submittal number will either be made up of a number or a number/letter combination. For example, suppose 20 submittals of information have been received from subcontractors/suppliers since construction began on a project. Then, the next submittal received will then be labeled as "submittal #21." If this submittal is sent to the reviewing architect/engineer and comes back as "unapproved," this submittal must be resubmitted with the correct data. Then, this submittal will be labeled as "submittal #21A." A variation of the simple numbering system described above is to keep track of submittals.

Each submittal that is received is listed on the submittal log under its given submittal number. Spaces for information regarding a description of the submittal, number of shop drawings (if applicable), submittal originator, and pertinent dates should also be provided on this log. A code column should be included, stating whether the submittal is "approved" or "unapproved."

The U.S. Army Corps of Engineers uses the following submittal action codes in the submittal review process:

A - Approved as noted
B - Approved, except as noted
C - Approved except as noted; resubmission required
D - Will be returned by separate correspondence
E - Disapproved
F - Receipt acknowledge*
FX - Receipt acknowledged does not comply with contract requirements
G - Other (specify)

With the exception of government construction projects, submittal action codes vary between projects. Thus, one must research for the codes that are used in the submittal process.

Each construction deficiency discovered on the jobsite must be documented to ensure that the proper action is taken to correct the deficiency. Construction deficiency logs are used in conjunction with a notice of construction deficiency to track the identification and correction of defective construction work/materials.

The notice of construction deficiency states the details of the deficiency, while the deficiency log tracks each deficiency until the problem is corrected. Information included on these forms should give a description of the deficiency, responsible party, and a description of corrective action taken. The use of these forms will help ensure that the correction of each deficiency is not forgotten.

The concrete placement log is used to keep track of the date, time, location, amount, and type of concrete poured on the jobsite. A space for listing the concrete testing lab and the concrete cylinder set number is also provided. This cylinder sets a number that is useful due to trying to match the concrete compressive test results received from the testing laboratory with the date and location that the representative sample was taken.

8.4.3.7.2 Pre-installation Inspection Reports

Pre-installation inspection report forms are helpful due to trying to schedule an inspection for work-in-place prior to being covered up by the next phase of work. These forms are signed once the stated portion of work is completed. The general contractor's quality control personnel perform their final inspection once everyone else has "signed off" on their portion of work. However, it should be noted that quality control inspections have to be performed on a continual basis while work is being performed. These pre-work installation forms are used for final inspection purposes, not for the initial inspection of the work.

8.4.3.7.3 Punch List Log

The last document to be discussed is the punch list log. This provides a general form that is used to keep track of deficiencies pointed out during project closeout. Blank copies of this form should be used on the jobsite to keep a handwritten list of punch list items. Then the list can be sorted by the names of the responsible parties and their respective punch list items.

8.4.3.8 Quality Control Plans

Quality control should involve company executives as well as field personnel. Quality control plans provide the written "reference" document for the implementation of the quality control program.

This plan must explain the duties and activities of the quality control personnel as clearly and concisely as possible. The following writing suggestions should be used due to drafting such a plan.

The plan should be from the different departments involved with the quality control process. Also, it includes the field office personnel and the participation of the owner, engineer, subcontractors, and suppliers.

Preparation and implementation of the QC plan must be more than a "cosmetic" fix. The quality control program may look good on paper, but it can only serve its intended purpose by daily execution of the stated quality control procedures.

The plan must be easily understood by the person who is going to implement the procedure listed in the manual. Items that should be included are organizational charts showing the chain of command, explanation of duties, lists of procedures, and examples of documents to be used.

The plan must be kept up-to-date by reflecting all changes required to maintain effective quality control on the job-site. This may include using suggestions from the employees responsible for QC duties.

The following guidelines have been established by the U.S. Army Corps of Engineers to be used when writing an organizational chart for the QC department:

- Lines of authority
- QC resources
- Adequately sized staff
- Qualifications of QC personnel
- List of QC personnel duties
- Clearly defined duties, responsibilities, and authorities
- Deficiency identification, documentation, and correction
- Letter to QC personnel giving full authority to act on all quality issues
- Letter stating responsibilities and authorities addressed to each member of the QC staff
- Procedures for submittal management
- Submittals must be approved by the prime contractor before review by owner's representative
- Log of required submittals, listing all required submittals showing scheduled dates that submittals are needed
- Control testing plan
- Testing laboratories and qualifications identified
- Listing of all tests required as stated by contract documents
- Testing frequencies listed
- Reporting procedures
- Quality control reporting procedure addressed

8.4.4 Quality Assurance

The following is an example of the importance of quality assurance. You decide to perform a sewage system project. Seven years earlier, a contractor company built you the same system in high quality in the plan time and cost. You are responsible for the decision without any influence from others.

Is it a good decision to go directly to this company or not? Why? (Please consider the answers to these questions before going to the next paragraphs.)

There are now different multinational companies worldwide in different industries; one such industry is construction. So, every company and every one of us are both a customer and manufacturer or service provider sometimes. For instance, the contractor company provides services to the client, and at the same time this contractor company is a client of the manufacturer for the plumbing equipment, HVAC, ceramic tiles, and other materials and equipment required to complete the project. At the same time, the factory that sells the ceramic tiles is also a client to the mechanical spare parts company to maintain their machines working.

So, a defect in any one of the systems will affect all systems. It is obvious that the quality system should apply to all the companies and organizations, assuming that everyone in the company has a good quality system.

Every company should build its own system to ensure that the product and service is based on specifications, requirements, and satisfaction.

When the quality assurance system is strong, it means that even if anyone in the organization moved or retired, the quality system remains the same.

As an answer to the first question, if this company is a family company with a father and a son, and the son becomes lazy and doesn't care, the project could be in trouble if his company is sharing in any of the project activity. On the other hand, if he has a real quality system, you can deal with him but an audit should also be done (this is discussed later).

On the other hand, for the multinational company the chairman is usually sitting in a country far away from the project, so quality assurance will be in a document that can be reviewed by an external or internal audit. If there are complaints about the company from the owner, the system should record and solve these complaints.

The purpose of quality assurance is as follows:

- To make sure that the final product is in conformity with the specifications, and the employment is highly qualified and able to achieve a high quality of the product through the administrative system
- To ensure the application of the company's established characteristics among all sectors in the factory, regardless of personnel
- The benefits of the application of quality assurance systems can be summed up in that it gives the ability to produce a product identical with the required

specifications and also to reduce manufacturing cost because it will reduce waste or defective products. In particular, projects have a major impact because in these projects the time factor is very important and may be the main driver of the project.

For example, with hotel construction projects, whatever happens to any day of the total time for the project will have a significant return on the owner. The same is true for oil projects. Therefore, when reducing or not rejecting any product, time is not wasted in removing what had been done or repaired or in negotiations between the team of the contractor and the owner and the supervisory, achieving savings of the total time for the project.

A quality product contributes to building a strong and good relationship between the seller and the client by reducing the number of complaints from the client. But a process that generates repeated complaints from the contractor probably has problems maintaining QA, and a flawed QA system can close off many market opportunities at home and abroad.

8.4.4.1 Quality Assurance in the ISO

ISO 9001 details the requirements of quality management systems when there is a contract between the parties and the manufacturer, setting out a model for quality assurance during the design, development, production, and use of the product.

8.4.4.2 The Responsibility of the Manufacturer

A "manufacturer" is defined as one who engages in the manufacturing or supplying of the product, as well as the one who is supplying any servicing that may be required, and. under a TQM regime, the first responsibility for meeting quality standards therefore lies with the manufacturer.

In the globalized marketplace of contemporary international commerce, a reputation for upholding and fulfilling the requirements of a TQM regime has itself emerged as a decisive competitive edge. This is seen in the proliferation of offices, international consulting, or multinational contracting companies bidding for construction contracts of all kinds throughout the Arab world, competing mainly over how thorough and reliable the quality assurance systems they offer are.

There are two main steps that serious competitors should take at this level. First, the senior management level has to demonstrate its genuine interest in QC and QA in the way it actually takes the lead in whatever projects it becomes involved in.

Second, an atmosphere is maintained at management level that facilitates dealing with QA rules easily and ensuring that all employees following the requisite instructions and steps of QA. At the administrative level, such a commitment may frequently be interpreted negatively as a constraint on the freedom of action believed necessary for discharge contract obligations in the timeliest and most efficient manner. To head this off, senior management should pay close attention to the training process, organizing training courses for all the employees of an organization on the quality assurance procedures and technical labor in particular.

8.4.4.3 Responsibility of the Owner

Where should ultimate responsibility for a project's overal failure be placed? This must fall on the shoulders of the owner who initiated and put together the financial outlays for the project's work. Following this same line of thinking with regard to a project's quality goals falling short — problems that range from poor quality final products to the project's non-conformity with various required specifications — this, too must ultimately be the responsibility of the owner or owner's representative, for having failed to communicate sufficiently or successfully the required specifications to those charged with executing the project. The TQM approach therefore mandates that the contractor gathers and maintains all data required for the project's execution, and that the consultants' office assembled by the owner has the responsibility to ensure that the contractor is thus equipped.

Figure (8.1) shows the relationship between owner, contractor, and consultant / engineer. Its lines of information exchange traffic clarify the principal complexity of such a triangular relationship, simultaneously illustrating how any breach in QA/QC by any one of the parties affects the other parties.

Based on the specifications, the contractor or manufacturer determines the price and schedule based on the quality of the product itself. For them to achieve success on this front, however, it is in the first instance the responsibility of the owner to identify the required specifications of the project.

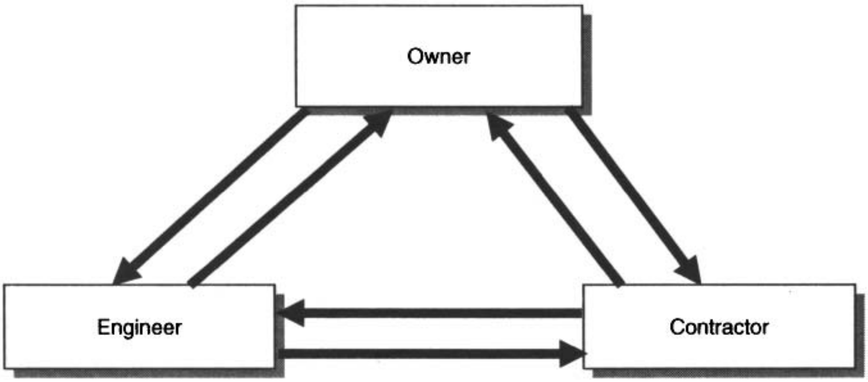


Figure 8.1 Relation between owner, contractor, and engineering company.

The selection of the contractor (i.e. the "manufacturer") is one of the most important and most serious responsibilities of the owner or representatives of the owner. The owner starts with selecting the Engineering Office. At the start of execution, the owner has to choose the contractor. Therefore, the owner or owner's representatives have a responsibility to gather enough information about the previous work experience of the engineering office and the contractor, and whether they had performed a similar project in the past. Reinforcing this responsibility is the simple fact that the owner is uniquely positioned in this triangular relationship to keep the full and actual financial situation of the project under constant review and ensure that the other two partner-groups are in a position to fulfill their obligations to the delivery of the project.

8.5 Project Quality Control in Various Stages

The most general definition of a project that this book has been written around describes a project as "a set of activities with a beginning and an end." This book has frequently used construction of industrial projects as a source of most of its key examples because the complexity and scale of such projects stand mutually in direct proportion to one, and this state of affairs also happens nicely to simplify the author's instructional task at the same time that it lightens the reader's learning burden. There are cultural projects or social projects, such as building opera, theater, and library or other. The housing project as constructing residential or office buildings. The civil construction projects such as roads, bridges and railway. There are also irrigation projects , but in this book is focusing on construction industrial projects and specifically for oil and gas projects.

This is once again the case with the present chapter's focus on QA, QC and TQM. The precise manner in which these concepts might apply to software design projects or literacy training projects, for example, may not be as well-defined as ISO standards for large capital projects involving some construction component, but the arguments to be mustered in favor of the most conscious approach possible to setting quality expectations for such projects and monitoring how they are to be fulfilled would involve the same matters of fundamental principle.

As just mentioned, construction industrial projects will vary from one project to another depending on the size and value of the project. One key point not to be lost sight of here, however, is that the degree of quality control must necessarily also vary depending on the size of the project. This is starkly evident today in the case of construction projects undertaken in many developing countries. Quality control may be sufficient in small businesses, but the contracting companies or small engineering offices that operate amid international competition are also increasing the quality of the projects. This of course necessarily also increases the total cost of these projects.

Where, and what, is the key to getting a handle on this? The secret is to break quality issues down to the level of the phase or stage of a project's life cycle, and to control the project during all those stages. The discussion will now zero in on the quality control issues that arise within the various the project lifecycle stages first discussed back in Chapter 2.

8.5.1 Feasibility Study Stage

Depending on the nature, circumstances, value and purpose of the project, each stage has its own importance and impact on the project as a whole, The feasibility study phase, followed up with initial studies, marks the starting point that will set the goal, enabling selection of the guiding ideas and subsequent engineering. The feasibility stage defines the goal as well as the economic feasibility of selected movement in any direction.

A thorough feasibility study conducted by an experienced and competent consultancy is characterized by full discussions and deliberation on all the relevant economic data, with the aim of making all the possibilities fully conscious and eliminating as far as possible any "surprises."

The purpose behind engaging a feasibility study through a competent consultancy is to enable emergence of a more fully-formed and grounded idea of what the owner or ownership group can reasonably expect. After this, the strategic decision must be taken as to whether to go ahead with the project, and — if so — when and how.

In the case of relatively large-scale projects, the selection by the owner or ownership group of the outfit that will conduct the feasibility study is critical, and within this the most critical factor is the consultancy's track record and history with such projects. In today's global marketplace, it often turns out that the best combination of skills will be found offshore, somewhere outside the home country of the owner or ownership group.

8.5.2 Quality Considerations During FEED (Front-End Engineering and Design) Preliminaries

Following the completion of the feasibility study for the project, strategic decision-taking and goal-setting, the second phase of front-end engineering and design (FEED) begins. No less important than the feasibility-study stage, this phase of technical studies establishes the most likely "geometry" of how the project can actually proceed. The success of the rest of the project from this point will depend not only on the fundamental feasibility of the idea of the project in principle but the specifics of the engineering "how-to" developed in this phase of technical studies. The owner should do a huge effort to choose and select expertise and experience of the consultancy with this particular type and scale of project. One of the most important considerations the experience of engineering projects vary depending on the kind of industrial project whereas it belongs to the petrochemical industries, oil and gas plant or power stations or other industrial projects.

For example, in the case of small projects such as building apartments, offices, or a small factory, the construction "gender" of the building required will be more fully developed in this phase of initial engineering studies. Will reinforced concrete or precast or pre-stressed concrete be required? The answer to this question determines the construction elements needed: solid slabs or flat slab or hollow blocks, different types of columns, beams, frames, shear walls, etc. The selection and amount of each of these choices will be a function of the size of the building itself and the requirements of the owner.

In the case of major works such as stadiums or oil and gas projects, the complexity of this phase increases as a function of the intersection of these studies with spatial principles. This can involve such critical matters as the capacity of a land surface, as a function of soil type, to support load-bearing structures of various kinds. This, will in turn determine the type of foundation to be designed and the depth to which it is to be sunk. In oil and gas projects, considerations of this kind affect decisions about how pipelines are to be laid and-or how other methods of surface transport are undertaken onsite. Yet another element that these studies must determine is the relationship during the project's construction of the various civil, mechanical, electrical and chemical engineering disciplines involved.

The engineering studies are an important input to the process of determining precisely the project's requirements to be stipulated in the Statement Of Requirement (SOR). That document contains all the owner's information, which means it is also a crucial document for the quality assurance system. The SOR is not only required for new projects or large-scale projects but should also be used when making some modifications to the structure. In the case of a residential building, the owner should determine the number of floors required, the number of apartments on each floor, and the number of shops and any other useful requirements.

Informed by the specifications in the SOR, the engineering office presents its engineering study in a Basis Of Design document (BOD). Therein, the Engineering Consulting office clarifies the relevant codes and specifications for the design, the equations to be used for calculations, any computer software package(s) that will be used, the required number of copies of drawings, and the sizes of the drawings. In addition, where relevant, other information may also be included in the BOD such as terrestrial or maritime meteorological data and physical survey data. The BOD is reviewed jointly by the owner and the Engineering office, and all updates and revisions are noted in each version of the BOD that emerges from further review.

Attention must be maintained regarding the protocols followed in the handling of drawings and their updates. The group responsible for FEED should be sent any prepared drawings so that they can be reviewed and carried out. The specified period of time is agreed upon in advance, the drawings are returned to the Engineering Office of the owner. Comments are returned to the owner until the engineering studies reach the final stage.

In large projects, this phase may take months, placing something of a premium on project cost control and an increased weight of responsibility on the engineers responsible for maintaining a running yet increasingly accurate estimate of project costs going forward. The goal in cost control at this stage is the refinement of the project cost estimate to as accurate a level as possible given that preliminary studies are being completed and the project schedule is being finalized to fit what the engineering studies have determined.

At this same point, before actual construction begins, and given what the engineering study serves to disclose about the ways and means now available to proceed, another important area of future costs on which to begin to get a handle is the ongoing cost of project maintenance. This starts with determining the project lifetime, noting the rules of construction being followed, type of structure and method of maintenance. The project site itself and the surrounding environment must be protected from weather as a measure for reducing the cost of maintenance over time.

There are various protection systems that each has its impact of the project outlays curve. Using stainless steel, for example, entails high costs at the beginning of construction followed by periodic maintenance that adds relatively little further cost. Alternatively, there are protection systems with low initial capital cost whose maintenance over time will increase the amount to be budgeted annually for inspections and any maintenance required as a result thereof.

The engineering studies should take into account various aspects of the structure connected with its geographic location and the consequent ease or difficulty of maintenance work. Similarly, the initial selection of mechanical equipment has to weigh the advantages and disadvantages of the various possibilities: project units of the highest reliability and thus low maintenance expense but a high initial capital outlay, or equipment with lower reliability ratings and probable increasing maintenance costs down the road but an inexpensive initial price tag. In rubric after rubric, the engineering studies have to bring to the surface the same choice, between high initial costs followed by anticipated low ongoing maintenance expense versus cheaper expedients with unknown and possibly growing maintenance expense down the road For example, in a power station construction project, a water tank is manifesting reliability issues. Does it need repair or clean during the operation of the plant along its life time? The answer to this question entails deciding whether an additional tank is needed. If it is not needed, other design principles can be followed. Judgment calls of this kind make special demands on the experience of the engineers and contractors involved. Any error could result in future problems that put the project at a serious loss, whereas a simpler solution entailing lower costs can be performed from the beginning without loss in operation performance.

8.5.3 Quality Considerations of Detailed Study

The project lifecycle moves forward from the engineering study to the stage of completed construction drawings and specifications for the project as a whole.

This phase entails many working hours, extensive contacts, good coordination, and excellent organization, with sufficient freedom of communication between individuals that facilitates management review while maintaining strong and continuous coordination. The administrative organization and the nature of the documents and forms from this stage, as well as the movement of documents within the enterprise have been discussed earlier in detail in Chapter 6. As with each of the other stages so far, this stage has its own quality issues to be addressed.

Engineers have a tendency to believe in utopias where our lives are dependent on the accuracy of the accounts and reviews, but teamwork is not always so precise. Often work reaches someone late, or action must be taken to correct it, or there may be some change in procedures within the company or department without the project manager's knowledge. All of this leads to time losses, creating an incentive to reform the overall working atmosphere — which itself a kind of starting-point for grasping the need for a system of quality assurance. While the system of quality assurance provides stable functioning of all departments, changes of personnel can happen which can create a short-term challenge to maintaining the QA system. This problem often arises at the stage of studies where the QA system is needed to facilitate intensive cooperation.

When there is a strong relationship between the managers of the departments of civil and mechanical during a project, information will tend to be shared in a timely manner, with the work carrying on smoothly, amid ongoing periodic meetings and productive correspondence.

The importance of the QA system within this stage derives from its embodiment of the processes of organizational work. Everyone should know the goal of the foundation and the goal of the project by the institution. The responsibility of each individual and the concept of quality is clear at all times and supported by documentation.

Documents are considered the operational arm of the quality application process. Drawings are set to be received at a specific time for the owner to review, discussion takes place of any amendments, and remarks are incorporated identifying changes.

In the event that development of a particular activity is canceled, there needs to be a quality system procedure in place to ensure that confusion with the other copies of drawings avoided, thus eliminating a source of human error. The modification revision number continues to be updated, and this process carries on until final approval of the drawing, indicating by sealed stamp that it has been "Approved for Construction." "Approved For Construction" drawings obtained at the completion of the study phase and the start of the execution phase should have specifications and drawings fully ready to start the construction phase. In some projects, this may reach hundreds of drawings, incorporating any additional specifications, operational manuals, and provisions for maintenance and repair in the event of failures or trouble-shooting.

Generally the following five principles of design should be covered in each quality assurance system:

1. Planning, design and development – Determine who does what in the design.
2. Entrance design – The project manager must know what the client wants in the design.
3. Troubleshooting design – Provide clarity for the final form of the design.
4. Verification of the design – Review with the client to make sure that the design is consistent with the needs of the client.

5. Change Design – Ensure that any change in design will be adopted by responsible persons.

8.5.3.1 Design Quality Control

The main objective of quality control during the operational phase of studies in ISO 9001 (ISO 9001 Section4.1) is to control the design at various stages as follows:

The input design includes all the technical information necessary for the design process. Any information that is not clear must be resolved at this stage. Instructions to control operations are often stipulated in the contract by the client. Marketing considerations are also a factor in the design process, which should carry on with some awareness of current market constraints and opportunities connected with the project. The designer must take into account the available materials in the market and the abilities of the owner. Specifications and tolerances must be identical with the design specifications of the project, and the tolerances must be compatible with the specifications and requirements of the owner. The designer must take the standards of health, safety and environment into consideration in design for the work at the site during the design phase.

The processes of modification and renewal of drawings has been speeded up with the widespread use of (CAD) Computer-Aided Design (CAD) programs. These also enable presenting more accurate information, facilitating its display with tables and graphs included as part of the drawings set.

Output design must be compatible with all design requirements established as a result of internal audit. The output design must

Table 8.1 Design QC in ISO 9000

Design Input	Output Design
• Instructions and control operations • Taking into account the marketing materials • Specifications and tolerances allowed • Health and Safety and Environment • Computer workstation(s)	• Design review • Design review process • Verification of the design

be compatible with the specifications of safety and health, so any changes or modifications should not be tied too closely to an older design.

Review must be set in the earlier stages of design. The design itself should always take constraints of the timetable and costs into account. Review should include verification of the design calculations for accuracy. This verification process can take previous similar designs into account, as a model for the design and operation test.

8.5.4 Execution Phase

The next stage of the project lifecycle, the execution phase, now dawns. This stage requires both QA (quality assurance) and QC (quality control). For example, working with reinforced concrete structures, it happens that concrete itself consists of various materials such as cement, sand, gravel, water and additives in addition to steel reinforcement. This must be controlled both for the quality of each component individually as well as for the quality of their mixture. To this end, QC is applied during the preparation of wooden forms and assembling of the steel, casting and processing. As a moment's reflection upon this example illustrates, the contractor needs to have administrative matters well organized in order to achieve the required quality control, in this case to maintain documents that identify the time and date when work is carried out to determine the number of samples of concrete and the time, date and result of pressure resistance tests on each.

Often during construction, there are changes in the drawings as a result of the emergence of some problems at the site during the implementation or appearance of some ideas and suggestions that reduce the project time. Such changes must be recorded in the project documents, and the drawings themselves adjusted to represent what has actually been constructed.

In most cases the owner have his own organization as follow:

1. Owner has the supervision team on site.
2. Owner chooses a consulting office that performs the design and handles the supervision.

In both cases, there should be strong organization, similar to the organization of the contractor, as it is the tools that control quality.

But when the contractor has a working group who has full knowledge of QA and QC, the dispute between the supervisory and the contractor will be more narrow and it is very important to the owner that the project is in good shape in the end.

Both project owner and contractor will have representatives of their organizations working onsite at the project. If the owner has a competent staff and a strong knowledge about QC and QA while the contractor staff has little or none, there will be problems. On the other hand, if the concept of quality assurance for the work team is quite clear, the construction phase will disclose the true strengths of the contractor.

You can imagine that if the owner has a competent staff with a strong knowledge about QC and QA while the contractor staff has no any knowledge about it, there will be more trouble that will affect the project as a whole.

8.5.4.1 ISO and Control Work

Standardization of processes of execution has been developed in ISO 9001 Section 4.9. The following general implementation requirements are intended assure the required quality:

- controlled execution of special operations, environmental conditions, specifications, work instructions, procedures, control, and follow-up; development of a plan for the execution of all processes, structures, and construction that affect the final quality of the project; and
- registration, with their own documents, of all actions of the execution process, including all measures found necessary for ensuring that equipment is working properly for the duration of the project without any malfunction that would affect workflow.

8.5.4.2 Inspection Procedures

Procurement of required materials from many different locations, and their installation, describes the essential content of project execution. The responsibility of the general contractor is to attain both objectives up to the required standards of quality. This includes and entails specific instructions determining the manner in which the materials and installations are to work and the proper equipment to be used. The procedures of check-up on the completed work constitute both an ongoing and finalizing step of the QA process. This includes continuous inspection and testing being conducted throughout the duration of the project's construction/execution.

The inspection process must specify:

- the substance to be tested
- test procedure
- equipment required for testing and inspection and calibration of such equipment
- inspection method
- environmental conditions required, which will be maintained during operation, inspection, and testing
- the sampling method or a way to choose an appropriate sample
- a definition of the limits of acceptance or rejection of the samples tested

The following items are from the ISO 9000 Section 4.11 and the inspection and measurement test.

- control inspection
- measurement and test equipment
- calibration, maintenance, and the surrounding environment, and storage and documents
- registration and inspections

8.5.4.3 Importance of Well-Prepared Contracts in Assuring Project Quality

In Chapter 7 the diversity of contractual arrangements and types of contract between an owner and contractor, as well as between an owner and an Engineering Office was discussed. Contracts are as diverse as the projects they order. However, they are also only as good as the experience of owners, contractors and engineering offices, and even then "bugs" can creep in. These can cause numerous problems, may be difficult to resolve, and the additional time needed to fix such problems may adversely affect the project's final cost.

8.5.4.4 Checklists

The ISO 9000 standard sets forth who conducts the review process. Some of the menus contain questions from the manufacturer or internal departments. These cover many important aspects of basics and quality control in all stages of the manufacturing or implementation of product.

Checklists contain the following specific questions, which are with the auditors of public review of the company's performance with other lists in the special design phase and implementation phase. Those lists include detailed questions whose answers are intended to enable full and comprehensive review of the quality system at the stage of design and implementation.

8.5.4.4.1 Checklists for Reviewers

(What follows is an itemized description of the questions.)

1. **Management Tasks**
    - Is representative of the department responsible for achieving ISO 9000?
    - Is it specific responsibilities and authorities of all influential individuals in the quality?
    - Are the available resources adequate?
    - Has skilled labor been engaged in the work related to their skills?
    - Is the audit done by independent auditors?

2. **Quality Management System**
    - Is the establishment of a system and the number of complete documentation of the quality management system to make sure that the product will achieve specifications?
    - Is there an audit of the contract for the review of contracts and to achieve cooperation between the activities to implement the contract?

3. **Control Design**
    - Are individuals eligible to complete the work assigned to them?
    - Are the design requirements reviewed by the owner?
    - Is the output compatible with the design input?

4. **Control of Documents**
   - Is there a procedure to control all documents quality?
   - Do the documents have been reviewed and approved before use?

5. **Purchases**
   - Were products purchased in conformity with the requirements of quality?

6. **Supplier of the Product Suppliers**
   - Is there a procedure to verify the storage and maintenance of products supplied by the supplier?

7. **Control in Manufacturing or Implementation**
   - Is the manufacturing process or implementation of specific and planned through the documents with instructions to work?
   - Do the procedures control manufacturing and implementation of special operations?

8. **Inspection and Testing**
   - Whether a procedure is to ensure that the product has not been used before, testing or verification that they were identical with the specifications is necessary?
   - Is there a procedure to verify conformity with the product specifications during manufacturing?
   - Is there a procedure for final inspection tests?

9. **Test Devices**
   - Is there a procedure to control the calibration and maintenance of tests?

10. **Test Results**
    - Is there a procedure to make sure that the product non-conformity with the specifications is controlled?

11. **Step Corrective**
    - Is there a procedure during inspection to determine the cause of the incompatibility of the

product with customer requirements and specifications and to determine the steps necessary to fix it and avoid the problem occurring in the future?

12. **Entrepreneurship and Storage**
    - Are there procedures and documentation for the control of contractors, storage and handling?

13. **Quality Recording**
    - Is there a procedure to maintain the action and to identify, collect, and store all documents related to quality?

14. **Review of Internal Quality**
    - Is there a planned system of internal audit documents?

15. **Training**
    - Are there training procedures for identifying training needs for employees to have an impact on quality?

16. **The Service**
    - Are the service procedures present to achieve service?

17. **Statistical Processes**
    - Are there procedures to determine the statistical information required to accept or reject the product?

8.5.4.4.2 External Auditing

External auditing is done by a team from the contractor or the service provider. A company that takes the ISO should also be a company whose products and safety can be trusted. But, in reality, in some countries, such a list is nowhere to be had, while companies in other countries have the ISO but do not apply any of the system for quality *assurance*, as most of the companies are focused on quality *control* rather than on quality assurance or even on developing a quality manual.

Therefore, in major projects, the owner may consider forming a team from his own company's quality department to conduct external audits for other engineering or contracting services providers.

First, the contractor or other service provider delivers his quality manual for review by the quality team. They visit the site with a company representative to show their system in action and to inspect it. The process is as follows:

- the Supplier's site is visited and a complete inspection performed;
- the Supervisor gives the visiting team an exact description of how their Q.C. system works;
- the contractor supplies examples of Q.C. documentation;
- the inspection team may ask to re-check a previously inspected batch ;
- test equipment is checked for regular maintenance; and
- rejected or unacceptable products are clearly marked and segregated to avoid any chance of their accidental inclusion with acceptable products.

Three possible outcomes may ensue following this visit:

1. **Acceptable to be registered in company bidder list**
   If the evaluation has shown that the supplier has a satisfactory Quality Management System (QMS), there are no deficiencies and the supplier is able to give an assurance of quality.

Table 8.2 Design check list

Item	Questions	Yes/No	Remarks
1	Do they have a system to assure the client presents his or her needs clearly?		
2	Are the client requirements clear to all the design members?		
3	What is the international standard and specification they use?		
4	Are these standards available in their office?		
5	Are the drawings and documents sent by the client registered?		

Table 8.2 (cont.) Design check list

Item	Questions	Yes/No	Remarks
6	Do they have a document management system?		
7	Do they define the name of the discipline lead?		
8	Are the activities clear to them?		
9	How can they select the new engineers?		
10	Do the drawings have a number?		
11	Are there strong numbering systems to the drawings?		
12	Do they prepare a list of the drawings?		
13	Are they updating this list?		
14	What is the checking system in calculation?		
15	What is the checking system in the drawings?		
16	Are the employees familiar with CAD?		
17	Do they have a backup system to the documents and drawings?		
18	Do they have antivirus?		
19	Do they use a sub engineering office?		
20	What is the method and criteria for the selection?		
21	Is there a good relation between the design team and the supervision team on site?		
22	Are they experienced with the technical inquiry?		

Table 8.3 Construction checklist

Item	Questions	Yes/No	Remarks
1	Is there a quality control procedure?	1	
2	IS the QC procedure understood by all members and how?	2	
3	Does the QC match with the task?	3	
4	What is the way to assure with the tests?	4	

Table 8.3 (cont.) Construction checklist

Item	Questions	Yes/No	Remarks
5	Is there equipment to do the test calibrated?	5	
6	How they do the test piping, concrete, welding, and what is the confidence for this test?	6	
7	Is a third party used for the test?	7	
8	What are the criteria for choosing the third party?	8	
9	Do they use a sub contractor?	9	
10	What are the criteria for choosing these sub contractors?	10	
11	Do they regularly maintain their equipment?	11	
12	Do they have a certificate for the cranes and wire?	12	
13	Is there a team on site that knows if the project is time or cost driven?	13	
14	Does their team know the project objective and target?	14	
15	Do they control the documents and drawings on site?	15	
16	Do they have a document management system?	16	

Also, in this case the supplier may have proven that they are up to satisfactory standards.

2. **Weak Quality System**
If the team finds several significant weaknesses in the supplier's system, the supplier will have to take steps to overcome these failures and improve their QMS.

The supplier can ask for another evaluation to confirm that their quality is approved. To enhance their company and employee work will take time, so it is not preferred to register the company but to give it a period to change.

3. **Unacceptable Quality System**
   In this case the team found that the supplier will have to make radical changes to improve their overall QMS.
   Note that in this case the actions from the supplier to reach the target to satisfy Q.M.S. will take not less than one year, so avoid dealing with this supplier.
   ISO 9000 provides a check list that is essential and important for the auditing team. The following is the check list for every phase of the project. In the design phase there is a sample for what will be asked from the engineering company. For the construction phase, this check list is tailored to be a sample when auditing a contractor company.

From the above, and indeed as stated in ISO 9001 section 4.18, it is clearly important that all project employees possess appropriate technical skills as well as a QMS. Training may be required to increase these skills levels to the standard required.

8.6 Operational Phase of the Project

The owner is responsible for the operation phase, as in this phase the owner will have full authority and responsibility to operate the project after the commissioning and start-up phase.

During operation there is usually a requirement to modify the facilities due to operation needs.

This is traditional in the oil and gas industry in the case of an increase in production or a need to modify the mode of operation.

In some regular cases workshops are extended in normal industry. Most international companies that follow ISO have a management of change system and procedure.

In this procedure the required modification is identified and approval is granted from all the engineering disciplines. In new projects, it is preferred to go to the original engineering office that performed the design to do the engineering for this modification.

An example of poor "management of change" (MOC) in an international hotel is the conversion of one room from normal use to be a planet land for entertainment. They put clay on the floor without performing any management of change process, and due to this heavy load, the floor collapsed and damaged 4 cars in the garage underneath the room.

From previous experience, projects in every step of engineering and construction concentrate on these goals, and usually the input from the operation is very little.

In most oil and gas projects, the owner creates a separate organization for this project (described in Chapter 5). In most cases, the project is under the responsibility of different departments. However, the operation is the end user but usually a limited number of operation engineers share in the project for many reasons, as the operation cannot release. On the other hand, the operation members who are usually one or two engineers just define what they need. In this circumstance there is usually an expectation for not full satisfaction from the operations department.

8.7 The "Total Building Commissioning System"

This system is very important in oil and gas projects. However those in the oil field are more familiar in commissioning, and there are many professionals in this area but they apply in the start up of a project to be a link between the projects staff and operations staff. In fact, the USA applies this system for normal buildings to formulate the team responsible for commissioning from the engineering phase until the operation phase.

As discussed in the previous section of this chapter, in some cases the operation is not satisfied with the project output. The optimum solution is to apply a "total building commissioning system," which is already applied in the USA for residential, administration, commercial and public buildings.

Historically, the term "commissioning" has referred to the process by which the heating, ventilation and air conditioning (HVAC) systems of a building were tested and balanced according to established standards prior to acceptance by the building owner. Today's use of the commissioning concept recognizes the integrated nature of all building systems' performance, which has impacts on sustainability, workplace productivity, occupant safety and security.

In the USA, the U.S. General Services Administration (GSA), through its Public Buildings Service (PBS), manages buildings that house over a million Federal associates and has an on-going planning, design and construction program to meet the federal customers housing needs.

PBS' project delivery program is the vehicle for transforming our customer agencies' vision into reality. The built environment for the nation's public buildings, including courthouses, federal office buildings, laboratories, and border stations, in turn shapes the communities and landscape in which they reside.

In our case the engineering team in the owner company will have the same responsibility as GSA.

The National Conference on Building Commissioning has established an official definition of 'Total Building Commissioning' as follows:

> "Systematic process of assuring by verification and documentation, from the design phase to a minimum of one year after construction, that all facility systems perform interactively in accordance with the design documentation and intent, and in accordance with the owner's operational needs, including preparation of operation personnel."

What we need here is to have a wide definition of "total facilities commissioning," which would refer to any discipline activity sharing in the project.

It is the author's experience with major projects in the engineering phase that the engineering company worries about man-hours and approves the bill, while each of the engineering disciplines focuses on matching the design to the standard and specifications of the owner. On the other hand, the owner's engineering staff representative focuses on the "engineering" deliverable, which is strong technically and matches the stipulated standard and specification. In reality, however, it will be a representation of operations in the engineering group. Unfortunately, however, with time, the owner will focus on technical issues only, his objective will switch to bringing the engineering to within the stipulated standard , finish the review cycle on time and avoid excess expenditure. This reality illuminates the necessity for a separate entity to look at the owner's requirements.

Below is information from the GSA document, tailored and changed to be match the needs of oil and gas and other industrial projects.

- Philosophy provides GSA's definition and expectations for commissioning.

- Building Commissioning Process details the considerations, practices and recommendations for commissioning along the GSA project process including Planning, Design, Construction and Post-Construction Stages.
- Appendices provide samples, tools, definitions and links to further resources for additional information on commissioning.

Benefits of Commissioning for GSA Buildings

- Improved facilities productivity and reliability
- Lower utility bills through energy savings
- Increased operations and owner satisfaction
- Enhanced environmental, health conditions, and occupant comfort
- Improved system and equipment function
- Improved facilities operation and maintenance
- Increased operations safety
- Better facilities documentation
- Shortened transition period from project to operation
- Significant extension of equipment/systems life cycle

GSA defines the benefits in industry sources and indicates that on average the operating costs of a commissioned building range from 8% to 20% below that of a non-commissioned building. So this philosophy applies for the plant buildings only.

8.7.1 Planning Stage

Figure (8.2) presents the main steps in applying a building commissioning system in planning, design, construction and post construction phase. These steps will be discussed in detail in the following sections.

8.7.1.1 Identifying the Commissioning Team

The first step in the commissioning process is for the GSA project manager (GSA PM) to identify and layout the makeup of the Commissioning Team. The exact size and members of the commissioning team will vary depending on project type, size and complexity.

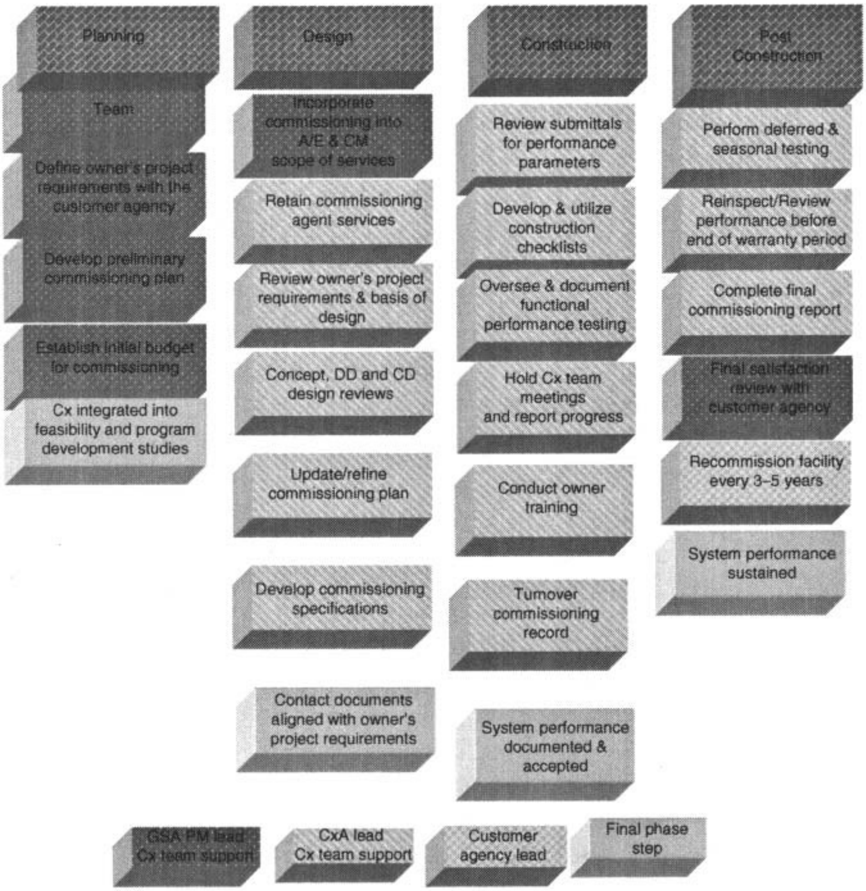


Figure 8.2 Building commissioning system main steps.

In general the team will consist of the following:

- GSA Project Manager (Team Leader)
- GSA Operating Personnel
- Customer Agency Representative(s)
- GSA Technical Experts (i.e., Structural, Mechanical, Electrical, Fire Protection, Elevator, Seismic, LEED/ Sustainability, etc.)
- Construction Manager (CM)
- Construction Contractor and Subcontractors
- Commissioning Agent (CxA)
- Architect/Engineer (A/E)

The Responsibility Definition is presented in Table (8.4). The following definitions apply to the Roles and Responsibilities Matrix:

- Lead (L) = Direct and take overall responsibility for accomplishment
- Support (S) = Provide assistance
- Approve (A) = Formally accept either written or verbal depending on the situation
- Participate (P) = Take part in the activity (i.e., attend the meeting, etc.)
- Inform (I) = Make this party aware of the activity or result or provide a copy of the deliverable
- Verify (V) = Confirm the accuracy or completeness of the task

8.7.1.2 Defining the Owner's Project Requirements with the Customer Agency

The objective of commissioning is to provide documented confirmation that a facility fulfills the functional and performance requirements of GSA, occupants, and operators. To attain this goal, it is necessary to establish and document.

The owner projects requirements and criteria for system function, performance, and maintainability. The Owner's Project Requirements will form the basis from which all design, construction, acceptance, and operational decisions are made. The following suggested categories provide a framework for the types of requirements that shall be considered.

8.7.1.3 Developing Preliminary Commissioning Plan

The Commissioning Plan establishes the framework for how commissioning will be handled and managed on a given project. This includes a discussion of the commissioning process, schedule, team, team member responsibilities, communication structures, and a general description of the systems to be commissioned. This preliminary version of the plan shall be developed by the GSA PM in conjunction with the Customer Agency. The suggested structure of the Commissioning Plan is as follows. All information in the Commissioning Plan must be project specific.

Table 8.4 Commissioning roles and responsibilities matrix

Legend **L = Lead P = Participate** **S = Support I = Inform** **A = Approve V = Verify**	**GSA Project Manager**	**GSA Operating Personnel**	**Customer Agency Reps**	**GSA Technical Experts**	**CM**	**Construction Contractor**	**CxA**	**A/E**
Planning Stage								
Identify Commissioning Team	L/A	S	S	P/S				
Develop Owner's Project Requirements	L/A	S	S	S				
Develop preliminary commissioning scope	L	S	S	P/S				
Develop Preliminary Commissioning Plan	L	S	S	S				
Establish budget for all Cx work & integrate costs for commissioning into project budget	L	S	S	S				
Include time for Cx in initial project schedule	L	I	I	I				
Include Cx responsibilities in A/E & CM scope of services	L/A	S		S				

Table 8.4 (cont.) Commissioning roles and responsibilities matrix

Legend **L = Lead P = Participate** **S = Support I = Inform** **A = Approve V = Verify**	**GSA Project Manager**	**GSA Operating Personnel**	**Customer Agency Reps**	**GSA Technical Experts**	**CM**	**Construction Contractor**	**CxA**	**A/E**
Design Stage								
Contract fro Commissioning Agent Service	L/A	P	P	P	L			
Hold Design Stage Cx meeting	P	P	P	P	P		L	P
Identify project specific responsibilitie	L	P	P	S	S		P	P
Review Owner's Project Requirements documentation for completeness & clarit	S	S	I		I		L	I
Develop Basis of Desig	A	P	P	S/A	I		I	L
Perform focused Cx reviews of design drawings & specification	P	P		P	S		L	S
Perform project constructability review	P			I/P	L		I/S	S

Incorporate appropriate changes to contract documents based upon design review	A	P	P	I	I		L	L
Refine Owner's Project Requirements based upon Design Stage Decision	A	P	P	S	I		L	S
Create Cx specifications including testing protocols for all commissioned equip./system	I	I	I	P/S	S		L	S
Integrate Cx activities into project schedul	A	I	I					
Coordinate integration issues & responsibilities between equipment, systems & discipline	A	I	I	P/S	S		V	L
Update Commissioning PlaN	A	I	I	I	S		L	I
Incorporate commissioning requirements into Construction Contractor's Scope of WorK	A			I	L		S	S
Construction Stag								
Revise Commissioning Plan as necessary								

Table 8.4 (cont.) Commissioning roles and responsibilities matrix

Legend **L = Lead P = Participate** **S = Support I = Inform** **A = Approve V = Verify**	**GSA Project Manager**	**GSA Operating Personnel**	**Customer Agency Reps**	**GSA Technical Experts**	**CM**	**Construction Contractor**	**CxA**	**A/E**
Review submittals applicable to equipment/ systems being commissioned								
Review project submittals for construction quality control & specification conformance	A	I	I	I	I	S	I	L
Develop functional test procedures and documentation formats for all commissioned equipment & assemblies	I			P	A	S	S	L
Include Cx requirements and activities in each purchase order and subcontract written	I			I/P	A	L	S	V
Develop construction checklists for equipment/ systems to be commissioned	A			P	I	I	I	L

Install components & system	I	I	I		A	A	L	V
Review RFIs and changes for impacts on Cx	A	I	I	I/S	S	L	S	V
Demonstrate operation of systems	I		P/I		I	P	L	V
Complete construction checklists as the work is accomplished	I	I		I	I	S	L	A
Continuously maintain the record drawings and submit as detailed in the contract documents	A	S			I	S	L	V
Coordinate functional testing for all commissioned systems & assemblies	I	I	I	P/A	I	S	S	L/A
Perform quality control inspections	I			I/P		L	S	P/I
Maintain record of functional testing	I	I	I	I/P	I	S	S	L
Prepare Cx Progress Report	A	I	I	I/P	I	P	S	L
Hold Construction Phase Cx meeting	P	P	P	P	P	P	P	L

Table 8.4 (cont.) Commissioning roles and responsibilities matrix

Legend **L = Lead P = Participate** **S = Support I = Inform** **A = Approve V = Verify**	**GSA Project Manager**	**GSA Operating Personnel**	**Customer Agency Reps**	**GSA Technical Experts**	**CM**	**Construction Contractor**	**CxA**	**A/E**
Maintain master Issues Lo	I	I	I	I	I	S	I	L
Review equipment warranties to ensure GSA responsibilities are clearly define	I	I				S	S	L
Implement training program for GSA Operating Personnel	I	P	P	I/S	P	S	S	L
Compile and deliver Turnover Package	A	A			S	S	L	S/V
Deliver Commissioning Record	A	P	P	I	S	S	S	L
Post-Construction Stag								
Coordinate & supervise deficiency correction	A	P		I	I/S	L	S	I
Coordinate & supervise deferred & seasonal testing	A	P		I		S		I
Review & address outstanding issue	A	P		I	I/S	S	S	I

Review current building operation at 10 months into 12 month warranty period	A	P		I	S	S		I
Address concerns with operating facility as intended	A	P		I	S	S	S	S
Complete Final Commissioning Report	A	P			I/P	I		I
Perform Final Satisfaction Review with Customer Agency 12 months after occupancy	A	S		S		S		S
Recommission the facility at 3–5 years after turnover to reset optimal performance	L	P		L	P			

L = Lead P = Participate S = Support I = Inform A = Approve V = Verify

CM = Construction manager

A/E = Architectural and engineering

CxA = commissioning agency

8.7.1.4 Commissioning for Certifications (LEED, Energy Star, etc.)

For housing building, the building commissioning system looks for the building design that will achieve energy saving through Leadership in Energy and Environmental Design (LEED) certification. Any building will be certified as a green building if its design

Table 8.5 Owner requirements

Accessibility	Access and use by children, aged, and disabled persons
Acoustics	Control of internal and external noise and intelligibility of sound
Comfort	Identify and document those comfort problems that have caused complaints in the past and which will be avoided in this facility (i.e., glare, uneven air distribution, etc.)
Communications	Capacity to provide inter- and intra-telecommunications throughout the facility Constructability Transportation
Constructability	Transportation to site, erection of facility, and health and safety during construction
Design Excellence	Potential/Objectives for design recognition
Durability	Retention of performance over required service life
Energy	Goals for energy efficiency (to the extent they are not called out in the Green Building Concepts)
Fire Protection and Life Safety	Fire protection and life safety systems
Flexibility	For future facility changes and expansions
Green Building Concepts	Sustainability concepts including LEED certification goals
Health & Hygiene	Protection from contamination from waste water, garbage and other wastes, emissions and toxic materials
Indoor Environment	Including hydrothermal, air temperature, humidity, condensation, indoor air quality and weather resistance

Table 8.5 (cont.) Owner requirements

Life Safety	Fire protection and life safety systems
Light	Including natural and artificial (i.e., electric, solar, etc.) illumination
Maintenance Requirements	Varied level of knowledge of maintenance staff and the expected complexity of the proposed systems
Security	Protection against intrusion (physical, thermal, sound, etc.) and vandalism and chemical/ biological/radiological threats
Standards Integration	Integration of approved federal, state, and local as well as GSA and customer Agency standards and requirements
Structural Safety	Resistance to static and dynamic forces, impact and progressive collapse

achieves points to be a gold, silver, or platinum building and some of its points are gained by using total building commissioning system.

Development of the preliminary Commissioning Plan and initial commissioning scope shall also include a discussion regarding project certifications and goal attainment (i.e. LEED, Energy Star, Energy Goals, Design Awards, etc.).

For the project to be LEED-certified, commissioning process activities must comply with the prerequisite requirements for fundamental building commissioning, and the project team may opt to pursue an added LEED point for additional commissioning.

Table 8.6 Commissioning plan

Purpose and general summary of the Plan	Introduction
Overview of the project, emphasizing key project information and delivery method characteristics	General Project Information
The commissioning scope including which building assemblies, systems, subsystems and equipment will be commissioned on this project	Commissioning Scope

Table 8.6 (cont.) Commissioning plan

Project specific commissioning team members and contact information	Team Contacts
Documentation of the communication channels to be used throughout the project	Communication Plan and Protocols
Detailed description of the project specific tasks to be accomplished during the Planning, Design, Construction and Tenant Occupancy Stages with associated roles and responsibilities	Commissioning Process
List of commissioning documents required to identify expectations, track conditions and decisions, and validate/certify performance	Commissioning Documentation
Specific sequences of events and relative timeframes, dates and durations	Commissioning Schedule

Table 8.7 Work during the commissioning process

Appendices	Work Completed During the Commissioning Process
A	Owner's Project Requirements
B	Basis of Design
C	Commissioning Specifications
D	Design Review
E	Submittal Review
F	Issues Log
G	Construction Checklists
H	Site Visit and Commissioning Meeting Minutes
I	O&M Manual Review
J	Training
K	Functional Performance Tests & Seasonal Testing
L	Warranty Review
M	Test Data Reports

The process provided in this guide provides the necessary steps to comply with both prerequisite and additional commissioning requirements.

8.7.1.4.1 Establishing Initial Budget for Commissioning

- Based upon the Preliminary Commissioning Plan, the GSA owner Project Manager includes budgetary costs for commissioning in the Feasibility Study and the Program Development Study. It is critical that the overall established budget, which is submitted for funding approval, contains necessary monies for commissioning.
- Specifically, Feasibility Study and Program Development Study deliverables per the owner's Project Planning Guide call for estimated construction costs (ECC) and estimated total project costs (ETPC). These estimates must include line items for both commissioning services and testing.

8.7.1.5 Commissioning Agent Costs

The following can be taken as a guide from GSA:

- Total building commissioning costs for (CxA) services can range from 0.5% to 1.5% of total construction costs (according to U.S. Department of Energy's Rebuild America Program, written by the Portland Energy Conservation, Inc. (PECI)).
- The National Association of State Facilities Administrators (NASFA) recommends budgeting 1.25% to 2.25% of the total construction costs for total building (CxA) services.
- GSA's commissioning practice is expected to cost approximately 0.5% of the construction budget for federal buildings and border stations.
- More complex projects such as courthouses could run 0.8% – 1% of the construction budget, and even more complex facilities such as laboratories can exceed 1%.
- Factors influencing commissioning costs include facility type, phasing 24/7 operations, the level of commissioning desired and the systems and assemblies chosen to be commissioned.

The above costs only cover Commissioning Agent fees. There are also costs to the Construction Manager, Construction Contractor,

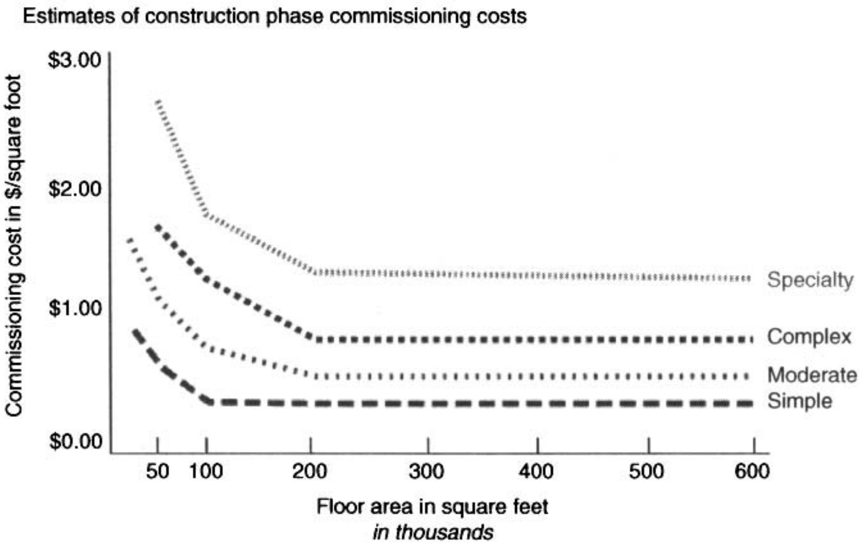


Figure 8.3 Relationship between the commissioning cost and the building area.

engineering office, and owner staff for sharing part in the commissioning process. The profile of these costs will vary depending on roles and responsibilities chosen. For a detailed estimate of professional service fees, an itemized level of effort needs to be performed based on unique project requirements.

The relationship between commissioning cost per square feet and the floor area is presented in Figure (8.3).

8.7.1.6 Cost-Benefit Analysis for Commissioning

Recent PECI studies indicate that on average the operating costs of a commissioned building range from 8% to 20% below that of a non-commissioned building.

Discussing the cost data for office buildings suggests that building commissioning can result in energy savings of 20% to 50% and maintenance savings of 15% to 35%.

Beyond operating efficiency, successful building commissioning has been linked to reduced occupant complaints and increased occupant productivity.

8.7.2 Design Stage

Design Stage commissioning activities serve to assure that the owner's project requirements for items such as energy efficiency, sustainability, indoor environmental quality, fire protection and life safety, etc., are sufficiently defined and adequately and accurately reflected in the contract documents.

The Design Stage is the commissioning team's opportunity to assure that building systems and assemblies as designed will function according to user expectations.

Further, specific tests and procedures designed to verify the performance of systems and assemblies are developed and incorporated into the contract documents.

8.7.2.1 Incorporation of Commissioning into A/E and CM Scope of Services

GSA commissioning activities may be more rigorous than A/Es and CMs typically included in their scope of services.

Design, construction, and post-construction commissioning activities must be defined and written into the architect/engineer and construction manager scopes of work and executed contracts.

By this stage of project development, the GSA project manager must have an awareness of how commissioning services will be delivered. GSA's preferred method for engaging a commissioning agent is to arrange for the construction manager to contract directly with a commissioning agent. However, there will be exceptions based on project specific drivers. Should the project team determine that the CM will contract the commissioning agent, this must be written into the CM's scope of work.

Commissioning services for design and construction management professionals shall minimally include, but are not limited to, the items listed on the following sections.

8.7.2.1.1 Project Lifecycle of the Design Professional

1. Participate and aid in the documentation of the owner's project requirements.
2. Document revisions to owner's project requirements and obtain GSA approval.
3. Document the basis of design.
4. Integrate Cx process requirements and activities provided by the CxA into the contract documents.
5. Attend commissioning team meetings (3 design review meetings and monthly construction stage Cx team meetings).

6. Specify and verify that the operation and maintenance of the systems and assemblies have been adequately detailed in the construction documents.
7. Review and incorporate as appropriate the CxA's comments into the contract documents.
8. Participate in the operations and maintenance personnel training as specified in the training program.
9. Review test procedures submitted by the contractor.
10. Review and comment on the CxA's progress reports and issue logs.
11. Witness the functional testing of all commissioned systems and assemblies.
12. Review and accept record documents as required by the contract documents.
13. Review and comment on the final commissioning record.
14. Recommend final acceptance of the systems to GSA.
15. Verify systems are installed as specified.

8.7.2.1.2 Project Lifecycle of the Construction Manager

1. If appropriate, lead the RFQ process for commissioning services and award a contract to a Commissioning Agent directly under the Construction Manager.
2. Include commissioning process activities and requirements into all general contractor bid packages.
3. Work with the commissioning team to develop a schedule for commissioning activities and incorporate commissioning activities into the overall project schedule.
4. Provide personnel with the means and authority to coordinate implementation of the commissioning process as detailed in the contract documents.
5. Attend commissioning team meetings (3 design review meetings and monthly construction stage Cx team meetings).
6. Coordinate with the Commissioning Agent in the development of a commissioning plan.
7. Perform quality control functions, particularly in the areas of design reviews for constructability and inspection.

8. Participate in and assist with the functional testing of all commissioned systems and assemblies.
9. Provide technical expertise such as testing, cost estimating, and resolving disputes.
10. Coordinate and document owner/operator training.
11. Issue a statement that certifies all work has been completed and the facility is operational, in accordance with the contract documents.
12. Coordinate General Contractor remedies for deficiencies identified by the Commissioning Agent during their verification of the installation or tests.
13. Review and comment on the final Commissioning Record.

8.7.2.1.3 Retain Commissioning Agent Services

GSA's suggested practice is to have the CM hire a subcontractor to act as the Commissioning Agent, resulting in no additional contract management responsibilities for GSA.

In this case the CM will lead the RFQ process for commissioning services. There will be exceptions to this suggested practice, and in these cases, GSA will lead the RFQ process for a Commissioning Agent. Regardless of the contracting method, the Commissioning Agent shall be on board by the beginning of Design Development.

8.7.2.1.4 Commissioning Agent Qualifications

The Commissioning Agent and the CM generally have different skills. In general, the CM provides management, technical, and administrative expertise during the design and construction phases to ensure that the customer agency's goals relating to schedule, budget, scope, and quality are met.

A CxA has technical background and in depth expertise with the commissioning process including verification techniques, functional performance testing, system equipment and operation and maintenance (O&M) knowledge.

Furthermore, the CxA shall bring a total building commissioning perspective to the project, be knowledgeable in national building fire codes, as well as water-based extinguishing systems, detection systems, LEED, energy efficiency imperatives, and demonstrate experience with Federal requirements (i.e., blast, progressive collapse, security, etc.).

8.7.2.1.5 Request for Qualifications (RFQ) for Commissioning Agent

The RFQ for CxA services is based upon the Preliminary Commissioning Plan and the commissioning budget established in the Program Development Study (PDS).

Depending on the CxA delivery method (i.e., CM versus GSA contracts), this may be the responsibility of either GSA or the CM.

Table 8.8 CxA selection

Building type, square footage, general program, overall project Budget, milestone schedule dates, LEED and other certification pursuits, etc.	Project Background
GSA project objectives for commissioning	Objectives
Design, Construction, and Post-Construction Stage expectations for the Commissioning Agent	Scope of Work
Preliminary identification of the systems and assemblies to be commissioned. Once contracted, the CxA will further develop this matrix	Systems and Assemblies
Desired qualification of the CxA	Qualifications
Expectations for format and content of prospective CxA's proposal	Proposal
Statement on GSA review of CxA changes in personnel for the project	Change in Personnel
A table indicating the selection criteria and scoring system for evaluating CxA proposals	Selection Criteria
	Proprietary Information (disclaimer)
	Protection and Control of Government Documents (disclaimer)

8.7.2.1.6 Commissioning Agent Selection

This service shall be acquired in the same manner as other professional services. The Commissioning Agent shall be chosen on the primary basis of qualifications and not solely based on price. The involved work order and selection procedures should adhere to the involved provisions for work order issuance and be fitted with requirements/contents that are aligned with standard work order formats. National contracts are in place that can support commissioning services.

It is recommended that the CxA is contracted according to a two phase fee negotiation process.

The first phase includes Design Stage responsibilities, and the second phase includes construction and post-construction activities.

The negotiation of the construction and post-construction stage fee is based upon a substantially completed design and the actual type and number of equipment, systems, and assemblies to be inspected, started, and tested.

Within the Design Stage proposal, the CxA shall be asked to provide budgetary numbers for the construction and post-construction stages.

8.7.2.1.7 Review Owner's Project Requirements and Basis of Design

- As described in previous sections, the owner's project requirements are developed as part of GSA's project planning processes and established baseline criteria for facility function, performance, and maintainability.
- The Basis of Design (BOD) is developed by the engineering office early in the Design Stage based on th owner's project requirements. It is the primary document that translates the GSA's and customer agency's needs into building components such as HVAC systems, building envelope, security systems, building automation system, etc.
- The BOD describes the technical approach planned for the project as well as the design parameters to be used. The BOD is typically developed by the engineering office and done in technical terms, whereas the owner's project requirements are developed by GSA

in concert with the customer agency and expressed in layman's terms.

8.7.2.1.8 CxA Roles in BOD

- Through the design process, a key role for the Commissioning Agent is to facilitate a clear understanding of expectations by the design team. To do this, the practice of conducting program review workshops is to be used to offer all stakeholders the opportunity to indicate what they want to see in the next design submission.
- The Project Planning Tools' Commissioning Tool identifies such practices in the work breakdown structure associated with defining roles and responsibilities.

8.7.2.1.9 Concept, DD, and CD Design Reviews

- The Commissioning Agent provides three focused reviews of the design documents. It is recommended that these reviews occur first at the end of Design Concepts (FEED), the second shall occur during Design Development (Detail) (50%), and the third toward the end of Construction Documents Phase (95%).
- The CxA compares the design with the interests and needs of GSA as identified in the owner's project requirements. The CxA also compares the proposed design against GSA design standards as defined in the latest version of the *PBS* or the company specification in case of applying it in industrial projects like petrochemical or oil and gas projects.
- The CxA identifies any improvements that can be made in areas such as energy efficiency, indoor environmental quality, operations and maintenance, etc. Though the CxA is responsible for reviewing the design from a commissioning perspective, the CxA is not responsible for design concepts and criteria or compliance with local, state, and Federal codes (unless it is specifically called out in their contract).

Table 8.9 Commissioning agent focused design review scope

Certification Facilitation	Review contract documents to facilitate project certification goals (i.e. does design meet Energy Star requirements; does Cx meet LEED criteria, etc.).
Commissioning Facilitation	Review contract documents to facilitate effective commissioning (sufficient accessibility, test ports, monitoring points, etc.).
Commissioning Specifications	Verify that bid documents adequately specify building commissioning, including testing requirements by equipment type.
Control System & Control Strategies	Review HVAC, lighting, fire control, emergency power, security control system, strategies and sequences of operation for adequacy and efficiency.
Electrical	Review the electrical concepts/systems for enhancements.
Energy Efficiency	Review for adequacy of the effectiveness of building layout and efficiency of system types and components for building shell, HVAC systems and lighting systems.
Envelope	Review envelope design and assemblies for thermal and water integrity, moisture vapor control and assembly life, including impacts of interior surface finishes and impacts and interactions with HVAC systems (blast, hurricane, water penetration).
Fire Protection & Life Safety*	Review contract documents to facilitate effective Cx of fire protection and life safety systems and to aid Fire Protection Engineer in system testing to obtain the GSA Occupancy Permit.
GSA Design Guidelines & Standards	Verify that the design complies with GSA design guidelines and standards (i.e. GSA P-100, Court Design Guide, Border Station Guide and Federal Facility Council requirements).
Functionality	Ensure the design maximizes the functional needs of the occupants.
Indoor Environmental Quality (IEQ)	Review to ensure that systems relating to thermal, visual acoustical, air quality comfort, air distribution maximize comfort and are in accordance with Owner's Project Requirements.

Table 8.9 (cont.) Commissioning agent focused design review scope

Life Cycle Costs	Review a life cycle assessment of the primary competing mechanical systems relative to energy efficiency, O&M, IEQ, functionality, sustainability.
Mechanical	Review for owner requirements that provide flexible and efficient operation as required in the P-100, including off peak chiller heating/cooling AHU operations, and size and zoning of AHUs and thermostated areas.
Operations and Maintenance (O&M)	Review for effects of specified systems and layout toward facilitating O&M (equipment accessibility, system control, etc.).
O&M Documentation	Verify adequate building O&M documentation requirements.
Owner's Project Requirements	Verify that contract documents are in keeping with and will meet the Owner's Project Requirements.
Structural	Review the structural concepts/design for enhancements (i.e. blast and Progressive collapse).
Sustainability	Review to ensure that the building materials, landscaping, water and waste management create less of an impact on the environment, contribute to creating a healthful and productive workspace, and are in accordance with Owner's Project Requirements. See also P-100 LEED requirements.
Training	Verify adequate operator training requirements.

8.7.2.1.10 Issues Log

All comments and issues identified must be tracked in a formal Issues Log. The Issues Log must be sufficiently detailed so as to provide clarity and a point of future reference for the comments. The Issues Log shall contain the following at a minimum:

- Description of issue
- Cause
- Recommendation
- Cost and schedule implications (on design, construction, and facility operations)
- Priority

- Actions taken
- Final resolution

The Issues Log serves as a vehicle to track, critically review, and resolve all commissioning related issues. The Log is maintained by the CxA and becomes part of the final Commissioning Record.

8.7.2.1.11 Design Review Meetings

- The CxA Team shall have a minimum of 3 design review meetings (kick-off, concept/DD, and CD). Additional meetings may be required to resolve outstanding issues.
- The CxA is responsible to lead design review meetings and work collaboratively with the Commissioning Team toward the presentation, discussion, and resolution of design review comments.
- Upon resolution of the CxA's comments, the A/E is responsible to incorporate all approved changes into the design documents.

8.7.2.1.12 Update/Refine Commissioning Plan

Now that the Commissioning Agent is on board and has performed Design Stage reviews, the team realigns and updates the Commissioning Plan in preparation for the construction stage.

The Commissioning Team shall formally accept the updated Commissioning Plan before moving into construction. Furthermore, all outstanding comments and issues relative to the CxA's review of the design shall be resolved, and accepted changes shall be incorporated into the contract and construction bid documents.

- Commissioning team directory
- Commissioning process activities
- Roles and responsibilities
- Communication structures
- Commissioned systems and equipment
- Commissioning process schedule
- Appendices (owner's project requirements, BOD, Design Review, Issues Log)

8.7.2.1.13 Develop Commissioning Specifications

The commissioning tasks for the contractors will be identified in the commissioning specifications and will include the following:

- General commissioning requirements common to all systems and assemblies
- Detailed description of the responsibilities of all parties
- Details of the commissioning process (i.e., schedule and sequence of activities)
- Reporting and documentation requirements and formats
- Alerts to coordination issues
- Deficiency resolution
- Commissioning meetings
- Submittals
- O&M manuals
- Construction checklists
- Functional testing process and specific functional test requirements including testing
- Conditions and acceptance criteria
- As-built drawings
- Training

Specifications must clearly indicate who is witnessing and documenting startup of each commissioned system. Specifications must also clearly indicate who is writing, directing, conducting, and documenting functional tests.

The CxA and the A/E must work together to ensure that commissioning requirements are fully integrated and coordinated in the project specifications.

8.7.2.1.14 Written Test Procedures

Written functional test procedures define the means and methods to carry out system/intersystem tests during the construction phase. To the extent possible, these test procedures shall be defined by the Commissioning Team in the Design Stage and written into the contractors' scopes of work.

Test procedures will necessarily be refined early in the construction phase based on the submittal process.

Test procedures provide the following:

- Required parties for the test, which may include the CM, Construction Contractor, specific subcontractor(s), designer, GSA PM, GSA Operating Personnel, GSA Technical Experts and Customer Agency representatives. The roles of each required party must also be clearly defined.

- Prerequisites for performing the test including completion of specific systems and assemblies. Prerequisites are of critical importance when undertaking phased construction and/or phased occupancy. The CxA must coordinate tests with the CM in terms of the overall construction schedule and the anticipated completion of given systems.
- List of instrumentation, tools, and supplies required for the test.
- Step-by-step instructions to exercise the specific systems and assemblies during the test. This includes instructions for configuring the system to begin the test and the procedure to return the system to normal operation at the conclusion of the test.
- Description of the observations and measurements that must be recorded and the range of acceptable results.

8.7.3 Construction Stage

During the Construction Phase the Commissioning Team works to verify that systems and assemblies operate in a manner that will achieve the Owner's Project Requirements.

The two overarching goals of the Construction Phase are to assure the level of quality desired and to assure the requirements of the contracts are met.

The Construction Phase commissioning activities are a well-orchestrated quality process that includes installation, start-up, functional performance testing, and training to ensure documented system performance in accordance with the owner's project requirements. This testing and documentation will also serve as an important benchmark and baseline for future recommissioning of the facility.

8.7.3.1 Review Submittals for Performance Parameters

As submittals for products and materials are received from contractors, copies of submittals critical to the commissioning process shall be forwarded to the CxA.

In general the CxA is responsible to review the following types of submittals:

- Coordination drawings
- Redline as-builts
- Product data and key operations data submittals
- Systems manuals
- Training program

Clearly, the CxA cannot review every project submittal. The CxA's review of submittals shall be limited to those items that are critical to the focus of the commissioning process. This review allows the CxA to check the submittals for adherence to the owner's project requirements, basis of design, and project specifications. The CxA shall pay special attention to substitutions and proposed deviations from contract documents and the BOD. The CxA will only comment on submittals to the extent that there is a perceived deviation from the owner's.

8.7.3.2 Develop and Utilize Construction Checklists

Construction checklists are developed by the Commissioning Agent, maintained by the Construction Manager, and used by the Construction Contractor and subcontractors.

The intent of construction checklists is to convey pertinent information to the installers regarding the customer agency's concerns on installation and long-term operation of the facility and systems.

The approach to the checklists structure is to keep it short and simple by focusing on key elements.

Checklists span the duration from when equipment is delivered to the job site until the point that the system/component is started up and operational. This includes testing, adjusting, and balancing and control system tuning.

Checklists Categories

- Delivery and storage checks
- Document and track delivery of equipment and materials to site
- Verify submittal information (avoid accepting and installing equipment that does not meet specifications)
- Ensure equipment or materials remain free of contamination, moisture, and other

- Installation and start-up
- Component-based checks
- Systems-based checks

The CxA will develop the checklist that identifies components and systems for which checklists are required. He or she is responsible for reviewing the owner's project requirements for key success criteria, specifications, and submittals for key requirements. CxA develops sample checklists for GSA PM and CM review and incorporates feedback and finalizes checklists for distribution.

8.7.3.3 Oversee and Document Functional Performance Testing

Functional performance testing takes over where the construction checklists ended.

The intent of functionally testing the system/building as a whole is to evaluate the ability of the components in a system to work together to achieve the owner's project requirements.

For functional testing to provide valid results, first the individual components and systems have to be verified to be operating properly (see Develop and Utilize Construction Checklists). This includes start-up and testing, adjusting, and balancing (TAB).

The GSA PM must coordinate start-up and installation activities with the GSA.

Fire Protection Engineer's role in occupancy permitting to include testing for compliance with life safety and code requirements.

8.7.3.4 Test Data Records

Test data records capture outcomes of functional performance testing including test data, observations and measurements. Data may be recorded using photographs, forms or other means appropriate for the specific test. Test data records shall include, but are not limited to, the following information:

- Test reference (number, specific identifier, etc.)
- Date and time of test
- First test or retest following correction of an issue
- Identification of the systems, equipment, and/or assemblies under test including location and construction document designation

- Conditions under which the test was conducted (i.e., ambient conditions, capacity/ occupancy, etc.). Tests shall be performed under steady-state and stable conditions.
- Expected performance
- Observed performance including indication of whether or not this performance is acceptable
- Issues generated as a result of the test
- Dated signatures of those performing and witnessing the test

8.7.3.4.1 Test Issues and Follow-up

The functional performance tests are the heart of the commissioning process, and they are also the most difficult and time consuming. System troubleshooting is a critical function of the CxA.

As inspecting and testing proceed, despite the team's best efforts, the CxA will find a number of items that do not appear to work as intended. There will be a certain amount of system retesting that will be performed by the CxA because of system deficiencies during the initial testing.

In order to assure success, the GSA PM shall allow some time in the schedule and money in the budget for retesting. The GSA PM shall be apprised that issues resolution and associated financial implications are a common point of contention between parties.

If equipment or systems are found to be malfunctioning, these problems shall be documented and listed in the Issues Log for team resolution. The Issues Log must be very clear about the test, system(s) involved, and tracking of the problem as it is corrected.

Both the amount of retesting paid for by GSA versus the amount paid by the contractor and/or designer, as well as the parameters for which parties are responsible for correcting deficiencies, shall be very clearly spelled out in the contracts.

8.7.3.5 Hold Commissioning Team Meetings and Report Progress

Consistent, regular Commissioning Team meetings are essential to maintain the progress of the project and the momentum of the commissioning process.

The schedule of meetings shall be defined, documented, and included in appropriate bid documents during the Design Stage (monthly construction phase Cx Team meetings are recommended).

Team members at meetings must be authorized to make commitments and decisions for their respective parties. The typical agenda for construction phase Commissioning Team meetings shall include items such as previous action items, outstanding issues, schedule review, new issues, etc.

In addition to regular meetings, the CxA is responsible for preparing monthly commissioning process reports during the construction phase. These reports shall include, at a minimum, the following information:

- Progress and status report along with look-ahead
- Identification of systems or assemblies that do not perform in accordance with the owner's project requirements
- Results from latest version of the Issues Log (importance, cost and measures for correction)
- Test procedures and data
- Deferred and seasonal tests (and reason for deferring)
- Suggestions for enhancements that will improve the commissioning process and/or the delivered facility

8.7.3.6 Conduct Owner Training

An important step in the commissioning process is ensuring that GSA Operating Personnel are properly trained in the required care, adjustment, maintenance, and operations of the new facility equipment and systems. It is critical that operations and maintenance personnel have the knowledge and skills required to operate the facility to meet the owner's project requirements. Training shall specifically address the following:

- Step-by-step procedures required for normal day-to-day operation of the facility
- Adjustment instructions including information for maintaining operational parameters
- Troubleshooting procedures including instructions for diagnosing operating problems
- Maintenance and inspection procedures

- Repair procedures including disassembly, component removal, replacement and reassembly
- Upkeep of maintenance documentation and logs
- Emergency instructions for operating the facility during various nonstandard conditions and/or emergencies
- Key warranty requirements

Because of the Commissioning Agent's in-depth knowledge of the design intent and building systems, it is important to have the CxA intimately involved in the training.

The CxA is responsible for facilitating the entire owner training process. This process begins in the Design Stage by assuring that appropriate levels of training are planned and included in the specifications.

The CxA maintains a system-based, as opposed to component-based, focus in the training to ensure that operating personnel understand the interrelationships of equipment, systems, and assemblies. The CxA also reviews agendas and material developed by the contractors in advance of the trainings for quality, completeness and accuracy.

The CxA shall also attend a number of the key training sessions to evaluate effectiveness and suggest improvements in the delivery of the material.

The majority of training shall be done during the construction phase prior to substantial completion. Some systems and assemblies may require ongoing training during occupancy and post-construction. The exact systems, subsystems, equipment and assemblies that require training as well as the required number of hours of training are spelled out in the project specifications. The CM utilizes attendee sign-in sheets to verify that the training was delivered to the intended staff.

The instruction shall be given during regular work hours (for all shifts) on such dates and times that are selected by the GSA Project Manager. The instruction may be divided into two or more periods at the discretion of the GSA PM.

It is highly recommended that all trainings be videotaped. Videotaping trainings allows for future reference of the material and training of new employees down the road.

The team may also wish to consider DVDs in lieu of videotapes for reasons of longevity and convenience.

The Contractor shall be required to provide the GSA PM with an edited draft version of the taped training sessions (generally within seven days), which include all aspects of the operation, inspection, testing and maintenance of the systems.

Technical experts will review the videotape and provide the contractor with comments. The contractor will then resubmit an edited final version of the tape (generally within seven days of receipt of comments).

Instructor Qualifications

- The instructor shall have received specific training from the manufacturer regarding the inspection, testing, and maintenance of the system provided. The instructor shall train the government employees designated by the contracting officer in the care, adjustment, maintenance and operation of the new facility equipment and systems.
- Each instructor shall be thoroughly familiar with all parts of the installation. The instructor shall be trained in operating theory as well as practical operation and maintenance work.

8.7.3.7 Turnover Commissioning Record

It is critical to understand that commissioning documentation is developed throughout the project and turned over before substantial completion. Commissioning documentation turned over at this stage of the project is a result of a well thought out documentation plan and collection of information throughout all of the project phases.

Table (8.10) outlines necessary documentation of the commissioning process by project phase in order to complete the commissioning.

The Commissioning Record shall include a brief summary report that includes a list of participants and roles, a brief building description, overview of commissioning and testing scope, and a general description of testing and verification methods. For each piece of commissioned equipment, the report shall contain the disposition of the CxA regarding the adequacy of the equipment, documentation and training meeting the contract documents in the following areas:

Table 8.10 Commissioning record document

Document	Phase Started	Developed/ Provided By
Commissioning Plan	Planning	GSA PM
Commissioning Plan Appendices		
A. Owner's Project Requirements	Planning	GSA PM
B. Basis of Design	Design	A/E
C. Commissioning Specifications	Design	A/E/CxA
D. Design Review	Design	CxA
E. Submittal Review	Design	CxA
F. Test Procedures	Design	CxA
G. Issues Log	Construction	CxA
H. Construction Checklists	Construction	CxA/Construction Contractor
I. CxA Site Visit & Cx Team Mtg. Minutes	Construction	CxA
J. O&M Review	Construction	CxA
K. Training Documentation	Construction	CxA/Construction Contractor
L. Warranty Review	Construction	CxA
M. Test Data Reports	Construction	CxA/Construction Contractor
Summary Report	Construction	CxA
Recommissioning Management Manual	Construction	CxA/GSA PM

1. Equipment meeting the equipment specifications
2. Equipment installation
3. Functional performance and efficiency
4. Equipment documentation
5. Operator training

The Recommissioning Management Manual provides guidance and establishes timelines for recommissioning of building facilities systems and components. The format of the Recommissioning Management Manual will closely parallel the Commissioning Plan for the facility.

8.7.4 Building Commissioning Process in the Post-Construction Stage

8.7.4.1 Post-Construction Stage

Systems, assemblies, equipment, and components will tend to shift from their as-installed conditions over time.

In addition, the needs and demands of facility users typically change as a facility is used.

The post-construction stage allows for the continued adjustment, optimization, and modification of building systems to meet specified requirements.

The objective of the post-construction stage is to maintain building performance throughout the useful life of the facility.

The active involvement of the Commissioning Agent and the Commissioning Team during initial facility operations is an integral aspect of the commissioning process.

Commissioning activities during Post-Construction include issues resolution, seasonal testing, delivery of the Final Commissioning Report, performing a post-occupancy review with the Customer Agency, and developing a plan for recommissioning the facility throughout its life cycle.

8.7.4.2 Perform Deferred and Seasonal Testing

Due to weather conditions, not all systems can be tested at or near full load during the Construction Phase.

For instance, testing of a boiler system might be difficult in the summer, and testing of a chiller and cooling tower might be difficult in the winter. For these reasons, commissioning plans shall include offseason testing to allow for testing of certain equipment under the best possible conditions.

In addition to seasonal testing, several systems may have been deferred during the initial testing for a number of reasons including prerequisite activities not complete, phased occupancy issues, and improper testing conditions.

The commissioning team must use the Issues Log as a guide during post-construction stage to complete all deferred testing.

8.7.4.3 Re-inspect/Review Performance Before End of Warranty Period

During the first year of the building's operation, it is important to assure that the performance of the facility is maintained, particularly before the warranty period expires.

10 months into a 12 month warranty period, the operation of system and components is critically reviewed by CxA, the owner, and CM to identify any items that must be repaired or replaced under warranty.

This review is based on warranty items and continued performance with the owner's project requirements.

Discrepancies between predicted performance and actual performance and/or an analysis of any complaints received may indicate a need for minor system modifications.

The CxA documents the results and forwards recommendations to Owner and CM for resolution.

The GSA PM shall be cognizant of the impacts of a phased occupancy, if applicable, on the warranty period and make necessary adjustments for review and inspection.

Proper maintenance programs, training, and familiarization of the systems by the new operating staff are important to support post-construction commissioning.

For example, a standard method of recording and responding to complaints must be in place and used consistently.

As equipment and controls are replaced throughout the maintenance program, calibration and performance must be checked, documents revised and any changes or new equipment data sheets included in the operations and maintenance manuals.

Ongoing training includes refresher training of existing personnel, training of new personnel and training of all personnel on newly installed equipment or revised operating procedures.

8.7.4.4 Complete Final Commissioning Report

During Post-Construction, the CxA is responsible for delivering a Final Commissioning Report. This document is additive to those items detailed in the "Turnover Commissioning Record." The Final Commissioning Report shall include the following, at a minimum:

- A statement that systems have been completed in accordance with the contract documents and that the

systems are performing in accordance with the final owner's project requirements document
- Identification and discussion of any substitutions, compromises, or variances between the final design intent, contract documents and as-built conditions
- Description of components and systems that exceed owner's project requirements and those which do not meet the requirements and why summary of all issues resolved and unresolved and any recommendations for resolution
- Post-construction activities and results including deferred and seasonal testing results, test data reports, and additional training documentation
- Lessons learned for future commissioning project efforts
- Recommendations for changes to GSA standard test protocols and/or facility design standards

The Final Commissioning Report will serve as a critical reference and benchmark document for future recommissioning of the facility. In addition, the CxA is responsible at this stage to assure the engineering office is completely updated with the as-built drawings.

8.7.4.4.1 Final Satisfaction Review with Customer Agency

The GSA PM lead a final satisfaction review with the Customer Agency. This review shall occur at one year after occupancy.

Minimum attendees shall include the Commissioning Team and other selected Customer Agency representatives.

The purpose of this review is to obtain honest, objective and constructive feedback on what worked well throughout the commissioning process and what the Commissioning Team could have done better. The group shall be focused on identifying root causes and proposing corrective action for future projects. Specific discussion topics may include the following:

- Owner's Project Requirements
- Systems selected for commissioning
- Coordination issues
- Commissioning budget and costs
- Commissioning schedule relative to project schedule
- Occupant comments/complaints

- Documentation issues
- Lessons learned

The GSA PM takes the lead on documenting this session in a formal lessons learned report. This information will be an important input to future projects.

8.7.4.5 Recommission Facility Every 3–5 Years

At this stage of operation a considerable investment has been put into assuring the facility operates as intended. Understanding that systems tend to shift from their as-installed conditions over time due to normal wear, user requests and facility modifications, it is strongly recommended that Customer Agencies consider recommissioning facilities every 3–5 years.

A facility recommissioning program serves to assure operational efficiency and continued user satisfaction. Maintaining good O&M and occupant complaint records is key to continued recommissioning efforts.

8.7.4.6 Recommissioning

Recommissioning shall generally include the following:

- Establishing that original basis of design and operation is still appropriate for use, occupancy, tenant agencies and GSA goals, and modify the operations/controls sequencing as appropriate for optimum operations
- Reviewing and benchmarking key systems operations/performance against the Basis of Design
- Evaluating envelope tightness/pressurization by infrared or other methods
- Performing energy analysis
- Recommending repairs/modifications to optimize building performance

It is important to recognize that at 3–5 years after occupancy, the GSA PM will likely not still be involved with a particular project. Therefore, the Customer Agency will take the lead on facility recommissioning.

Recommissioning shall include Commissioning Agent services. While there are obvious benefits of familiarity, the Customer

Agency may or may not bring back the project Commissioning Agent. Recommissioning is not part of the original CxA's contract, and therefore the Customer Agency must procure these services through a RFQ/RFP process at the time of recommissioning.

8.7.5 Advantages for Total Building Commissioning System

This system was applied to different administration buildings. Table (8.11) presents the cost for the commissioning a retrofit project. Table (8.12) shows the cost for applying building commissioning to existing buildings. One can see that the cost payback varies from 0.3 to 1.6 years.

Although little research has been completed to document the link between comfort and productivity in the office environment, comfortable employees are generally considered to be more productive than are uncomfortable employees.

Table 8.11 Costs for commissioning retrofit project

Scope	Cost Range
Total building commissioning	0.5–1.5% of total construction contract cost
HVAC and automated control system	1.5–4% of mechanical contract cost
Electrical system	1–1.5% of electrical contract cost

Table 8.12 Existing building system commissioning cost

Building Type	Commissioning Cost (USD in 1995)	Annual Savings (USD in 1995)	Payback Cost (Years)
Computer facilities/ office	24000	89758	0.3
High rise office	12745	8145	1.6
Medical institute	24768	65534	0.4
Retail	12800	8042	1.6

Table 8.13 Annual energy and cost savings from commissioning existing building systems projects

Building Type	Energy Savings	Cost Savings (USD in 1995)
2043 m^2 office	130800 KWh	7736
10200 m^2 office	279000 KWh	12447
5574 m^2 high-tech manufacturing facility	336000 KWh	12168

When occupants of an office building complain of discomfort, additional costs and lost productivity have been estimated to be significant.

One such estimate assumes that the typical building has one occupant per 200 square feet of space and an annual payroll cost of $34,680 per person (or $173 per square foot of office space).

If one out of every five employees spends 30 minutes a month complaining about the lighting, the temperature, or both, the employer loses $0.11 per square foot in annual productivity. In a 100,000-square-foot building, this loss amounts to $11,000 per year.

The comparison of cost savings in energy by applying the building commissioning system for an existing building in 1995 is presented in Table (8.13), noting that the cost saving is about $12,168 for 60,000ft^2 manufacturing facilities.

9

Project Risk Management

9.1 Introduction

Earlier in Chapter 3, risk assessment was discussed from the standpoint of the overall economic prospects, positive and negative, of a project proposal. This chapter discusses how to define, control, and mitigate risks that emerge during project execution.

When studying risk assessment for a project from an economic point of view, the probabilistic studies and Monte-Carlo simulation techniques are key in this assessment, which is called quantitative risk assessment. But this method of analysis and assessment requires special software with specialized skills. On applying risk assessment in the execution phase using qualitative risk assessment tools, as we will describe in detail in this chapter. This assessment method is not required a special skills or software. Risk management during project execution is a combination of experience and qualitative skills, deployed usually by a team involved in the project's execution, led by someone experienced in qualitative risk assessment strategies from other similar projects. One of the greatest sources of risk to be managed is poor, shoddy or otherwise inadequate execution of some programmed task(s) whose correction will increase project costs, time or overall output quality.

Risk potential is less at the end of the project than at the outset.

The risks can be classified in two categories:

- Project risks are the risks that can happen during a project due to technical mistakes that can occur during construction.
- Process risks are the risks that can occur during the project due to procedural mistakes, poor communication between the project team, or poor team performance.

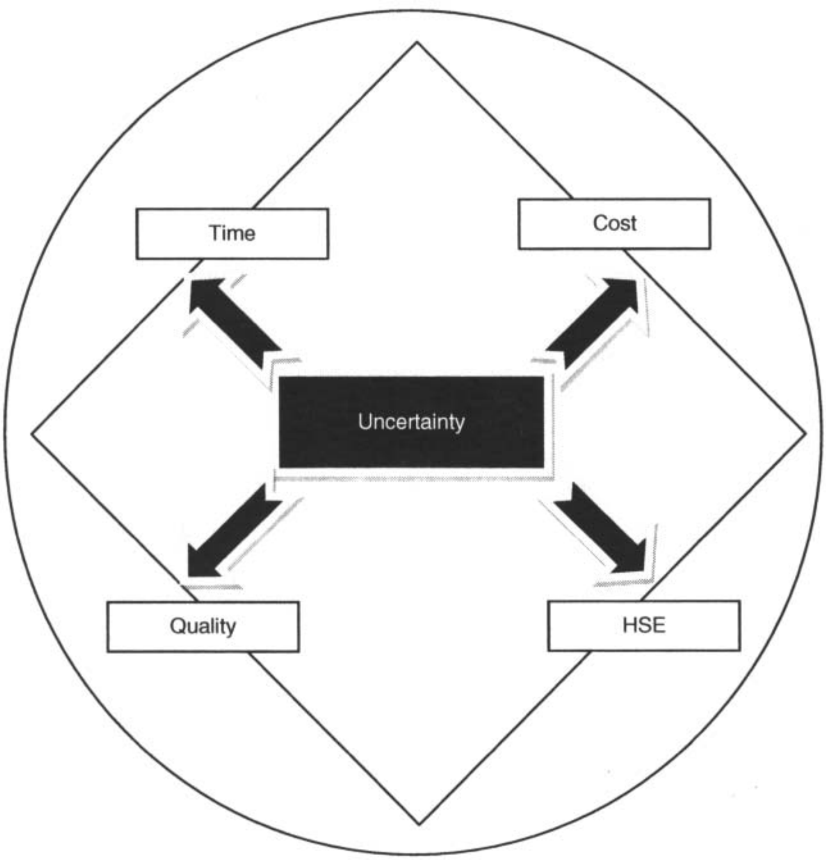


Figure 9.1 Sources of uncertainty.

In general, there are many sources of uncertainties, especially in the main elements of a project, which are cost, time, quality, and HSE as presented in Figure (9.1). Our target is to control these uncertainties, try to predict what could happen, and avoid it in a reasonable time.

As shown in Figure (9.1), the uncertainty involved is like the black box, in which no one can know what will happen. Objectives are things that must happen; uncertainties things that might.

9.1.1 The Risk Management Process

The Project Management Institute (PMI) uses the systems approach to risk management found in the *Guide to the PMBOK*. The risk process is divided into six major processes:

1. Risk management planning
2. Risk identification
3. Risk assessment
4. Risk quantification
5. Risk response planning
6. Risk monitoring and control

These will be discussed in the following section.

9.2 Project Risks

After completing the time schedule, the potential risk will be more obvious. Knowledge of the risks that may be faced during the project is extremely important for the project manager, as he is responsible for identifying the activities of higher risk impact on the overall project implementation, which will either increase the duration or increase the cost.

Therefore, the project manager should review the planning schedule and identify areas of planning that contain high risks, as known from the following:

1. Tasks on the critical path
2. Tasks that need a long time period in which to be executed
3. Tasks that have a little overtime

4. Activities that start with the beginning of other activities
5. Tasks that need many individuals for their execution
6. Complex tasks
7. Activities and tasks that need condensed training
8. Tasks that need new advanced technology

After selecting the tasks that would cause risk to the project and thus determine their position relative to other risks and tasks, the necessary steps to implement those tasks and how to follow up on implementation daily and assign reasonable persons who will be responsible for follow-up in that stage of the project must be identified and planned.

To better illuminate what sorts of things can be considered high-risk activities during project execution, the example of pouring concrete in Chapter 4 is instructive.

One of the riskiest activity of that project is excavation work. It needs a long time period in execution and it lies on the project's critical path. Therefore it has a high probability of delay which has a high potential impact on the complete project.

In any project the longest activity located on the critical path is the riskiest. On the other hand, delivery of machinery and other mechanical equipment ordered abroad has a known and hence more manageable risk of suffering delays. The consequences of such delay may be somewhat mitigated by rearranging tasks that can be performed without that equipment, to be started or finished before delivery of the equipment. The complexity of such task rescheduling will be a function of how many other activities depend on the delivery of the awaited equipment. Both these examples — excavation and awaiting delivery of needed equipment — have a high-risk assessment, as they lie beyond the full control of project management.

The success of the project means that the project's objectives were achieved according to a specific time schedule and budget. During the project's execution, however, specific costs, the time period, and the objectives of the project can increase or decrease. These three elements affect one another, so the project success is really a measure of how cohesively these elements work together, as presented in Figure (9.2).

From the probability theory discussed earlier in Chapter 3, it emerges that the probability of success is small. The goal is to locate the project in the zone of mutual intersection.

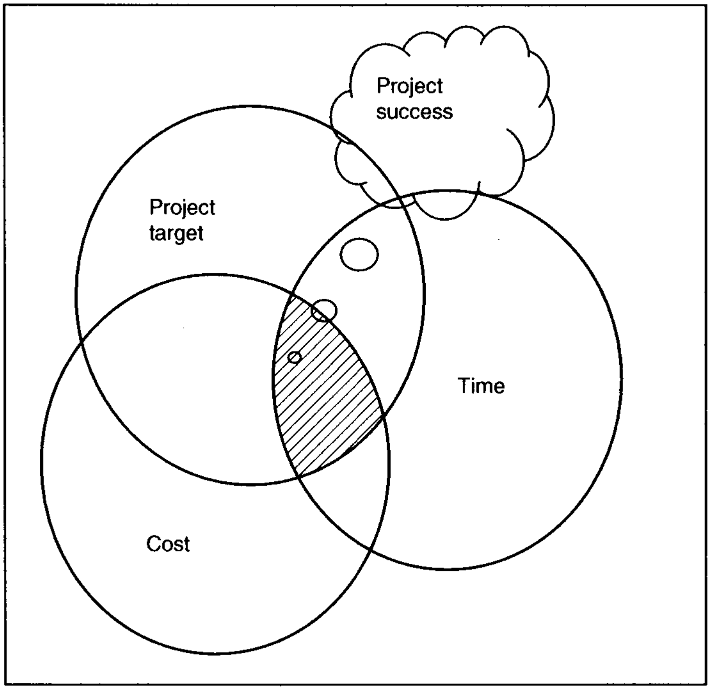


Figure 9.2 Point of project success.

There are many areas in the project that are not specific, and these are sources of risks. These can be any of the following:

- Activities of a long period of time and on the critical path
- A lack of identification of the project objectives
- A non-competent project manager
- An inaccurate cost estimate
- A bad atmosphere, in general, in the project
- Achieving customer satisfaction
- A rapid change in resources during time periods, as shown in Figure (9.3)

Figure (9.3) presents staff and other resources distribution onsite within a construction period. At the start of the project, the activities and resources are low. There is a transition zone, in which resources increase consequent upon an increase in activities. This transition

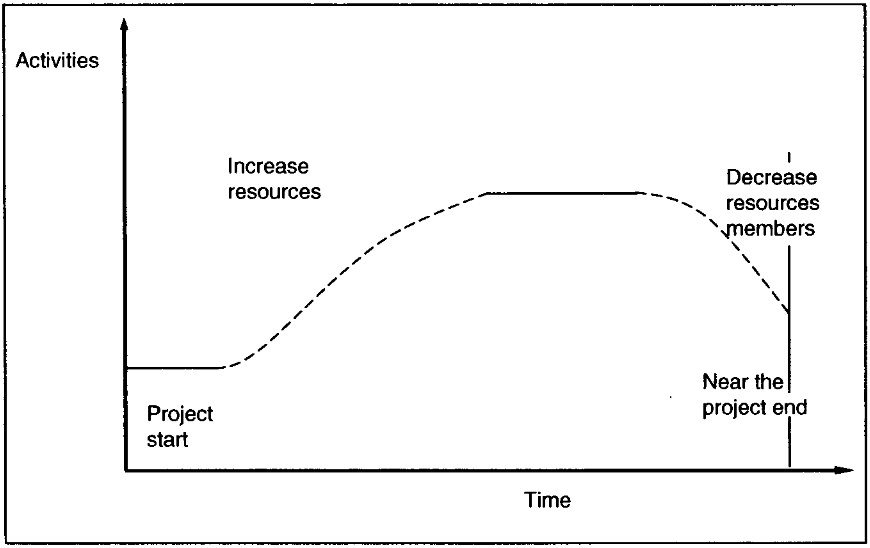


Figure 9.3 Change in staff volume during a project.

zone will be one of high risk, as it will rapidly increase the working resources in the project in a short time period. Therefore, the likelihood of bad quality, misunderstanding the objective, and mistakes in safety procedure will be very high.

In the middle of the project, there will be stability in the number of resources, so the risk will be less. After that, start the other transition zone by decreasing the resources which this stage will be a high risk also as in this case there will be a likelihood of manpower shortage fast and missing the handover or transfer equipment by mistake that you may need it later, in the same time the staff decreasing, so everyone in the project will be busy for searching to the other opportunity in another projects.

The list below can be your guide as a checklist for defining uncertainty risks in your project. In general, the common sources of uncertainty in a project are as follows:

- Scope of work
- Quality of estimates
- False assumptions
- Technological novelty
- Changes in technical specs

- User interface
- Staffing
- Staff productivity
- Skill levels
- Contractor performance
- Subcontractor performance
- Approvals and funding
- Market share
- Competition
- Economic climate
- Inflation and exchange rate
- Site conditions, such as soil characteristics
- Weather, as it has a high impact in the case of offshore projects
- Transportation logistics
- Change in law
- Political environment
- Public relations
- Customers
- Extensive software development

9.3 Risk Assessment

The risk assessment procedure is shown in Figure (9.4). The first step is to define the expected risks during the project execution and then analyze this risk. The last step is to prioritize these risks.

Each project has a risk, no matter what the project. Focusing on the risks affecting the management of the project, priorities can be set to develop solutions and mitigation.

In order to assess these risks, the following questions must be addressed accurately and impartially:

- What is the risk exactly?
- How do these risks affect the project?
- What can be done to reduce the impact of the risks?

In this stage the risks will be assessed by their effects on the objectives, time, and cost. Now we need an easy way to assess the risks practically, and this method is called "qualitative risk assessment."

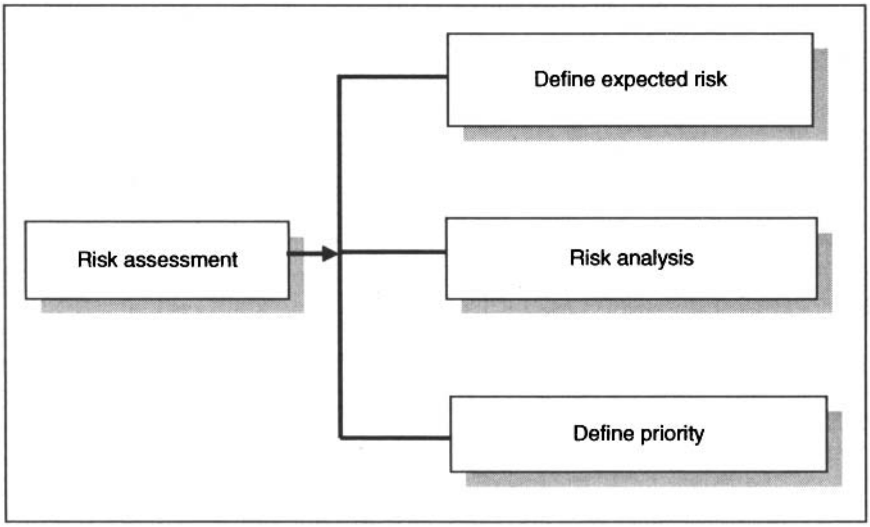


Figure 9.4 Risk assessment tools.

9.4 Risk Identification

The identification of risks is very important. Each item must be described in detail so that it will not be confused with any other risk or project task that must be done. Each risk should be given an identification number. During the course of the project, as more information is gathered about the risk, all of this information can be consolidated.

Initially a meeting of the working team should convene to discuss and identify risks. The meeting should be convened offsite at a hotel or other meeting room away from the work environment. The reasons for such an approach are twofold. First, the team has to start working together, and for this some discussion venue away from the stress of the workplace work can help "melt the ice." Second, team members' minds need to work free from any outside stress, so that the benefits of their previous experience can be brought more fully into play.

At this meeting, a "brainstorming" approach can be applied to encourage each individual to bring forward his or her own thoughts regarding expected risks during the project. These can be collected and reduced to written form in the order illustrated in Table (9.1). This list will become a basic document of the project.

Table 9.1 List of project risk

Project Name:							
Project Manager:							
Client Name:							
Responsible	**Risk Degree: High Medium Low**	**Date**	**Impact: High/ Medium/ Low**	**The Probability: 1–9**	**Risk Description**	**Key Stage Code**	**Item No.**
Project manager signature:						Date:	

The first component to discuss is the identification of the risk event. The project team, subject-matter experts, stakeholders, and other project managers are all called upon to contribute to this risk-identification process. Much of the work already done in the project will be utilized in the risk management process. Among these items that will be used are the project charter, the work breakdown structure, project description, project schedule, cost estimates, budgets, resource availability, resource schedules, procurement information, and assumptions that have been made and recorded.

9.4.1 Methods of Defining Risk

There are many ways to discover and identify risks, several of which are discussed here. Brainstorming remains the most traditional and practical method for "kicking off" this process, although other approaches can also be used in special circumstances:

- Brainstorming
- Delphi technique
- Nominal group technique
- Crawford slip
- Expert interviews
- Root cause identification
- Checklists
- Documentation reviews
- Strengths, weaknesses, opportunities, and threats (SWOT) analysis
- Analogy

9.4.1.1 Brainstorming

Brainstorming, probably the most popular technique for identifying risks, entails a session, usually not more than two hours long, involving between ten and fifteen participants. Less than 10 risks limiting interaction, while more than 15 poses problems of meeting control / chairmanship and maintenance of focus. (For larger projects, it may be necessary to hold several meetings. In that case, each session addresses only distinct parts of the project and the risks that could arise in that part.) The facilitator / chair should come from a part of the organization not involved in the immediate project and its risk issues, but who has some experience with the type of project involved.

The facilitator introduces the project briefly. A chart hanging on the wall indicates the project time schedule and key stages. The facilitator defines at the outset the stakeholder(s), budget, and location of the project.

From this point, a dialogue begins about the potential risks, directed by the facilitator and team leader. At this point, before discussion is engaged on any particular item, every expected or defined risk should be put on a list visible to all. After this listing task is completed, the next stage of actual brainstorming can be launched. Care should be taken by the facilitator with regard to the following:

- Not to stop or reject any idea.
- Not to entertain any suggestion to remove any idea.
- Not to allow interruption of the discussion.
- Not to permit too-deep delving into the detail of any particular risk item.

The collected list of items can now be "filtered," and any two or three more or less similar connected risks merged with a single more general one. The result becomes the content to be filled into Table (9.1).

9.4.1.2 Delphi Technique

Brainstorming has potential disadvantages. When meeting attendees are not familiar with risk assessment technique, their suggestions may not be particularly helpful. If there is a high level manager in the meeting room, individuals may feel a certain chill about uttering their thoughts too forthrightly. Furthermore, the meeting method can miss taking note of important sources of risk. The effort will have been vitiated if, later during project execution, potential risks emerge that were not identified back at the time of the brainstorming session.

The Delphi method is not traditional in practical life, but it has its uses and advantages for focusing the consciousness of key project personnel not only upon identifying sources of risk but also their own responsibility, both individual and collective, to be prepared to manage whatever risks emerge during project execution. The name "Delphi" is derived from the Oracle of Delphi. The authors of the method were not happy with this name, because it implies "something oracular, something smacking a little of the occult." The Delphi method is based on the assumption that group judgments are more valid than individual judgments.

The Delphi method was developed at the beginning of the Cold War to forecast the impact of technology on warfare (1999). In 1944, General Henry H. Arnold ordered the creation of the report for the U.S. Army Air Corps on the future technological capabilities that might be used by the military.

Different approaches were tried, but the shortcomings of traditional forecasting methods, such as theoretical approach, quantitative models, or trend extrapolation, in areas where precise scientific laws have not been established yet, quickly became apparent. To combat these shortcomings, the Delphi method was developed by Project RAND during the 1950s and 1960s (1959) by Olaf Helmer, Norman Dalkey, and Nicholas Rescher (1998). It has been used ever since, together with various modifications and reformulations such as the Imen-Delphi procedure.

This method is based on the idea that the opinion of a group is better than the opinion of one person. As during the Vietnam War when the US Chiefs of Staff repeatedly resorted to this approach, the Delphi method was used by asking experts to give their opinion on the probability, frequency, and intensity of possible enemy attacks. Other experts could anonymously give feedback. This process was repeated several times until a consensus emerged.

In the same way, every expert in this type of project should be queried separately about the expected potential risk of the project. Nowadays, this method is easy due to e-mail, video conferences, and other methods of communication that appear every day. The process begins with the facilitator using a questionnaire to solicit risk ideas about the project. The responses from the participants are then categorized and clarified by the facilitator. Several such rounds of one-on-one may be repeated until a consensus emerges around the final list of project risks. The largest benefit from this method is its relatively low cost, but it makes greater demands on whoever fills the facilitator role.

9.4.1.3 *Nominal Group Technique*

The nominal group technique is similar to the brainstorming meeting. In this variant, the facilitator requests everyone in room write down their idea of risks to anticipate. This modified brainstorming approach works well with groups of 7 to 10 persons. Each participant's list is posted on a flip chart or blackboard. Up to this point, no discussion has been engaged; that proceeds after the flip-chart or blackboard list is compiled. Risks that are similar can be grouped.

While this process reduces the possibility of excessive influence of a high-ranking person on other members of the group, it does not eliminate it like the Delphi technique does. The nominal group technique is faster and requires less effort on the part of the facilitator than the Delphi technique.

9.4.1.4 *Crawford's Slip*

The Crawford's Slip process has become more popular in recent times. The meeting procedure is that of the brainstorming technique. Advantages of this approach include the lack of any limit on the number of participants and the reduced burden on a facilitator. Its advantage is that it produces a lot of ideas very quickly. On individual pieces of paper (Post-It-Notes are popularly used), participants write down a single suggestion in answer to a facilitator-posed question such as: "What risks could you could anticipate during this project?" There might be 10 suggestions each from 10 participants, creating 100 answers to the one question that are subsequently filtered and grouped under more or less common rubrics. The entire process can take as little as half-an-hour for a small group, but it gets longer faster for larger groups.

9.4.1.5 *Expert Interviews*

An expert source, preferably from within the company, can be consulted for his/her views of the risks to watch out for. Selection of an outside expert may roil internal company politics by implying, at least in the minds of some, that the company's own personnel may be insufficiently expert to manage certain tasks that an outside "expert" might tend to focus upon. For example if a company's procurement policies and facilities are weak or insufficiently developed, senior management might be leery of having an outside expert come in, take notice of this deficiency and spread some hint to competitors about this vulnerability. Probably the single greatest material benefit of using "in-house" expertise is that comes free of any charge over and above continuing to pay that employee's regular salary.

All data on the project is collected before the interview for presentation to the expert. The goals of the interview should be clearly understood by the expert going in, and the interview itself, or detailed notes of his views, recorded. If more than one expert is used, information from the interviews should be consolidated and circulated to the other experts.

9.4.1.6 Root Cause Identification

This method, based on "Root Cause Analysis" (RCA), is used in conjunction with the brainstorming technique and other similar meetings, as the facilitator should be able to define the root cause in any item. The goal of RCA is to find answers to the questions about what, how, and particularly why something could go wrong in the project. This method researches deeply into event probabilities and consequences beyond the immediate cause of the unwanted event. For example, assume that there has been a delay in performing a job offshore due to weather. This method needs to define the way to obtain the weather forecast. For another example assume the potential risk is that spare parts will be delivered late on the offshore platforms. Subsequent investigation uncovers the fact that there was a high wind speed and the transfer of the parts was delayed for five days. The root cause of the problem is not the high wind speed. The root-cause approach establishes that ordering the mechanical spare parts early enough to allow for the likelihood of bad weather could avoid repetition of this problem.

9.4.1.7 Checklists

Checklists have gained popularity in recent years because of the ease of communicating through computers and the ease of sharing information through databases. Every company has established checklists based on their experience, and examples of some of the risks are presented in section 9.2. However, while the checklist is based on concrete thinking around what is known and set out in the checklist, the anticipation of risk and its possible consequences demands a freer-thinking approach that allows thinking "outside the box" of any checklist, no matter how apparently exhaustive.

9.4.1.8 Documentation Review

This method depends on reviewing lessons learned from previous projects. Its use must be approached with some care, however.

Project close-out reports are the usual documentary source of reviews of lessons learned from improper management of unanticipated risks or other failures during project execution. However, ISO standards setting out quality standards to be maintained at all stages of project execution may neither have been followed nor existed for many projects executed before the 1990s, not to mention the broad principles that Project Management Professionals are expected to be following today. The documentary review method works best for companies that have performed this type of project before many times, and maintained their own database of lessons learned. Its inherent attractiveness is cost, which is effectively zero.

9.4.1.9 SWOT (Strengths, Weaknesses, Opportunities, and Threats) Analysis

Among other methods used in defining risk, the SWOT method is probably those single most widely applied practical tool. At its core is a diagrammatic approach that identifies "strengths, weaknesses, opportunities and threats" by developing a flowchart of the expected sequence of project execution. Like expert interviews, checklists and documentation review, this approach develops a new document on the basis of information gathered and recorded earlier in other formats.

9.4.1.10 Analogy

The analogy method is part of the document review, as this method depends on obtaining the risk management plan of other projects that were similar, an analogy can be formed. By comparing two or more projects, you can find similar characteristics for each project can be found from which to gain an overview of the risks of the new project.

9.4.2 Grouping of Risks

After defining the entire range of events that may occur during project execution, affect the project objective or increase the project time or cost, the risks need to be grouped. Quantitative methods are employed to rank identified areas of risk, which also serves to establish the key stage of the project by relatively objective criteria. Project participants are then brought together in a brainstorming session aimed at forming a consensus as to what risks are likeliest in which time periods, and their possible effect on project cost and time targets.

Grouping risks will be more important for large projects than small ones. The general consensus in the business world is that if it takes more than ten people to meet and deal with a group of risks, the meeting is probably too large and will be inefficient. As projects become larger, it is necessary to have a series of risk management meetings, whereas in a small project, one meeting might do. To facilitate this, techniques similar to the techniques that were used in the development of the work breakdown structure can be used. Indeed, the WBS itself can be used to organize meetings for risk management.

Responsibility to look for risk should be assigned to the person most closely associated with where the risk will have its largest impact, or to the person who has the most familiarity with the technology of the risk. A risk that takes place during the completion of a particular task and directly affects only that task should be a concern to the person responsible for that task. However, since no task in a project is truly independent of all the others, the assignment of responsibility moves up the organizational ladder to the individual above the person directly or immediately responsible for the task.

Often in projects where risk is of great concern, the project manager creates the position of risk manager. This person is responsible for tracking all risks and maintaining the risk management plan. As projects become larger or tolerance for risk is low, this approach becomes more necessary.

The responsible person who will mitigate and follow up this task should be defined clearly, and his or her name can be place in Table (9.3), at the end of Section 9.5.1 below.

9.5 Defining Priorities

There are many ways to define the risk ranking for each risk item that was defined before. In this step, the facilitator will ask the team in the meeting to define the degree of the likelihood that the event will occur and also define how much it can impact the project. There are two traditional methods. The matrix method is the most popular and is defined in the PMBOK guide. The other way depends on ranking the risks in a table and defining them in three categories: red, yellow, and green for every identified risk.

9.5.1 Matrix Method

In a previous meeting, everyone wrote down all expected risks. Now a determination needs to be made concerning the priority of those risks. This involves a two-stage evaluation process.

In the first phase, the likelihood of a risk is determined and rated it from 1 to 9, 1 symbolizing the least likely and 9 the most likely. In the second stage, the team determines the impact / outcome of an event upon the project, or the expected losses due to this event occurring. This is then prioritized as follows:

- High: It has a greater significant impact on the time schedule or the cost of the project.
- Medium: It has a medium impact on the time schedule and cost.
- Low: It has a lower influence on the time schedule and little impact on the cost.

In summary, the following table can be used to determine the risk priorities.

The team must know what is the probability that the event will occur and what its impact to the project. The impact will be obtained through the discussion for each event by answering the two questions: what is the probability of potential risks, and what is their impact on the project The category of the risk can be obtained directly from the matrix just illustrated in Table (9.2).

- Any event posing an ***unacceptable risk*** needs to be analyzed thoroughly and with great precision. These are the risks that threaten the project as a whole, so the focus must be on measures that would reduce or remove the risk or its impact before it could happen.

Table 9.2 Risk ranking score

		Impact on the project		
Probability of event occurring		Low	Medium	High
	7–9	Medium	High	Not acceptable
	4–6	Low	High	Not acceptable
	1–3	Low	Medium	High

- A ***high-risk*** situation is distinguished from an unacceptable-risk situation by the fact that it would be costly but not necessarily fatal for the project as a whole. Management of high-risk situation requires sustained monitoring.
- The potential damage of a ***medium-risk*** event, associated with an impact on some but not all key points of the project, may be mitigated by ongoing review at each meeting of the project of actions taken to manage this risk and of any follow-up.
- The ***low-risk*** event is one that is not expected to have significant impact on the project but on a watching brief is consciously maintained. Also to be paid careful attention are changes in the actual unfolding and implementation of the work plan of the project and their potential to increase or lower the risks identified on the matrix, and or their priority within it.

After all the risks have been identified individually, they are ranked from lowest-risk to unacceptable, Solutions are proposed and responsibility assigned in each case, and the complete panorama is registered according to the schema outlined in Table (9.3).

Table 9.3 Risk management

Project:	
Project Mgr.:	
Risk Number:	**Risk Title:**
Risk Description:	
Risk Degree:	**Probability: 1 2 3 4 5 6 7 8 9** **Impact: High Medium Low**
Project areas that will affect by the event:	
Ordering of the event impact on the project:	

Table 9.3 (cont.) Risk management

Who is responsible:	**Solution step:**
Prepared By:	
Project Mgr. Sign.:	**Date:**

9.5.2 Tabulated Method

Another approach to calculating the project risk is to estimate the probability of its occurrence with the knowledge of the possible impact of such an event on the project as a whole. This contingency makes it possible and necessary to put a monetary value on the aforesaid risk, and define the degree of the event's impact on the project accordingly.

Some modern views are inevitable to take into account the ability to manage the event and to understand that there are some events that can be managed easily where other event that is more complicated to manage. This approach is vital special in calculating the risk in project execution phase, undoubtedly contributing to the rapidity with which it has entrenched itself as one of the most widely-recognized and applied methods for estimating and managing project risks during execution. There is a second additional subtlety that emerges from the fact that, as knowledge and technology both advance, many specific risks come to be managed and handled more pro-actively. Not surprisingly, therefore, one of the columns of this particular tabulation approach indicates the "manageability" of an identified risk. The subtle point here is that the manageability of many kinds of risk may be improved as part of sorting out inter-departmental discrepancies addressed during interdepartmental meetings that take place from time to time in any event, i.e., without necessarily having to prepare any particularly exceptional budgetary or scheduling contingency solely for the purpose of addressing the risk in question. Accordingly, following this risk-tabulation method, such an item, because of this acknowledged higher manageability, would and should be given a lower score, decreasing the overall risk score. If the source of the risk is related to contact involving some outside organization, such as licensing or other special permissions from a government department, the fact that neither the contractor nor the owner has it in their power to manage this eventuality means its degree of risk lies beyond the project's control and must therefore be assigned a higher, if not the highest, score.

This tabulation method is arranged to be applied in a face-to-face meeting of all those with project responsibilities. The ranking of probability and impact (consequence), is relatively simplified, using the numbers 3, 2, 1 to rank what is high, medium and low, respectively. Manageability is ranked 1, 2, 3 for high, medium, and low respectively.

In defining impact, the pessimistically-minded manager will tend to rank everything as highly probable, while the carelessly-minded one can be expected to rank everything as less probable. The project manager or his designate in charge of this meeting, therefore, should proactively define the probability as follows:

- High probability – if the probability of occurrence is higher than 50%
- Medium probability – if the probability of occurrence is 10–50%
- Low probability – if the probability of occurrence is less than or equal to 10%

The same criteria should be defined by the facilitator and team leader before assessing the risks. This criterion is different from one project to another based on size and budget. The assumed criteria for the example in Chapter 4, as will be discussed in Section 9.8, is as follows:

- High consequence – when the risk becomes reality and the impact on the project will cost higher than or equal to $500,000
- Medium consequence – when the risk becomes reality and the impact on the project will cost between $50K and $500K
- Lower consequence – when the risk becomes reality and the impact on the project will cost less than $50K

9.6 Risk Response Planning and Strategies

Risks having been identified, the next task is what is to be done about them, or in managerial jargon: risk response planning.

Risk response planning is the process of developing the procedures and techniques to enhance opportunities and reduce threats to the project's objectives. In this process it will be necessary to assign individuals who will be responsible for each risk and generate a response that can be used for each risk.

Risk response strategies are techniques that will be used to reduce the effect or probability of the identified, or even the unidentified, risks.

Of course, in the case of opportunities we should want to increase the probability and increase the impact. The opportunity can be exploited by adding resources to encourage and maximize the effect. Opportunities can be shared. In the case where our own organization is not able to maximize an opportunity, a partnership or other arrangement with another organization may be made where both organizations benefit in a greater way than one of them can. By enhancing an opportunity we can maximize the drivers that positively impact the risks. Both impact drivers and probability drivers may be enhanced.

In terms of the risk strategy that should be employed, a qualitative or quantitative evaluation of the severity of the risk will be a guideline as to how much time, money, and effort should be spent on the strategy to limit the risk.

9.7 Risk Monitoring and Control

Risk monitoring and control is the process of keeping track of all the identified risks and identifying new risks, as their presence becomes known, and residual risks that occur when the risk management plans are implemented on individual risks. The effectiveness of the risk management plan is evaluated on an ongoing basis throughout the project.

Figure (9.5) presents the steps of risk monitoring and control. After obtaining the priority for each risk, you should obtain a solution with the project team and then agree on the emergency plan and, according to every risk, define the monitoring system that you will follow as the project manager.

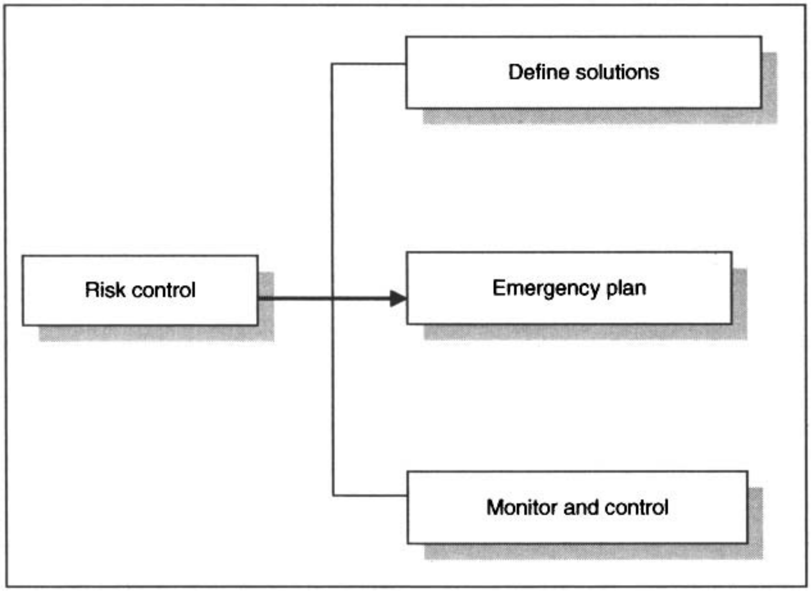


Figure 9.5 Steps in controlling the risks.

When a risk is apparently going to eventuate, a contingency plan is put into place.

If there is no contingency plan, then the risk is dealt with on an ad hoc basis using what is termed a "workaround." A workaround is an unplanned response to a negative risk event. A corrective action is the act of performing the workaround or the contingency plan.

The concern of the project manager and the project team is that risk responses have been brought to bear on the risk as planned and that the risk response has been effective.

After they have observed the effectiveness of the risk response, additional risks may develop or additional responses may be necessary.

Risk management is a continuous process that takes place during the entire project from start to end. As the project progresses, the risks that have been identified are monitored and reassessed as the time that they can take place approaches. Early warning indicators are monitored to reassess the probability and impact of the risk. As the risk approaches, the risk strategies are reviewed for appropriateness, and additional responses are planned.

Risk assessments, reviews, and audits may be performed periodically to review the probability and potential impact of risks that have been identified and are nearer to their possible occurrence. Risks that have already taken place can be reviewed and audited to assess the effectiveness of the risk response.

As each risk occurs and is dealt with or is avoided, these changes must be documented.

Good documentation ensures that risks of this type will be dealt with in a more effective way than before and that the next project manager will benefit from these lessons learned.

9.8 Example

Consider a small project for new gas compressor. When looking at the project, everyone may jump to conclusions and define what he or she is afraid might occur during the project. In fact, when we go through the meeting using brainstorming, we may find the output from the following table (9.4).

9.9 Methods of Risk Avoidance

There are many ways to reduce the risk in general, and these methods depend on eliminating the source of risk or transferring the risk to a third party. If this is done with a firm fixed-price contract, the risk is effectively transferred to the vendor.

Generally, in firm fixed-price contracts the vendor will always raise the price of the service to compensate for the effect of the risk. In addition to that the warrantees, performance bonds, and guarantees are additional methods for transferring risk.

The following techniques can be used to reduce and avoid risks:

- Clarifying requirements and objectives
- Improving communication
- Obtaining information
- Acquiring expertise
- Changing strategy
- Reducing scope
- Adopting familiar approach
- Using proven methods, tools, and techniques

Table 9.4 Risk assessment weight and monitoring sheet

ID	Description	Owner	Probability H>=50% =3 M 10–50% =2 L<=10% =1	Overall Consequence H=>500K$ =3 M=50–500K$=2 L<=50K$=1	Manageability L=3 M=2 H=1	Score Max 27	$K If Risk Comes True	Weeks Delay If Risk Comes True	Risk Reduction Action	Date Identify	Date Close
1	manufacturer delivery on time	SCM	1	3	2	6			To monitor performance regularly		
2	pump not match with specs requirement	ME	1	3	1	3			Review specs with the manufacture/ clarification meeting with the vendor		
3	anchor bolt and dimension problems during construction	CE	1	1	1	1			Review drawings with machine		
4	permits to work from operation	CM	1	1	1	1			a meeting with operation		
5	Shut down plan coordination	CM	3	3	2	18			Meeting with operations		

6	Missing bolts for thief	CM	1	1	2	2			security guard		
7	weather effect during construction (fog)	CM	2	1	2	4			Late work hours procedure/ telecom		
8	H2S leakage in plant	CM	1	1	3	3			Procedure to overtime policy		
9	Security pass to enter plant	CM/ SD	2	2	2	8			Review security every month with the contractor		
10	Procurement approval	SCM	1	2	2	4			Sign by hand/ presentation to management		
11	lake in labour language	CM	1	1	2	2			training matrix		
12	Pump truck manoeuvre	HSE	1	2	1	2			Discuss moving by location layout		

Table 9.4 (cont.) Risk assessment weight and monitoring sheet

ID	Description	Owner	Probability H>=50% =3 M 10–50% =2 L<=10% =1	Overall Consequence H=>500K$ =3 M=50–500K$=2 L<=50K$=1	Manageability L=3 M=2 H=1	Score Max 27	$K If Risk Comes True	Weeks Delay If Risk Comes True	Risk Reduction Action	Date Identify	Date Close
13	crane mobilization	CONT	2	3	2	12			Check with the crane		
14	late of concrete delivery	CONT	1	2	1	2			Confirm with the contractor		

Where:

CM is the construction manager

SCM supply chain manager

CONT is the contractor

SD security department

HSE health, safety and environment department

ME mechanical engineering department

CE Civil engineering department

You can transfer risk by transferring liability and ownership through the following:

Financial means:

- Insurance
- Performance bond, warranty

Contractual means:

- Renegotiate contract conditions
- Use subcontractor in parts of the project
- Joint ventures/ teaming
- Risk-sharing partnership with client
- Target-cost
- Note limit to which risk can be transferred
- Note that transfer usually involves a price tag

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10

Quiz for Project Management

10.1 Introduction

The following quiz is designed as a complement to the previous chapters of this book. The objective is to develop a checklist of the most important determinants of correct decisions. The right decision may differ from one project to another, and it is based on ambient conditions. The questions here are for general cases, and the answers are based on the *Guide to the Project Manager's Body of Knowledge* (PMBOK). The questions are posed so as to assist decision-making in real-life situations where more of the scenario may be gray rather than black or white.

10.2 Questions

Choose the best answer to the questions using the multiple choices. The answers with clarifications are in Section 10.3.

1. The construction manager is away from the project and is replaced by a new one. The project manager meets with the replacement

construction manager and his team. In this meeting, what is the first issue the project manager should start on in the meeting?

- Introduce team members.
- Communicate the objectives of the project.
- Clarify the authority.
- Create a communication plan.

2. After you have been assigned to a project, according to the schedule 50% of the project should be completed. You discover that the project is running far behind schedule. The project will probably take double the time originally estimated by the previous project manager. On the other hand, you discover that upper management has been informed that the project is on schedule. What will be the BEST action?

- Try to restructure the schedule to meet the project deadline.
- Turn the project back to the previous project manager.
- Report your assessment to upper management.
- Move forward with the schedule as planned by the previous project manager and report at the first missed milestone.

3. You are a project manager on an international project of great importance to the client. The client is from another country and is so excited by how well the project is going that he presents you with a company automobile for your personal use. The BEST thing for you to do would be to:

- thank him and offer a gift in exchange.
- politely turn down the gift.
- ask that the gift be changed to something that can be shared by the team.
- ask for a gift that can be used before you return home.

4. The client project manager asks you to provide a written cost estimate that is 30% higher than your estimate of the project's cost. He explains that the budgeting process requires managers to estimate pessimistically to ensure enough money is allocated for projects. What is the BEST way to handle this?

- Add the 30% as a lump sum contingency fund to handle project risks.

- Add the 30% to your cost estimate by spreading it evenly across all project tasks.
- Create one cost baseline for budget allocation and a second one for the actual project plan.
- Ask for information on risks that would cause your estimate to be too small.

5. You are reviewing bids from various contractors for work on your project. One of the bidding contractors has a history of delivering on time within budget, and you have personally worked with this company successfully on previous engagements. You receive a call from the manager submitting the bid inquiring about how the process is going. He asks to have lunch with you to discuss the bid. What is the BEST response?
   - Do not mention the other bidders but simply inform him that based on past experience, he has a good chance of winning the business.
   - Inform him that it would be inappropriate to discuss the matter at all, and inform the customer or a team member of the conversation.
   - Inform him that it would not be appropriate to discuss the matter over the phone during business hours, but that an informal lunch discussion would be more appropriate.
   - Politely avoid continuing the conversation and disregard the bid.

6. All of the following are part of the team's stakeholder management effort EXCEPT?
   - Giving stakeholders extras
   - Identifying stakeholders
   - Determining stakeholders' needs
   - Managing stakeholders' expectations

7. There are over 20 stakeholders on your project. The project is running in another country with people from three countries as team members. Which of the following is the MOST important thing to keep in mind?
   - The communication channels will be narrow.
   - Many competing needs and objectives must be satisfied.

- There must be one sponsor from each country.
- Conflicts of interest must be disclosed.

8. Your management has decided that all orders will be treated as "projects" and that project managers will be used to update orders daily, resolving issues and ensuring that the customer formally accepts the product within 30 days of completion. The revenue from the individual orders can vary from US $100 to US $150,000. The project manager will not be required to perform planning or provide documentation other than daily status. How would you define this situation?
   - Because each individual order is a "temporary endeavor," each order is a project - this is truly project management.
   - This is program management since there are multiple projects involved.
   - This is a recurring process.
   - Orders incurring revenue over US $100,000 would be considered projects and would involve project management.

9. Who determines the role of each stakeholder?
   - The stakeholder and the sponsor.
   - The project manager and the stakeholder.
   - The project manager and the sponsor.
   - The team and the project manager.

10. A project manager has a problem with a team member's performance. Choose the best way of communication to address this problem:
    - Formal written communication
    - Formal verbal communication
    - Informal written communication
    - Informal verbal communication

11. You are the project manager for a large government project. This project has a multi-million dollar budget which will be spent over 2 years; the contract was signed 6 months ago. You were not involved in contract negotiations or setting up procedures for managing changes, but now you are involved with changes from the

customer and from people inside your organization. Who is normally responsible for formally reviewing major changes in the project or contract?

- The change control board
- The contracting/legal department
- The project manager
- Senior management

12. You are a new project manager for company (X). You previously worked for company (Y) that had an extensive project management practice. Company (X) has its own procedures, but you are more familiar with and trust those from company (Y). What should you do?

- Use the practices from company (Y) but include any forms from company (X).
- Use the forms from company (X) and begin to instruct them on ways to upgrade their own.
- Talk about changes to the change control board of company (X).
- Interact with others in an ethical way by sharing the good aspects of company (Y)'s procedures.

13. You as the project manager discover a defect in a deliverable that should be sent to the client under contract today. The project manager knows the client does not have the technical understanding to notice the defect. The deliverable technically meets the contract requirements, but it does not meet the project manager's fitness of standard use. What should the project manager do in this situation?

- Issue the deliverable and get formal acceptance from the customer.
- Note the problem in the lessons learned so future projects do not encounter the same problem.
- Discuss the issue with the customer.
- Inform the customer that the deliverable will be late.

14. Your customer requires a 3,000-call capacity for the new call center project. However, one of your company's technical experts believes a 4,000-call capacity can be reached. Another thinks that

based on the technical needs of the customer, the capacity needs to be only 2,500 calls. What is the BEST thing to do?

- Meet with the customer to better understand the reasons behind the 3000 call capacity.
- Set the goal at 4,000 calls.
- Meet with the technical experts and help them to agree on a goal.
- Set the goal at 3,000 calls.

15. One employee is three days late with a report. Five minutes before the meeting where the topic of the report is to be discussed, he gives you the report. You notice that there are some serious errors in it. What will be your action?

- Cancel the meeting and reschedule when the report is fixed.
- Go to the meeting and tell the other attendees there are errors in the report.
- Force the employee to do the presentation and remain silent as the other attendees find the errors.
- Cancel the meeting and rewrite the report yourself.

16. You are a project manager working on a multimillion-dollar project. As the project has progressed, you have become friends with the general contractor. You are working on a $100,000 change request. He has offered to let you use his villa on the coast for the next weekend as he will be away in another country. What should you do?

- Accept the offer with thanks.
- Decline the offer.
- Decline the offer and report it to your supervisor.
- Ask your boss to approve your use of the boat.

17. You are working on a large construction project that is progressing within the schedule. Resource usage has remained steady, and your boss has just awarded you a prize for your performance. One of your team members returns from a meeting with the customer and tells you the customer said he is not happy with the project progress. What is the FIRST action you should take?

- Tell your manager.
- Complete a team building exercise and invite the customer's representatives.

- Change the schedule baseline.
- Meet with the customer to uncover details.

18. An employee approaches you and asks if he can tell you something in confidence. He advises you that he has been performing illegal activities within the company for the last year. He is feeling guilty about it and is telling you to receive advice as to what he should do. What should you do?
    - Ask for full details.
    - Confirm that the activity is really illegal.
    - Inform your manager of the illegal activity.
    - Tell the employee to inform their boss.

19. Although your company is not the lowest bidder for a project, the client has come to expect good performance from your company and wants to award the contract to you. To win the contract, the client asks you to eliminate your project management costs. The client says that your company has good project processes, and project controls unnecessarily inflate your costs. What should you do under these circumstances?
    - Eliminate your project management costs and rely on experience.
    - Remove costs associated with project team communications, meetings and customer reviews.
    - Remove meeting costs but not the project manager's salary.
    - Describe the costs incurred on past projects that did not use project management.

20. Near the end of the project, additional requirements were demanded by a group of stakeholders when they knew that would be affected by your project. This became a problem because you had not included the time or cost in the project plan to perform these requirements. What is the learned lesson from this crisis?
    - Review the WBS dictionary more thoroughly, looking for incomplete descriptions.
    - Review the charter more thoroughly, examining the business case for "holes."
    - Pay more attention to stakeholder management.
    - Do a more thorough job of solicitation planning.

21. Your organization is having a difficult problem in time management all of its projects. The CEO asks you to help senior management get a better understanding of the problems. What is the FIRST thing you should do?

- Meet with individual project managers to get a better sense of what is happening.
- Send a formal memo to all project managers requesting their project plans.
- Meet with senior managers to help them develop a new tracking system for managing projects.
- Review the project charters and Gantt charts for all projects.

22. You are a project manager for a large installation project when you realize that there are over 100 potential stakeholders on the project. Which will be the best action?

- Eliminate some stakeholders.
- Contact your manager and ask which ones are more important.
- Gather the needs of all the most influential stakeholders.
- Find an effective way to gather the needs of all stakeholders.

23. What is the right way to overcome the cultural differences between employees in an international project?

- Training through project management
- Training for the different languages in the project
- Training about different cultures and civilizations
- Training about the differences in nationalities

24. You have just been assigned to take over a project that your management has told you is "out of control." When you asked your management what the problems were, they had no specifics, but said that the project was behind schedule, over budget and the client was dissatisfied. Which of the following should be of the MOST concern to you?

- The project is over budget and behind schedule.
- There is very little documentation related to the project.
- The client is very dissatisfied with the project's progress.
- Your management is looking for rapid and visible action on this project to rectify the problems.

25. During a meeting with some of the project stakeholders, you as a project manager were asked to add work to the project scope of work. You had access to correspondence about the project before the charter was signed and remember that the project sponsor specifically denied funding for the scope of work mentioned by these stakeholders. What is the best action to take?

- Let the sponsor know of the stakeholders' request.
- Evaluate the impact of adding the scope of work.
- Tell the stakeholders the scope cannot be added.
- Add the work if there is time available in the project schedule.

26. What are the project management process requirements?

- Initiating, developing, implementing, supporting
- Initiating, planning, executing, controlling, closing
- Feasibility, planning, design, implementation, supporting
- Requirements analysis, design, coding, testing, installation, conversion, operation

27. One of your team members informs you that he does not know which of the many projects he is working on is the most important. Who should determine the priorities among projects in a company?

- Project manager
- Sponsor
- Senior management
- Team

28. You are trying to help project managers in your organization understand the project management process groups and the project management life cycle. Many of them are confusing the project life cycle with the project management life cycle. Which of the following identifies the DIFFERENCE between these two life cycles?

- The project life cycle is created based on the top level of the work breakdown structure.
- The project management life cycle is longer.
- The project management life cycle only applies to some projects.
- The project life cycle describes what you need to do to complete the work.

29. Which of the following statements BEST describes why stakeholders are necessary on a project?

- They determine the project schedule, deliverables and requirements.
- They help to determine the project constraints and product deliverables.
- They supply the resources and resource constraints on the project.
- They help provide assumptions, the WBS, and the management plan.

30. You are in the middle of a new project when you discover that the previous project manager made a US $2,000,000 payment that was not approved in accordance with your company policies. Therefore, the project CPI is 1.2. What should you do?

- Bury the cost in the largest cost center available.
- Put the payment in an escrow account.
- Contact your manager.
- Ignore the payment.

31. While working on a project in another country, you are asked to pay under table money to facilitate the work to let the country officials issue a work order. What should you do?

- Make the payment.
- Ask the person for proof that the payment is required.
- Seek legal advice on whether such a payment is a bribe.
- Do not pay and see what happens.

32. Which of the following describes the BEST use of historical records?

- Estimating, life cycle costing, and project planning
- Risk management, estimating, and creating lessons learned
- Project planning, estimating, and creating a status report
- Estimating, risk management, and project planning

33. At which step of risk management does a determination of risk mitigation strategies take place?

- Risk identification
- Risk quantification
- Risk response planning
- Risk response control

34. A project manager for an offshore project is unsure how much cost contingency to add to the project. There is a 50% chance of a weather delay causing an impact of US $100,000 and a 20% chance of a delay in the testing center with a US $20,000 impact. How much should the cost reserve be?
    - Less than $50,000
    - More than $120,000
    - Less than $20,000
    - More than $54,000

35. You've just completed the initiating phase of a small project and are moving into the planning phase when a project stakeholder asks you for the project's budget and cost baseline. What should you tell her?
    - The project budget can be found in the project's charter, which has just been completed.
    - The project budget and baseline will not be finalized and accepted until the planning phase is completed.
    - The project plan will not contain the project's budget and baseline; this is a small project.
    - It is impossible to complete an estimate before the project plan is created.

36. Why is quality planned and not inspected?
    - It reduces quality and is less expensive.
    - It improves quality and is more expensive.
    - It reduces quality and is more expensive.
    - It improves quality and is less expensive.

37. Which of the following sequences represents straight line depreciation?
    - $200, $200, $200
    - $100, $120, $140
    - $100, $120, $160
    - $160, $140, $120

38. An analysis shows that you will have a cost overrun at the end of the project. Which of the following should you do?

- Evaluate options to crash or fast track the project and then evaluate options.
- Meet with management to find out what to do.
- Meet with the customer to look for costs to eliminate.
- Add a reserve to the project.

39. Your best professional structure engineer is a freelancer. Recently, you found out that he is working on a project in the evening for one of your competitors. What is best action to take?

- Replace him.
- Get him to sign a nondisclosure agreement.
- Inform him that you do not allow your contractors to work with your competition, and ask him to choose.
- Limit his access to sensitive data.

40. What is meant by your product or service completely meets a customer's requirements?

- Quality is achieved.
- The cost of quality is high.
- The cost of quality is low.
- The customer pays the minimum price.

41. A project is seriously delayed. Earned value analysis shows that the project needs to be completed 10% faster than the work has been going. To get the project back on track, management wants to add 10 people to a task currently assigned to one person. The project manager disagrees, noting that such an increase will not produce an increase in speed. This is an example of:

- law of diminishing returns.
- fast tracking.
- earned value.
- life cycle costing.

42. Which of the following are represented by a bar chart rather than network diagrams?

- Logical relationships
- Critical paths
- Resource trade-off
- Progress or status

43. All of the following are part of quality control EXCEPT?
    - Cost of quality
    - Inspection
    - Control charts
    - Flowcharting

44. A project is in progress and the project manager is working with the quality assurance department to improve stakeholders' confidence that the project will satisfy the quality standards. Which is the gain from this process?
    - Quality problems
    - Checklists
    - Quality improvement
    - Quality audits

45. You are finalizing the monthly projects status report due now to your manager when you discover that several project leads disciplines are not reporting actual hours spent on project tasks. Consequently, this results in skewed project plan statistics. What is the MOST appropriate action to be taken?
    - Discuss the impacts of these actions with team member(s).
    - Report team member actions to functional manager.
    - Continue reporting information as presented to you.
    - Provide accurate and truthful representations in all project reports.

46. You are in a project startup. As a project manager you are invited to meetings with the project execution team. What should you include in these meetings that would have the biggest impact on the project?
    - Review of the action item list
    - Review of identified risks
    - Assignment of tasks to team members
    - Estimating costs

47. After analyzing the status of your project, you determine that the earned value is lower than the planned value. What should you expect as an outcome if this trend continues?
    - The actual cost will be lower than planned.
    - The estimate at completion will be lower than planned.

- The project will finish behind schedule.
- The project will finish below the original cost estimate.

48. By which of the following techniques can you calculate the risk assessment?
    - Arrow diagramming method
    - Network diagramming
    - Critical path method
    - Program evaluation and review technique

49. One of the risks your team has discovered is a high probability that the separator you are constructing will not perform safely under operation pressure. In order to handle this risk, you have chosen to test the separator materials and review design. This is an example of risk:
    - mitigation
    - avoidance
    - transference
    - acceptance

50. Which part of the risk management process uses data precision as an input?
    - Risk management
    - Qualitative risk analysis
    - Quantitative risk analysis
    - Risk response planning

51. An example of the contract price in a cost plus fixed fee contract is:
    - $20,000 plus fee.
    - costs, whatever they are, plus $20,000 as fee.
    - $20,000.
    - $250 per hour.

52. Which of the following factors can govern the project contract type?
    - How your company does business
    - How complete the scope of work is
    - Type of contract the law requires
    - Type of contract you have experience with

53. A company has just contracted with a well-known software developer to provide services during planning and design phases

of your project. Invoicing requirements were specifically defined within the contract, but expense limits were overlooked. As the project manager, which form of corrective action should you take?

- Modify the terms of the contract.
- Define acceptable limits to be adhered to.
- Proceed in good faith.
- Terminate the contract.

54. You have just completed the design phase for a client's project and are about to enter the execution phase. All of the following need to be done EXCEPT:

- Lessons learned
- Updating records
- Formal acceptance
- Completion of the product of the project

55. All of the following are generally part of the contract documents EXCEPT:

- Proposal
- Scope of work
- Terms and conditions
- Negotiation process

56. Your company is receiving a shipment of goods from the seller when you get a call from the contracting officer who tells you that the shipment does not meet the requirements of the contract. You look at the shipment yourself and determine that the shipment meets the needs of the project. What should you do?

- Send the shipment back.
- Accept the shipment.
- Issue a change order to change the contract specifications.
- Expect to receive a claim from the seller.

57. During the execution phase of the contract, the project manager should be concerned about conflict with the contract administrator because:

- in many cases, the contract administrator is the only one who can change the contract.
- the contract administrator is not interested in the contract.

- the company favors the contract administrator rather than the project manager.
- the contract is complex.

58. Your contract mentions that the maximum charge for services from the vendor will be US $40K/month. However the actual invoices have been US $90,000 for the past three months. Stopping the vendor's service will impact the project schedule. Under these circumstances, the BEST thing to do is to review the:
    - contract change control system.
    - scope change control system.
    - performance reporting system.
    - cost change control system.

59. An advantage of a fixed price contract for the owner is:
    - cost risk is higher.
    - cost risk is lower.
    - there is little risk.
    - risk is shared by all parties.

60. A project manager has just been notified by the vendor that the cost increased. What should you determine first as the project manager?
    - There is enough reserve to handle the change.
    - Another vendor can provide it at the original cost.
    - Another task can save money.
    - The task is on the critical path.

61. An engineering office is giving you so much trouble that your time available allocated to the project has gone from 20% to over 80% for this small piece of the overall project. Most of the available engineering office's deliverables are late and inaccurate and you have little confidence in this company's ability to complete the project. What should you do?
    - Terminate the engineering office for convenience and hire another seller.
    - Assign a group within your team to meet with the engineering office and reassign project work so that the engineering office work is easier to accomplish.
    - Meet with the engineering office to discover the cause of the problem.
    - Provide some of your own staff to augment the engineering office's staff.

62. The vendor on your project abruptly goes out of business. What should you do?

- File for a portion of the company's assets.
- Hire a new vendor immediately under a time and materials contract.
- Terminate the project.
- Terminate the contract.

63. You are in the process of having work crews dig a trench to lay fiber for a high-speed internet connection. All of the work permits have been obtained and funding has been approved. There have been several weather related delays, but due to perseverance of the entire team, the project is on time. It is the customer's responsibility to provide entrance into facilities so the connection into the building can be made. You discover the customer does not have adequate facilities and will not have them in time. What should you do?

- Slow down the work, allowing the team time off but ensuring that you will be completed before the customer finishes their portion of the work.
- Continue working according to your contract. Remind the customer both verbally and in writing of the customer's responsibilities. Provide the customer with an estimate of the impact if they do not meet their responsibilities.
- Continue working with your company's portion of the work according to the contract. As a project manager, your job is done once this work is completed.
- Stop all work and request that the customer contact you when they have fulfilled their responsibilities.

64. IT manager says to you that he receives 35 new computers from the seller, but they were expecting only 30. In looking at the contract, you see that it says "seller to provide thirty (35) computers. What should you do ?

- Call the seller and ask for clarification.
- Return the five extra computers.
- Make payment for the 35 computers.
- Issue a change order through the contract manager.

65. From the contractor's point of view, the contract is considered closed when:

- scope of work is complete.
- lessons learned is complete.

- final payment is made.
- the archives document are completed.

66. Bidders' conferences can have a negative effect on the project if the project manager does not remember to make sure:
    - all questions are put in writing and sent to all contractors.
    - all contractors get answers to their questions only.
    - to hold separate meetings with each bidder to ensure you receive proprietary data.
    - there is room in the meeting for all contractors.

67. Two days ago, you joined a consulting company as project manager to lead an existing project for a client. Today a major change is requested. What should be done FIRST?
    - Quickly develop a change control board to approve or disapprove changes.
    - Approve the change if your sponsor approved it, otherwise suggest a review by the project team.
    - Hire an outside consultant to develop and manage overall change control.
    - Find out if any formal overall change control plans and procedures are in place for this project.

68. While testing the strength of concrete poured on your project, you discover that over 35% of the concrete does not meet your company's quality standards. You feel certain the concrete will function as it is, and you don't think the concrete needs to meet the quality level specified. What should you do?
    - Change the quality standards to meet the level achieved.
    - List in your reports that the concrete simply "meets our quality needs."
    - Ensure the remaining concrete meets the standard.
    - Report the lesser quality level and try to find a solution.

69. You are working on your research and development project when your customer asks you to include a particular component in the project. You know this represents new work, and you do not have excess funds available. What should you do?

- Delete another lower priority task to make more time and funds available.
- Use funds from the management reserve to cover the cost.
- Follow the contract change control process.
- Ask for more funds from the project sponsor.

70. Your company is very happy to work on this major new project. Noting that the contract is not yet signed, your management wants you to go ahead and begin to staff the project. What should you do as the project manager?

- Wait until the last minute to do so.
- Ask the customer for a letter of intent.
- Only start to collect resumes and not commit any funds.
- Explain to management that this would not be a good idea at this point.

71. You have been working for eight months on a 12 months project time. The project is ahead of schedule when one of the functional managers tells you the resources committed to the project are no longer available. After investigating, you discover the company has just started another project and is using the resources committed to your project. You believe the new project is not critical, but the project manager is the son of a board member. What is the best action in this situation?

- Determine when resources will become available.
- Ask upper management to formally prioritize the projects.
- Use the reserve to hire contractors to complete the work.
- Negotiate a new schedule with the other project manager.

72. Maintenance and on-going operations are very important to projects and should:

- be included as activities to be performed during the project closure phase.
- have a separate phase in the project life cycle because a large portion of life cycle costs is devoted to maintenance and operations.

- not be viewed as part of a project--a project is temporary with a definite beginning and end.
- be viewed as a separate project.

73. The project has a critical deliverable that requires certain specialized and competent engineers to complete. The engineer who is working to complete the task has left the company and there is no one who can complete the work within the company. For this reason, the project manager needs to acquire the services of a consultant as soon as possible. What is the best action as the project manager?
   - Follow the legal requirements set up by the company for using outside services.
   - Bypass the company procedures as they are not relevant to the situation.
   - Expedite and go directly to his/her preferred consultant.
   - Ask his manager what to do.

74. What is one of the KEY objectives during negotiations?
   - Obtain a fair and reasonable price.
   - Negotiate a price under the contractor's estimate.
   - Ensure that all project risks are thoroughly delineated.
   - Ensure that an effective communication plan is established.

75. You have just been assigned to a project that is in the middle of the execution phase. What is the best way to control the project as the project manager?
   - Use a combination of communication methods.
   - Hold status meetings because they have worked best for you in the past.
   - Refer to the Gantt chart weekly.
   - Meet with management regularly.

76. Your company is purchasing the services of a consultant. You know one of the consulting companies interested in the work. What should you do?
   - Work hard to get the consulting company selected for the project.
   - Tell your manager and remove yourself from the selection committee.

- Tell the people from the consulting company that you hope they get the work.
- Keep the information to yourself.

77. What leadership style should you employ during the first two weeks of project planning?
    - Coaching
    - Directing
    - Supporting
    - Facilitating

78. You have just been hired as a project manager and you are trying to gain the cooperation of others. What in your opinion is the BEST form of power for gaining cooperation under these circumstances?
    - Formal
    - Referent
    - Penalty
    - Expert

79. During project planning in a matrix organization, the project manager determines that additional human resources are needed. From whom would he request these resources?
    - Project manager
    - Functional manager
    - Team
    - Project sponsor

80. A team member who doesn't have the required skills or knowledge was assigned to a team. Who is responsible for ensuring that he receives the proper training?
    - Sponsor
    - Functional manager
    - Project manager
    - Training coordinator

81. All of the following are correct statements about project managers EXCEPT:
    - they are assigned after performance reports are distributed.
    - they have the authority to say no when necessary.

- they manage changes and factors that create change.
- they are held accountable for project success or failure.

82. A project manager must publish a project schedule. Activities, start/end times, and resources are identified. What should the project manager do next?
    - Distribute the project schedule according to the communications plan.
    - Confirm the availability of the resources.
    - Refine the project plan to reflect more accurate costing information.
    - Publish a Gantt chart illustrating the timeline.

83. You work in a matrix organization when a team member comes to you to admit he is having trouble with his task. Although not yet in serious trouble, the team member admits he is uncertain of how to perform part of the work on the task. He suggests a training class available next week. Where should the cost of the training come from?
    - Switch to a trained resource to avoid the cost
    - The human resource department budget
    - The team member's functional department budget
    - The project budget

84. Which of the following is an output of team development?
    - Management plan
    - Staffing management plan
    - Performance improvements
    - Reward system

85. You have been working on a project for six months with the same team, yet the team still shows a lack of support for the project. What should you do as a project manager to obtain the team's support for the project?
    - Reevaluate the effectiveness of the reward system in place.
    - Talk to each team member's boss with the team member present.
    - Find someone else to be project manager.
    - Tell the team he/she needs its support, and ask them why they do not support the project.

86. You have just been informed that one of your team members has not been adequately trained to complete project tasks as assigned to him. How would you handle this situation?

- Replace this team member with someone more qualified.
- Request proper training be provided through the functional manager.
- Revise the schedule to account for the decreased effectiveness of this resource.
- Mentor this resource during the remainder of project duration.

87. You are now a project manager for an international project and you use people from different countries. What should you expect as a project manager?

- Added costs due to shoddy or incomplete work
- Language or cultural differences that preclude effective team work
- Increased organizational planning and coordination activities
- Team building activities become impractical, and the cost is prohibitive

88. A senior engineer assigned to your project contacts you, trying to get off the team. He knows that an important project in his department is going to be approved and will take place at the same time as yours. He wants to work on the other project. What is the best action?

- Release him from the team.
- Talk to the functional manager about releasing him from the team.
- Release him after he finds a suitable replacement.
- Speak with the project sponsor about releasing him from the team.

89. Two lead processes and piping are having a big disagreement about how to accomplish a project from a technical point of view. The client is upset from that as it impacts time. What should you do as a project manager?

- Make the decision.
- Send the team members to their managers for advice on resolving the dispute.

- Ask for a benchmark analysis.
- Have the team members compromise.

90. Saying "Do the work because I have been put in charge!" is an example of what type of power?
    - Formal
    - Penalty
    - Effective
    - Expert

91. Which of the following is the BEST method to making a reward systems MOST effective?
    - Pay a large salary increase to the best workers.
    - Give the team a choice of rewards.
    - Make the link between performance and reward clear.
    - Present notifications of rewards within the company.

92. A project manager says to a team member, "If you cannot complete this task according to the quality standards you set in place, I will remove you from the team that is going to Paris for the milestone party with the customer." What form of power is the project manager is using?
    - Reward power
    - Formal power
    - Penalty power
    - Referent power

93. You are a project manager and your project schedule is tight and in danger of falling behind when structure and piping leads to disrupting status meetings by arguing with each other. What action should you take?
    - Separate the two until the project is back on track.
    - Speak with each team member and give each a verbal warning.
    - Discuss the problem with the manager of the two team members.
    - Meet with both team members and their function manager to determine the source of conflict.

94. What conflict resolution technique is a project manager using when he says, "I cannot deal with this issue now!"

- Problem solving
- Forcing
- Withdrawal
- Compromising

95. A team member complains to the project manager that another team member has once again failed to provide necessary information. The project manager meets with both team members to uncover the reason for the problem. This is an example of:
    - withdrawal.
    - confronting.
    - compromising.
    - smoothing.

96. The forms below present a power derived from the project manager all EXCEPT:
    - Formal
    - Reward
    - Penalty
    - Expert

97. In which phase of the project should the project manager provide more direction?
    - Initiating
    - Planning
    - Executing
    - Controlling

98. A project manager has just been assigned a team that comes from many countries including Brazil, Japan, the US, and Britain. What is his or her BEST tool for success?
    - The Responsibility Assignment Matrix (RAM)
    - The teleconference
    - Team communication with the WBS
    - Communication and well developed people skills

99. A project manager needs to determine the resources needed for the project. Select the primary tool from the following:
    - Work breakdown structure
    - Schedule
    - Expert advice from functional managers
    - Expert advice from management

100. Your role is a project manager for a large project. One of your key resources has started to do his task behind schedule and work quality is beginning to suffer as well. You are confident that this person is well aware of the work schedule and required quality specifications. What action should you take?

- Report the problem to HR for corrective action.
- Reassign some work to other team members until performance starts to improve.
- Meet with the employee in private and try to determine the factors impacting performance.
- Escalate the situation to the employee's functional manager and ask for assistance.

10.3 The Right Decisions

1. The construction manager is away from the project and is replaced by a new one. The project manager meets with the replacement construction manager and his team. In this meeting, what is the first issue the project manager should start on in the meeting?

- **Introduce team members.**
- Communicate the objectives of the project.
- Clarify the authority.
- Create a communication plan.

> It is the ground rule for any meeting you attend with your team and the third party when there have been no previous deals between your team and him. This action will make the discussion easier for all the attendees. So the introduction should be done in the beginning of any meeting in a proper way according to the meeting type.

2. After you have been assigned to a project, according to the schedule 50% of the project should be completed. You discover that the project is running far behind schedule. The project will probably take double the time originally estimated by the previous project manager. On the other hand, you discover that upper management has been informed that the project is on schedule. What will be the BEST action?

- Try to restructure the schedule to meet the project deadline.
- Turn the project back to the previous project manager.
- **Report your assessment to upper management.**
- Move forward with the schedule as planned by the previous project manager and report at the first missed milestone.

The best and fastest action you should take is to assess the situation with a formal report to upper management. Don't be a hero and restructure the schedule, as if you fail it will be your responsibility. Again don't move the project forward and then tell the management. As in this case, upper management will wonder why you didn't tell them when they may have the capability to assist you in this situation.

3. You are a project manager on an international project of great importance to the client. The client is from another country and is so excited by how well the project is going that he presents you with a company automobile for your personal use. The BEST thing for you to do would be to:
   - thank him and offer a gift in exchange.
   - **politely turn down the gift.**
   - ask that the gift be changed to something that can be shared by the team.
   - ask for a gift that can be used before you return home.

Politely turn down the gift. If you accept or negotiate in any way, you will be on a black list with your team, and with time you could be terminated from the project.

4. The client project manager asks you to provide a written cost estimate that is 30% higher than your estimate of the project's cost. He explains that the budgeting process requires managers to estimate pessimistically to ensure enough money is allocated for projects. What is the BEST way to handle this?
   - Add the 30% as a lump sum contingency fund to handle project risks.

- Add the 30% to your cost estimate by spreading it evenly across all project tasks.
- Create one cost baseline for budget allocation and a second one for the actual project plan.
- **Ask for information on risks that would cause your estimate to be too small.**

> If you select the first three solutions, the client will be happy but may feel that you are just doing what he says. But if you ask for information on risks, then he may feel that you calculate everything and are professional in your work.

5. You are reviewing bids from various contractors for work on your project. One of the bidding contractors has a history of delivering on time within budget, and you have personally worked with this company successfully on previous engagements. You receive a call from the manager submitting the bid inquiring about how the process is going. He asks to have lunch with you to discuss the bid. What is the BEST response?

- Do not mention the other bidders but simply inform him that based on past experience, he has a good chance of winning the business.
- **Inform him that it would be inappropriate to discuss the matter at all, and inform the customer or a team member of the conversation.**
- Inform him that it would not be appropriate to discuss the matter over the phone during business hours, but that an informal lunch discussion would be more appropriate.
- Politely avoid continuing the conversation and disregard the bid.

> Inform him that it is wrong to discuss this matter, and inform the team about this conversation. If anyone from the team knows about this conversation from outsources, it will spread and questions will be raised. But if you let everyone know about this conversation, you professionally close this subject safely.

6. All of the following are part of the team's stakeholder management effort EXCEPT?

- **Giving stakeholders extras**
- Identifying stakeholders
- Determining stakeholders' needs
- Managing stakeholders' expectations

7. There are over 20 stakeholders on your project. The project is running in another country with people from three countries as team members. Which of the following is the MOST important thing to keep in mind?

- The communication channels will be narrow.
- **Many competing needs and objectives must be satisfied.**
- There must be one sponsor from each country.
- Conflicts of interest must be disclosed.

8. Your management has decided that all orders will be treated as "projects" and that project managers will be used to update orders daily, resolving issues and ensuring that the customer formally accepts the product within 30 days of completion. The revenue from the individual orders can vary from US $100 to US $150,000. The project manager will not be required to perform planning or provide documentation other than daily status. How would you define this situation?

- Because each individual order is a "temporary endeavor," each order is a project - this is truly project management.
- This is program management since there are multiple projects involved.
- **This is a recurring process.**
- Orders incurring revenue over US $100,000 would be considered projects and would involve project management.

9. Who determines the role of each stakeholder?

- The stakeholder and the sponsor.
- **The project manager and the stakeholder.**
- The project manager and the sponsor.
- The team and the project manager.

10. A project manager has a problem with a team member's performance. Choose the best way of communication to address this problem:

- Formal written communication
- Formal verbal communication
- Informal written communication
- **Informal verbal communication**

The best way and proper way is to be informal and verbal, but your statements should be clear, and the goals and target should be clear to everyone on the team.

11. You are the project manager for a large government project. This project has a multi-million dollar budget which will be spent over 2 years and the contract was signed 6 months ago. You were not involved in contract negotiations or setting up procedures for managing changes, but now you are involved with changes from the customer and from people inside your organization. Who is normally responsible for formally reviewing major changes in the project or contract?

- **The change control board**
- The contracting/legal department
- The project manager
- Senior management

12. You are a new project manager for company (X). You previously worked for company (Y) that had an extensive project management practice. Company (X) has its own procedures, but you are more familiar with and trust those from company (Y). What should you do?

- Use the practices from company (Y) but include any forms from company (X).
- **Use the forms from company (X) and begin to instruct them on ways to upgrade their own.**
- Talk about changes to the change control board of company (X).
- Interact with others in an ethical way by sharing the good aspects of company (Y)'s procedures.

> Take care that everyone who has worked in the company for a long time feels that the company procedure is the best. Keep in mind that you cannot change the company, but you must adapt to the new company system and procedure. But if your previous company is more upgradable, use your new company forms and begin to market your new ideas for upgrade, sharing with others and clarifying how it can make the work better.

13. You as the project manager discover a defect in a deliverable that should be sent to the client under contract today. The project manager knows the client does not have the technical understanding to notice the defect. The deliverable technically meets the contract requirements, but it does not meet the project manager's fitness of standard use. What should the project manager do in this situation?

- Issue the deliverable and get formal acceptance from the customer.
- Note the problem in the lessons learned so future projects do not encounter the same problem.
- **Discuss the issue with the customer.**
- Inform the customer that the deliverable will be late.

> The main benefit for PMP is to enhance the ethics for the project management. An unethical engineering firm will be happy with this situation because after review by the client, if there is a need to re-correct, it will be a change order and will increase profit. This is not a good business development because you will take more money from the client but you will lose any future tender, taking work from the company.

14. Your customer requires a 3,000 call capacity for the new call center project. However, one of your company's technical experts believes a 4,000 call capacity can be reached. Another thinks that based on the technical needs of the customer, the capacity needs to be only 2,500 calls. What is the BEST thing to do?

- **Meet with the customer to better understand the reasons behind the 3000 call capacity.**
- Set the goal at 4,000 calls.

- Meet with the technical experts and help them to agree on a goal.
- Set the goal at 3,000 calls.

> Focus your eye on repetition. Also, you should discuss with the client the reason for his choice and try to prove to him that your idea is technically based on your expertise.

15. One employee is three days late with a report. Five minutes before the meeting where the topic of the report is to be discussed, he gives you the report. You notice that there are some serious errors in it. What will be your action?

- **Cancel the meeting and reschedule when the report is fixed.**
- Go to the meeting and tell the other attendees there are errors in the report.
- Force the employee to do the presentation and remain silent as the other attendees find the errors.
- Cancel the meeting and rewrite the report yourself.

> Your role as project manager is to focus on the main goal, time, cost, and quality. Canceling the meeting and rescheduling it when the report is finished is the best action because to go the meeting and say there is an error in the report will waste your time and others' time also. Also, if you force the employee to go to the meeting only to blame him, that will be a waste of time. We need to look at other possibilities, such as there may be an error in the computer and printing system due to bad machines, bad contracts with IT services, etc.

16. You are a project manager working on a 700 million dollar project. As the project has progressed, you have become friends with the general contractor. You are working on a $100,000 change request. He has offered to let you use his villa on the coast for the next week end as he will be away in another country.

- What should you do?
- Accept the offer with thanks
- Decline the offer

- **Decline the offer and report it to your supervisor**
- Ask your boss to approve your use of the boat

> Always differentiate between business and friendship. You should decline the offer and report it to the supervisor. Be professional in your work.

17. You are working on a large construction project that is progressing within the schedule. Resource usage has remained steady, and your boss has just awarded you a prize for your performance. One of your team members returns from a meeting with the customer and tells you the customer said he is not happy with the project progress. What is the FIRST action you should take?
    - Tell your manager.
    - Complete a team building exercise and invite the customer's representatives.
    - Change the schedule baseline.
    - **Meet with the customer to uncover details.**

> Direct contact with the customer through a meeting is very important for discussing with him his point of view.

18. An employee approaches you and asks if he can tell you something in confidence. He advises you that he has been performing illegal activities within the company for the last year. He is feeling guilty about it and is telling you to receive advice as to what he should do. What should you do?
    - Ask for full details.
    - Confirm that the activity is really illegal.
    - **Inform your manager of the illegal activity.**
    - Tell the employee to inform their boss.

> I'm really confused by the answer in some textbooks to inform the manager about illegal activity. Yes, it is a good answer from a practical and professional point of view, except in some countries, as this situation depends on the culture of the country you are working in.

19. Although your company is not the lowest bidder for a project, the client has come to expect good performance from your company and wants to award the contract to you. To win the contract, the client asks you to eliminate your project management costs. The client says that your company has good project processes, and project controls unnecessarily inflate your costs. What should you do under these circumstances?

- Eliminate your project management costs and rely on experience.
- Remove costs associated with project team communications, meetings and customer reviews.
- Remove meeting costs but not the project manager's salary.
- **Describe the costs incurred on past projects that did not use project management.**

20. Near the end of the project, additional requirements were demanded by a group of stakeholders when they knew that would be affected by your project. This became a problem because you had not included the time or cost in the project plan to perform these requirements. What is the learned lesson from this crisis?

- Review the WBS dictionary more thoroughly, looking for incomplete descriptions.
- Review the charter more thoroughly, examining the business case for "holes."
- **Pay more attention to stakeholder management.**
- Do a more thorough job of solicitation planning.

21. Your organization is having a difficult problem in time management all of its projects. The CEO asks you to help senior management get a better understanding of the problems. What is the FIRST thing you should do?

- **Meet with individual project managers to get a better sense of what is happening.**
- Send a formal memo to all project managers requesting their project plans.
- Meet with senior managers to help them develop a new tracking system for managing projects.
- Review the project charters and Gantt charts for all projects.

22. You are a project manager for a large installation project when you realize that there are over 100 potential stakeholders on the project. Which will be the best action?

- Eliminate some stakeholders.
- Contact your manager and ask which ones are more important.
- Gather the needs of all the most influential stakeholders.
- **Find an effective way to gather the needs of all stakeholders.**

23. What is the right way to overcome the cultural differences between employees in an international project?

- Training through project management
- Training for the different languages in the project
- **Training about different cultures and civilizations**
- Training about the differences in nationalities

Training about different cultures is a direct way to solve this problem. This is done in the oil and gas company sectors in the Middle East, where any new employee takes a 2-day seminar about the culture. You waste 2 days but save many weeks. Other ways of training are good but do not have a direct impact.

24. You have just been assigned to take over a project that your management has told you is "out of control." When you asked your management what the problems were, they had no specifics, but said that the project was behind schedule, over budget and the client was dissatisfied. Which of the following should be of the MOST concern to you?

- The project is over budget and behind schedule.
- **There is very little documentation related to the project.**
- The client is very dissatisfied with the project's progress.
- Your management is looking for rapid and visible action on this project to rectify the problems.

In this case, the main target is to find the document, and usually for this type of project there will be very little documentation, so that will be your challenge.

25. During a meeting with some of the project stakeholders, you as a project manager were asked to add work to the project scope of work. You had access to correspondence about the project before the charter was signed and remember that the project sponsor specifically denied funding for the scope of work mentioned by these stakeholders. What is the best action to take?

- Let the sponsor know of the stakeholders' request.
- Evaluate the impact of adding the scope of work.
- **Tell the stakeholders the scope cannot be added.**
- Add the work if there is time available in the project schedule.

26. What are the project management process requirements?

- Initiating, developing, implementing, supporting
- **Initiating, planning, executing, controlling, closing**
- Feasibility, planning, design, implementation, supporting
- Requirements analysis, design, coding, testing, installation, conversion, operation

27. One of your team members informs you that he does not know which of the many projects he is working on is the most important. Who should determine the priorities among projects in a company?

- **Project manager**
- Sponsor
- Senior management
- Team

28. You are trying to help project managers in your organization understand the project management process groups and the project management life cycle. Many of them are confusing the project life cycle with the project management life cycle. Which of the following identifies the DIFFERENCE between these two life cycles?

- The project life cycle is created based on the top level of the work breakdown structure.
- The project management life cycle is longer.
- The project management life cycle only applies to some projects.
- **The project life cycle describes what you need to do to complete the work.**

29. Which of the following statements BEST describes why stakeholders are necessary on a project?

- They determine the project schedule, deliverables and requirements.
- They help to determine the project constraints and product deliverables.
- **They supply the resources and resource constraints on the project.**
- They help provide assumptions, the WBS, and the management plan.

30. You are in the middle of a new project when you discover that the previous project manager made a US $2,000,000 payment that was not approved in accordance with your company policies. Therefore, the project CPI is 1.2. What should you do?

- Bury the cost in the largest cost center available.
- Put the payment in an escrow account.
- **Contact your manager.**
- Ignore the payment.

31. While working on a project in another country, you are asked to pay under table money to facilitate the work to let the country officials issue a work order. What should you do?

- Make the payment.
- Ask the person for proof that the payment is required.
- **Seek legal advice on whether such a payment is a bribe.**
- Do not pay and see what happens.

32. Which of the following describes the BEST use of historical records?

- Estimating, life cycle costing, and project planning
- Risk management, estimating, and creating lessons learned
- Project planning, estimating, and creating a status report
- **Estimating, risk management, and project planning**

33. At which step of risk management does a determination of risk mitigation strategies take place?

- Risk identification
- Risk quantification

- **Risk response planning**
- Risk response control

34. A project manager for an offshore project is unsure how much cost contingency to add to the project. There is a 50% chance of a weather delay causing an impact of US $100,000 and a 20% chance of a delay in the testing center with a US $20,000 impact. How much should the cost reserve be?
    - Less than $50,000
    - More than $120,000
    - Less than $20,000
    - **More than $54,000**

35. You've just completed the initiating phase of a small project and are moving into the planning phase when a project stakeholder asks you for the project's budget and cost baseline. What should you tell her?
    - **The project budget can be found in the project's charter, which has just been completed.**
    - The project budget and baseline will not be finalized and accepted until the planning phase is completed.
    - The project plan will not contain the project's budget and baseline; this is a small project.
    - It is impossible to complete an estimate before the project plan is created.

36. Why is quality planned and not inspected?
    - It reduces quality and is less expensive.
    - It improves quality and is more expensive.
    - It reduces quality and is more expensive.
    - **It improves quality and is less expensive.**

37. Which of the following sequences represents straight line depreciation?
    - **$200, $200, $200**
    - $140, $120, $100
    - $160, $120, $100
    - $120, $140, $160

38. An analysis shows that you will have a cost overrun at the end of the project. Which of the following should you do?

- **Evaluate options to crash or fast track the project and then evaluate options.**
- Meet with management to find out what to do.
- Meet with the customer to look for costs to eliminate.
- Add a reserve to the project.

39. Your best professional structure engineer is a freelancer. Recently, you found out that he is working on a project in the evening for one of your competitors. What is best action to take?

- Replace him.
- **Get him to sign a nondisclosure agreement.**
- Inform him that you do not allow your contractors to work with your competition, and ask him to choose.
- Limit his access to sensitive data.

> Be calm and don't rush to replace him. He is a professional and knows your system. Usually, to hire a new employee takes 2–3 months. He is a freelancer so you cannot control him, and he can choose the another company. Preventing access to sensitive data is important, but the risk still exists. Make an agreement with him that leaves him happy but maintains his loyalty to your company.

40. What is meant by your product or service completely meets a customer's requirements?

- **Quality is achieved.**
- The cost of quality is high.
- The cost of quality is low.
- The customer pays the minimum price.

> You achieve quality when your service or products meet the customer requirement and satisfaction completely.

41. A project is seriously delayed. Earned value analysis shows that the project needs to be completed 10% faster than the work has been going. To get the project back on track, management wants to add 10 people to a task currently assigned to one person.

The project manager disagrees, noting that such an increase will not produce an increase in speed. This is an example of:

- **law of diminishing returns.**
- fast tracking.
- earned value.
- life cycle costing.

42. Which of the following are represented by a bar chart rather than network diagrams?

- **Logical relationships**
- Critical paths
- Resource trade-off
- Progress or status

43. All of the following are part of quality control EXCEPT?

- **Cost of quality**
- Inspection
- Control charts
- Flowcharting

44. A project is in progress and the project manager is working with the quality assurance department to improve stakeholders' confidence that the project will satisfy the quality standards. Which is the gain from this process?

- Quality problems
- Checklists
- **Quality improvement**
- Quality audits

45. You are finalizing the monthly projects status report due now to your manager when you discover that several project leads disciplines are not reporting actual hours spent on project tasks. Consequently, this results in skewed project plan statistics. What is the MOST appropriate action to be taken?

- Discuss the impacts of these actions with team member(s).
- Report team member actions to functional manager.
- Continue reporting information as presented to you.
- **Provide accurate and truthful representations in all project reports.**

46. You are in a project startup. As a project manager you are invited to meetings with the project execution team. What should you include in these meetings that would have the biggest impact on the project?

- Review of the action item list
- **Review of identified risks**
- Assignment of tasks to team members
- Estimating costs

> As discussed in the previous chapter, risk assessment should be done before starting the project. So the first meeting or review of identified risks is very important. Follow up the risk mitigation in the next meeting.

47. After analyzing the status of your project, you determine that the earned value is lower than the planned value. What should you expect as an outcome if this trend continues?

- The actual cost will be lower than planned.
- The estimate at completion will be lower than planned.
- **The project will finish behind schedule.**
- The project will finish below the original cost estimate.

48. By which of the following techniques can you calculate the risk assessment?

- Arrow diagramming method
- Network diagramming
- Critical path method
- **Program evaluation and review technique**

49. One of the risks your team has discovered is a high probability that the separator you are constructing will not perform safely under operation pressure. In order to handle this risk, you have chosen to test the separator materials and review design. This is an example of risk:

- **mitigation**
- avoidance
- transference
- acceptance

50. Which part of the risk management process uses data precision as an input?

- Risk management
- **Qualitative risk analysis**
- Quantitative risk analysis
- Risk response planning

51. An example of the contract price in a cost plus fixed fee contract is:

- $20,000 plus fee.
- **costs, whatever they are, plus $20,000 as fee.**
- $20,000.
- $250 per hour.

52. Which of the following factors can govern the project contract type?

- How your company does business
- **How complete the scope of work is**
- Type of contract the law requires
- Type of contract you have experience with

53. A company has just contracted with a well-known software developer to provide services during planning and design phases of your project. Invoicing requirements were specifically defined within the contract, but expense limits were overlooked. As the project manager, which form of corrective action should you take?

- **Modify the terms of the contract.**
- Define acceptable limits to be adhered to.
- Proceed in good faith.
- Terminate the contract.

54. You have just completed the design phase for a client's project and are about to enter the execution phase. All of the following need to be done EXCEPT:

- Lessons learned
- Updating records
- Formal acceptance
- **Completion of the product of the project**

55. All of the following are generally part of the contract documents EXCEPT:
- Proposal
- Scope of work
- Terms and conditions
- **Negotiation process**

56. Your company is receiving a shipment of goods from the seller when you get a call from the contracting officer who tells you that the shipment does not meet the requirements of the contract. You look at the shipment yourself and determine that the shipment meets the needs of the project. What should you do?
- **Send the shipment back.**
- Accept the shipment.
- Issue a change order to change the contract specifications.
- Expect to receive a claim from the seller.

57. During the execution phase of the contract, the project manager should be concerned about conflict with the contract administrator because:
- **in many cases, the contract administrator is the only one who can change the contract.**
- the contract administrator is not interested in the contract.
- the company favors the contract administrator rather than the project manager.
- the contract is complex.

58. Your contract mentions that the maximum charge for services from the vendor will be US $40K/month. However the actual invoices have been US $90,000 for the past three months. Stopping the vendor's service will impact the project schedule. Under these circumstances, the BEST thing to do is to review the:
- **contract change control system.**
- scope change control system.
- performance reporting system.
- cost change control system.

59. An advantage of a fixed price contract for the owner is:
- cost risk is higher.
- **cost risk is lower.**

- there is little risk.
- risk is shared by all parties.

60. A project manager has just been notified by the vendor that the cost increased. What should you determine first as the project manager?
- **There is enough reserve to handle the change.**
- Another vendor can provide it at the original cost.
- Another task can save money.
- The task is on the critical path.

61. An engineering office is giving you so much trouble that your time available allocated to the project has gone from 20% to over 80% for this small piece of the overall project. Most of the available engineering office's deliverables are late and inaccurate and you have little confidence in this company's ability to complete the project. What should you do?
- **Terminate the engineering office for convenience and hire another seller.**
- Assign a group within your team to meet with the engineering office and reassign project work so that the engineering office work is easier to accomplish.
- Meet with the engineering office to discover the cause of the problem.
- Provide some of your own staff to augment the engineering office's staff.

> You cannot solve the problem with the vendor. So terminating the engineering office early and hiring another one is the sole solution in this case.

62. The vendor on your project abruptly goes out of business. What should you do?
- File for a portion of the company's assets.
- **Hire a new vendor immediately under a time and materials contract.**
- Terminate the project.
- Terminate the contract.

63. You are in the process of having work crews dig a trench to lay fiber for a high-speed internet connection. All of the work permits have been obtained and funding has been approved. There have been several weather related delays, but due to perseverance of the entire team, the project is on time. It is the customer's responsibility to provide entrance into facilities so the connection into the building can be made. You discover the customer does not have adequate facilities and will not have them in time. What should you do?

- Slow down the work, allowing the team time off but ensuring that you will be completed before the customer finishes their portion of the work.
- **Continue working according to your contract. Remind the customer both verbally and in writing of the customer's responsibilities. Provide the customer with an estimate of the impact if they do not meet their responsibilities.**
- Continue working with your company's portion of the work according to the contract. As a project manager, your job is done once this work is completed.
- Stop all work and request that the customer contact you when they have fulfilled their responsibilities.

64. IT manager says to you that he receives 35 new computers from the seller, but they were expecting only 30. In looking at the contract, you see that it says "seller to provide thirty (35) computers. What should you do ?

- Call the seller and ask for clarification.
- **Return the five extra computers.**
- Make payment for the 35 computers.
- Issue a change order through the contract manager.

> Return the five extra computers. In the contracts, if there is a difference in the numbering return to the word as you see it.

65. From the contractor's point of view, the contract is considered closed when:

- scope of work is complete.
- lessons learned is complete.

- **final payment is made.**
- the archives document are completed.

66. Bidders' conferences can have a negative effect on the project if the project manager does not remember to make sure:
    - **all questions are put in writing and sent to all contractors.**
    - all contractors get answers to their questions only.
    - to hold separate meetings with each bidder to ensure you receive proprietary data.
    - there is room in the meeting for all contractors.

67. Two days ago, you joined a consulting company as project manager to lead an existing project for a client. Today a major change is requested. What should be done FIRST?
    - Quickly develop a change control board to approve or disapprove changes.
    - Approve the change if your sponsor approved it, otherwise suggest a review by the project team.
    - Hire an outside consultant to develop and manage overall change control.
    - **Find out if any formal overall change control plans and procedures are in place for this project.**

The last action is the solution. On the other hand, when you ask about the overall change controls plan your image may be good as a professional project manager, unless there is not an available overall change control plan.

68. While testing the strength of concrete poured on your project, you discover that over 35% of the concrete does not meet your company's quality standards. You feel certain the concrete will function as it is, and you don't think the concrete needs to meet the quality level specified. What should you do?
    - Change the quality standards to meet the level achieved.
    - List in your reports that the concrete simply "meets our quality needs."
    - Ensure the remaining concrete meets the standard.
    - **Report the lesser quality level and try to find a solution.**

> Avoid any technical issue even if you have excellent experience. Report the lesser quality and find a solution with your team.

69. You are working on your research and development project when your customer asks you to include a particular component in the project. You know this represents new work, and you do not have excess funds available. What should you do?

- Delete another lower priority task to make more time and funds available.
- Use funds from the management reserve to cover the cost.
- **Follow the contract change control process.**
- Ask for more funds from the project sponsor.

70. Your company is very happy to work on this major new project. Noting that the contract is not yet signed, your management wants you to go ahead and begin to staff the project. What should you do as the project manager?

- Wait until the last minute to do so.
- **Ask the customer for a letter of intent.**
- Only start to collect resumes and not commit any funds.
- Explain to management that this would not be a good idea at this point.

> The agreement is not signed yet, and there is no letter of intention. Take care that you should have a letter of intention before starting the project.

71. You have been working for eight months on a 12 months project time. The project is ahead of schedule when one of the functional managers tells you the resources committed to the project are no longer available. After investigating, you discover the company has just started another project and is using the resources committed to your project. You believe the new project is not critical, but

the project manager is the son of a board member. What is the best action in this situation?

- Determine when resources will become available.
- **Ask upper management to formally prioritize the projects.**
- Use the reserve to hire contractors to complete the work.
- Negotiate a new schedule with the other project manager.

We all like this man. In this critical case, you should be professional and intelligent when dealing with this situation.

72. Maintenance and on-going operations are very important to projects and should:

- be included as activities to be performed during the project closure phase.
- have a separate phase in the project life cycle because a large portion of life cycle costs is devoted to maintenance and operations.
- **not be viewed as part of a project--a project is temporary with a definite beginning and end.**
- be viewed as a separate project.

73. The project has a critical deliverable that requires certain specialized and competent engineers to complete. The engineer who is working to complete the task has left the company and there is no one who can complete the work within the company. For this reason, the project manager needs to acquire the services of a consultant as soon as possible. What is the best action as the project manager?

- **Follow the legal requirements set up by the company for using outside services.**
- Bypass the company procedures as they are not relevant to the situation.
- Expedite and go directly to his/her preferred consultant.
- Ask his manager what to do.

> Follow the procedure and legal requirements for the company and avoid any suspect.

74. What is one of the KEY objectives during negotiations?
    - **Obtain a fair and reasonable price.**
    - Negotiate a price under the contractor's estimate.
    - Ensure that all project risks are thoroughly delineated.
    - Ensure that an effective communication plan is established.

75. You have just been assigned to a project that is in the middle of the execution phase. What is the best way to control the project as the project manager?
    - **Use a combination of communication methods.**
    - Hold status meetings because they have worked best for you in the past.
    - Refer to the Gantt chart weekly.
    - Meet with management regularly.

> You are new on the project and entered halfway in to the project, so you need to use all communication methods.

76. Your company is purchasing the services of a consultant. You know one of the consulting companies interested in the work. What should you do?
    - Work hard to get the consulting company selected for the project.
    - **Tell your manager and remove yourself from the selection committee.**
    - Tell the people from the consulting company that you hope they get the work.
    - Keep the information to yourself.

> You should tell the manager and remove yourself from the selection committee, from an ethical point of view. If you keep information to yourself, you take a negative action and may lose an excellent engineering office.

77. What leadership style should you employ during the first two weeks of project planning?

- Coaching
- **Directing**
- Supporting
- Facilitating

78. You have just been hired as a project manager and you are trying to gain the cooperation of others. What in your opinion is the BEST form of power for gaining cooperation under these circumstances?

- **Formal**
- Referent
- Penalty
- Expert

79. During project planning in a matrix organization, the project manager determines that additional human resources are needed. From whom would he request these resources?

- Project manager
- **Functional manager**
- Team
- Project sponsor

80. A team member who doesn't have the required skills or knowledge was assigned to a team. Who is responsible for ensuring that he receives the proper training?

- Sponsor
- Functional manager
- **Project manager**
- Training coordinator

> The project manager is responsible for training team members and upgrading their competency.

81. All of the following are correct statements about project managers EXCEPT:

- **they are assigned after performance reports are distributed.**
- they have the authority to say no when necessary.

- they manage changes and factors that create change.
- they are held accountable for project success or failure.

82. A project manager must publish a project schedule. Activities, start/end times, and resources are identified. What should the project manager do next?
    - Distribute the project schedule according to the communications plan.
    - **Confirm the availability of the resources.**
    - Refine the project plan to reflect more accurate costing information.
    - Publish a Gantt chart illustrating the timeline.

83. You work in a matrix organization when a team member comes to you to admit he is having trouble with his task. Although not yet in serious trouble, the team member admits he is uncertain of how to perform part of the work on the task. He suggests a training class available next week. Where should the cost of the training come from?
    - Switch to a trained resource to avoid the cost
    - The human resource department budget
    - The team member's functional department budget
    - **The project budget**

84. Which of the following is an output of team development?
    - Management plan
    - Staffing management plan
    - **Performance improvements**
    - Reward system

85. You have been working on a project for six months with the same team, yet the team still shows a lack of support for the project. What should you do as a project manager to obtain the team's support for the project?
    - **Reevaluate the effectiveness of the reward system in place.**
    - Talk to each team member's boss with the team member present.
    - Find someone else to be project manager.
    - Tell the team he/she needs its support, and ask them why they do not support the project.

86. You have just been informed that one of your team members has not been adequately trained to complete project tasks as assigned to him. How would you handle this situation?

- Replace this team member with someone more qualified.
- Request proper training be provided through the functional manager.
- Revise the schedule to account for the decreased effectiveness of this resource.
- **Mentor this resource during the remainder of project duration.**

87. You are now a project manager for an international project and you use people from different countries. What should you expect as a project manager?

- Added costs due to shoddy or incomplete work
- Language or cultural differences that preclude effective team work
- **Increased organizational planning and coordination activities**
- Team building activities become impractical, and the cost is prohibitive

88. A senior engineer assigned to your project contacts you, trying to get off the team. He knows that an important project in his department is going to be approved and will take place at the same time as yours. He wants to work on the other project. What is the best action?

- Release him from the team.
- **Talk to the functional manager about releasing him from the team.**
- Release him after he finds a suitable replacement.
- Speak with the project sponsor about releasing him from the team.

89. Two lead processes and piping are having a big disagreement about how to accomplish a project from a technical point of view. The client is upset from that as it impacts time. What should you do as a project manager?

- Make the decision.
- **Send the team members to their managers for advice on resolving the dispute.**

- Ask for a benchmark analysis.
- Have the team members compromise.

90. Saying "Do the work because I have been put in charge!" is an example of what type of power?
    - **Formal**
    - Penalty
    - Effective
    - Expert

91. Which of the following is the BEST method to making a reward systems MOST effective?
    - Pay a large salary increase to the best workers.
    - Give the team a choice of rewards.
    - **Make the link between performance and reward clear.**
    - Present notifications of rewards within the company.

> Reward is a good tool when it is used correctly. If you increase the salary of the best workers, after a time he or she could begin to feel it is his right, so the raise may lose its meaning and the performance will become less. On the other hand, all the colleagues will not support him or her in future, and the work environment will not be good. The best thing is to make the link between performance and rewards clear and measurable.

92. A project manager says to a team member, "If you cannot complete this task according to the quality standards you set in place, I will remove you from the team that is going to Paris for the milestone party with the customer." What form of power is the project manager is using?
    - Reward power
    - Formal power
    - **Penalty power**
    - Referent power

93. You are a project manager and your project schedule is tight and in danger of falling behind when structure and piping leads to disrupting status meetings by arguing with each other. What action should you take?
    - Separate the two until the project is back on track.
    - Speak with each team member and give each a verbal warning.

- Discuss the problem with the manager of the two team members.
- **Meet with both team members and their function manager to determine the source of conflict.**

> The fast track action is the last one. The first solution to separate them is not a good solution, and if you speak to each one and their bosses separately, it will waste your time and take a long time to resolve.

94. What conflict resolution technique is a project manager using when he says, "I cannot deal with this issue now!"

- Problem solving
- Forcing
- **Withdrawal**
- Compromising

95. A team member complains to the project manager that another team member has once again failed to provide necessary information. The project manager meets with both team members to uncover the reason for the problem. This is an example of:

- withdrawal.
- **confronting.**
- compromising.
- smoothing.

96. The forms below present a power derived from the project manager all EXCEPT:

- Formal
- Reward
- Penalty
- **Expert**

97. In which phase of the project should the project manager provide more direction?

- Initiating
- **Planning**
- Executing
- Controlling

98. A project manager has just been assigned a team that comes from many countries including Brazil, Japan, the US, and Britain. What is his or her BEST tool for success?
- The Responsibility Assignment Matrix (RAM)
- The teleconference
- **Team communication with the WBS**
- Communication and well developed people skills

99. A project manager needs to determine the resources needed for the project. Select the primary tool from the following:
- **Work breakdown structure**
- Schedule
- Expert advice from functional managers
- Expert advice from management

100. Your role is a project manager for a large project. One of your key resources has started to do his task behind schedule and work quality is beginning to suffer as well. You are confident that this person is well aware of the work schedule and required quality specifications. What action should you take?
- Report the problem to HR for corrective action.
- Reassign some work to other team members until performance starts to improve.
- Meet with the employee in private and try to determine the factors impacting performance.
- **Escalate the situation to the employee's functional manager and ask for assistance.**

> The last solution is the best one. In the case of any technical problems, raise it to the function manager so he can provide a solution for the specific problem.

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References

Bourdaire J.M., R.J. Byramjee & R. Pattinson, 1985," Reserve assessment under uncertainty - a new approach"; *Oil & Gas Journal* June 10, 135–140.

Cozzolino, J., 1977. A Simplified Utility Framework for the Analysis of Financial Risk, Economics and Evaluation Symposium of the Society of Petroleum Engineers, Dallas, Texas. Paper 6359.

Crystal Ball program, Manual of risk Assessment, 1994

David Burchess, Specifications and quantities, Mcdonlad & Evans ltd, 1980.

Federation International des Ingenieurs-Conseils, *Client/consultant Model Service agreement*, Part I standard conditions, 1990.

J. Davidson Frame, *Project management competence*, J. Davidson Frame and Jossey-Bass Inc., 1999.

John P. Kotter, *Leading change*, Harvard Business School Press, 1996.

Market P., Gustar, M., and Tikalsky, P. J. (1993) " Monte-Carlo Simulation - Tool For Better Understanding of LRFD", *J. of Struct., Div.,ASCE*, Vol. 119, No.5, May, pp. 1586–1599.

Michael W. Newell "Preparing for the Project Management Professional (PMP) Certification Exam", AMACO, 2005.

Nikolaos Plevris, Thansis C. Triantafillou and Daniele Veneziano, (1995) "Reliability of RC Members Strengthened With CFRP Laminates", *J. of Struct Div., ASCE*, Vol. 121, No. 7, July, pp 1037–1044.

Project Management Institute Standards Committee. *A Guide to the Project Management Body of Knowledge*. Upper Darby, PA: Project Management Institute, 2000.

Project Management Institute Standards Committee. *A Guide to the Project Management Body of Knowledge*. Upper Darby, PA: Project Management Institute, 2004.

"The Modified Delphi Technique - A Rotational Modification," *Journal of Vocational and Technical Education*, Volume 15 Number 2, Spring 1999, web: *VT-edu-JVTE-v15n2*: of Delphi Technique developed by Olaf Helmer and Norman Dalkey.

Rashedi, M.R. (1984), "Studies on Reliability of Structural Systems," Ph.D. Thesis, Western Reserve University, Cleveland, Ohio.

Ray Tricker (1997) "ISO 9000 for Small Business," Butterworth-Heinemann, 1997.

Rescher(1998): *Predicting the Future,* State University of New York Press, 1998.

Richard Freeman, (1993) "Quality Assurance in Training and Education," Kogan Page, London.

Sackman, H. (1974), "Delphi Assessment: Expert Opinion, Forecasting and Group Process", R-1283-PR, April 1974. Brown, Thomas, "An Experiment in Probabilistic Forecasting", R-944-ARPA, 1972 - the first RAND paper.

Stephen Grey "Practical Risk assessment for Project Management", John Wiley & Sons, 1995.5

Turner, J. Rodney (1993). *The handbook of project-based management.* McGraw-Hill, London.

"The Building Commissioning Guide," U.S. General Services Administration Public Buildings Service Office of the Chief Architect, April 2005.

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About the Author

Mohamed A. El-Reedy's background is in structural engineering. His main area of research is the reliability of concrete and steel structures. He has provided consulting to different engineering companies and oil and gas industries in Egypt and to 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, and telecommunication towers and electrical projects with WorleyParsons Egypt. He has participated in Liquified 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 in the Red Sea.

Dr. El-Reedy has consulted with and trained executives at many organizations, including the Arabian American Oil Compnay (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 about repair and maintenance for reinforced concrete structures and the advanced materials in concrete industry worldwide, especially in the Middle East.

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