
Project Management for Environmental, Construction and Manufacturing Engineers

Nolberto Munier

Project Management for Environmental, Construction and Manufacturing Engineers

A Manual for Putting Theory into Practice

With additional contributions by
Fernando Jiménez-Sáez and Marta Fernández-Diego

 Springer

Nolberto Munier
INGENIO (CSIC-UPV)
Universitat Politècnica de València, Spain

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Preface

Project management is a very complex activity involving interacting and dealing with people with diverse skills, interests, and experience, different activities and lines of work, various trades and often working for the same project in different places at the same time. A project can take only a couple of weeks or a number of years. It can employ few people or several hundreds, often requiring large amounts of money in salaries, wages and equipment, with a few or perhaps thousands of activities which are to be executed sequentially, in series or in parallel, normally with the work finished by one trade as an input for another. It may have to deal with uncertainties or unfamiliar facts, sometimes involving risky operations and circumstances considering the welfare of workers as well as the nature of the work. All of this must be done on time, within budget, without accidents, aiming at the highest quality and to the entire satisfaction of the client and stakeholders. What a challenge!

Human contact, as a most fundamental attribute of any complex project, involves working with different professionals such as engineers, architects, accountants, planners, safety monitors, public relations specialists, finance and computer people, as well as suppliers, contractors, and of course, with the promoters of the project, both clients and stakeholders. Consequently, a project manager, who obviously needs to delegate most of the non-management work, must have a thorough understanding of the different particulars of the project under his/her direction and thus quality of leadership is essential for its development.

This book is devoted to exposing the practical side of project management, by which term we mean the project manager and all the technical staff under his/her authority. In other words, this book illustrates in a practical way the know-how of project management, which is *how* things are done, using the latest techniques and informatics tools.

The chapters are organized following approximately the subsequent scheme:

An abstract on its content.

- (a) Introduction to the chapter subject.
- (b) Concise information about its importance and a brief theoretical background.
- (c) Origin of the data needed to be processed in the technique explained in each chapter (from other groups or processes). The idea is to establish link/s with the source/s, for the analyst to know from where to get the necessary information. This procedure is essential in step (e). This dependency is shown graphically by an arrow diagram.
- (d) Destination and usefulness of results it produces (to same or other groups and processes). The idea is establishing link/s with destination/s, for the analyst to know who will use this information, or what it is for. This procedure is essential in step (e).
- (e) Analysis of feedback procedures when necessary (to same or other groups and processes).
- (f) Resolving an application example in an actual case and commenting on the use of pertinent available commercial computer software.
- (g) Even though each chapter is self-contained, there are no doubts that Project Management is not a lineal sequential procedure. More often than not a continuous feedback is necessary; therefore, there is a lot of intercommunication between the different processes, as per mentioned in steps (c), (d) and (e).
- (h) Conclusion and recommendations.
- (i) Bibliography and Internet references.

Twenty-seven case examples are proposed in this book, most of them taken from actual experience. Consequently, there are many tables and figures in an attempt to make reading and understanding as easy as possible. To avoid confusion, since a chapter may have more than one example and more than one case study, each table/figure bears two captions: the name of the table/figure, and the case study it belongs to. This second caption is underlined to identify the caption with the corresponding case study. Those tables/figures which do not refer to case studies bear only the caption with the name.

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Contributors

Marta Fernández-Diego Universitat Politècnica de València, Valencia, Spain

Fernando Jiménez-Sáez Universitat Politècnica de València, Valencia, Spain

Nolberto Munier Consulting Engineer TEAMIC, General Urrutia 37, 2nd, 03, Valencia 46006, Consultant in Project Management, Valencia, Spain

Additional Contributions

Chapter 3: Part II: Fernando Jiménez-Sáez, (INGENIO) Universitat Politècnica de València, Spain.

Chapter 6: Marta Fernández-Diego, Universitat Politècnica de València, Spain.

Abstract

This first chapter deals with the knowledge, understanding and analysis of an already determined project, and involves the difficult task of collecting the necessary information to allow stakeholders to make strategic decisions and managers to proceed with the tactics of their execution. It is assumed that part of this intelligence is the result of a prior market study, an activity not considered in this book because it does not belong to the project management area. It is input provided by the client or group of stakeholders, often in accordance with a decision from a Board of Directors, based on information and recommendations from specialized marketing people. Therefore, the assumption is that the project, group of projects, alternatives, programs, etc, have already been defined and their main characteristics known. That is, the nature of the project has been established; it could be a residential housing development, a large construction undertaking such as a tunnel, a railway, a dam, a highway, a pipeline, etc., or an informatics project such as the development of an E.R.P (Enterprise Resources Planning), or a plan to design a new heavy-duty truck.

The objective for developing the project being known, it then becomes necessary to define its scope, from which will arise estimates of completion time and cost. Then the stage of project integration begins, i.e. determining how to combine all the different expertise areas of the company and the processes required in order to design a set of tasks that will work in harmony. The result of this stage should be a tentative schedule and projected costs that will supply the Board of Directors with more information for decision-making.

This is also the stage when the promoter, which may be an individual, a company, a consortium, a government agency, a consulting firm, etc., needs to decide how its structural organization should be adapted to handle this particular project, which could perhaps involve the creation of a new company or could suggest considering a temporary association with another firm. Other actions involve establishing procedures and regulations for selecting personnel, formats and frequency of reports, fixing milestones, etc., and of course, a critical activity is appointing a project manager. As a summary, this is a fundamental stage of any project, from where everything starts; there are no operational techniques discussed here but rather the principles of good planning, sound reasoning, and appropriate structuring for the job.

Keywords

Project • Board of Directors • Firm structure • Tentative planning • Project manager • Project management

1.1 Some Definitions

1.1.1 Project

A finite, specific and usually unique undertaking with a precisely defined goal, requiring the execution of a series of activities in a certain order. It is finite because it requires a start date and a finish date; specific, since it is executed for a defined purpose or goal; and unique as it is seldom repeated, and even if it is, the next project will be different from the former.

We have thusly defined a project as with respect to its ‘physical’ components, but in reality what is a project? A project is a “system”; it has all the elements that qualify for this assertion. INCOSE (2000) defines it as:

A system can be broadly defined as an integrated set of elements that accomplish a defined objective.

A project can be then considered as an integrated set of actions, many of them linked in a feedback structure, defining the latter as an output of a sub process that is fed back to the same or to other sub processes. For instance, in the initiation process, sales for the product to be manufactured by the project are assumed; then the financial procedure determines – based on this sales estimate, and together with other variables such as raw material and production costs, transportation, risks, etc. – what will be the rate of return. If the resulting figure is not satisfactory, for instance because it is too low when compared with other potential investments, new values and perhaps expectations are entered into the initiation process which is run again.

1.1.2 Project Management

Project management is the art of directing and coordinating human and material resources throughout the life of a project by using modern management techniques to achieve predetermined objectives of scope, cost, time, quality and participation satisfaction. (Hendrickson 2008).

Stakeholder: Any group or individual who can affect or is affected by the achievement of the organization’s objectives (Mitchell et al. 1997).

1.1.3 Construction Project Management

It involves the management of the whole cycle of life of a project, that is from its inception until the expiration of the guaranty. Its primary authority is the Project Manager.

1.1.4 Construction Management

It involves the construction phase of the project. Its primary authority is the Construction Manager.

Alves (2004) is a good study for both functions and Integrated Project Management¹ with emphasis on quality.

1.2 Book Organization

This book is organized following a sequence of processes that has been established by the Project Management Institute (PMI), a worldwide-recognized authority in Project Management, which has prepared standards that materialize in a book called Project Management Body of Knowledge (PMBOK 2010) This not-for-profit organization identifies five groups of processes in the Cycle of Life of a project. These groups are:

1. Project initiation
2. Project planning
3. Project execution & oversight
4. Project control
5. Project closing

Even when this book follows these standards it addresses the project management issue from a different optic. Specifically, the PMBOK is a norm treatise dealing with *what* has to be done, while the present publication focuses on *how* it is done. To be more precise, the PMBOK is a collection of norms and standards aiming at doing things in the right way; it provides guidelines about best practices in project management and in so doing is a valuable tool, because it can be used as a yardstick for good project management engineering.

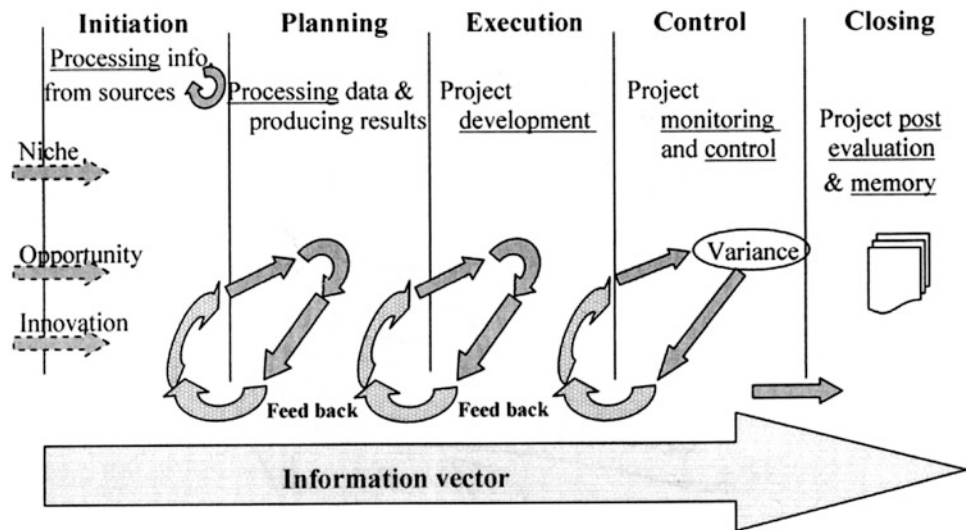
This book, in turn, adopts those principles and develops the necessary practical steps to get the job done; that is, it is a guide through the different stages of the project management process, suggesting procedures, instructing about different methodologies, and using mainly actual examples to illustrate each one.

Therefore, this is a practical book written to help practitioners in the development of the project management process. Although definitions and theoretical background are given for all items treated, it is done succinctly; for this reason it is advisable for the practitioner to have a look at PMBOK for detail information, norms, procedures and aspects to be considered. As an example, when analyzing the communications system it is convenient to read PMBOK’s Chapter 10, especially Section 10.1, regarding this issue, where there are useful hints as how to proceed in determining what information, must be given, when, and to whom.

This book focuses on the Integrated Management Systems (IMS) approach, which can be defined as “A system

¹ Integrated Project Management involves integrating with stakeholders in the management process.

Fig. 1.1 The information vector in the project management process



that integrates all of an organization's systems and processes in to one complete framework, enabling an organization to work as a single unit with unified objectives" (BSI Group 2007).

1.3 Strategic Sequence for Project Management

Project Management is a complex issue with many different activities that must be performed in a certain order, pertaining to different fields, having distinctive scope, and requiring each one a particular expertise. It is associated with the project lifecycle i.e. the series of activities executed in a sequential order from its very initiation to its closing out and beyond, reflecting in the latter the warranty extended to the customer. There is a certain direction to follow, starting with the germen of the idea to develop a project up to its successful completion, with information and work flowing from left to right, which can be represented as a straight arrow or 'Information vector', in the same sense, as shown in Fig. 1.1.

However, it is impossible to identify the process as a simple one, where once a group or phase is finished it is not visited again. In real life situations there are usually many feedback loops, meaning that information travels back and forth, i.e. the output, or part of it, from one group may come back to the precedent group, as it happens in actual projects, since it is very seldom that a project develops exactly as planned. These feedback loops are schematised as closed cycles in Fig. 1.1.

At first sight project management actions look like a chaotic endeavour, however, it is not so, since interrelationships are not at random, feedbacks are not arbitrary, and choices are not at will. Quite the opposite, the system is a well orchestrated network of information that trigger

actions, which are composed by hundreds or thousands of activities relevant to different areas of knowledge, pertaining to diverse frames, and spanning the five main processes, as mentioned before.

The object of this section is to establish the sequence through these processes using as a vector the information related with a project. This system starts in the initiation group based on ideas, opportunities and information from diverse drivers. This input is studied, analyzed and discussed, and, if it is attractive enough and has sufficient merit, passed to the planning group for a first technical and financial evaluation. There, the information is dealt with, processed, added, adapted to company possibilities and procedures, and the output, obtained using standard tools, is then fed back to the initiation group where it is discussed with more detail considering the information now available, and perhaps requiring more feedback, until stakeholders are satisfied with the outcome, which generally coincides with the green light to go ahead with the project.

In the execution group activities planned and scheduled in the planning group are implemented, however, many times information from the field or work is fed back to the planning group because things do not always go as planned, such as the necessity to introduce changes, which could be due to technical, commercial, social, legal, or whatever other reasons, or the appearance of unforeseen circumstances, or for the suspicion of risks ahead, etc. In these cases the information is analyzed in the planning group and the result or conclusion delivered back to the execution group. Usually this result is also sent to the initiation group if approval is necessary.

As project construction or project development continues, the control group working in parallel takes over, by monitoring if both the time elapsed and the cost of the work up to certain dates agree with time and budget in the same

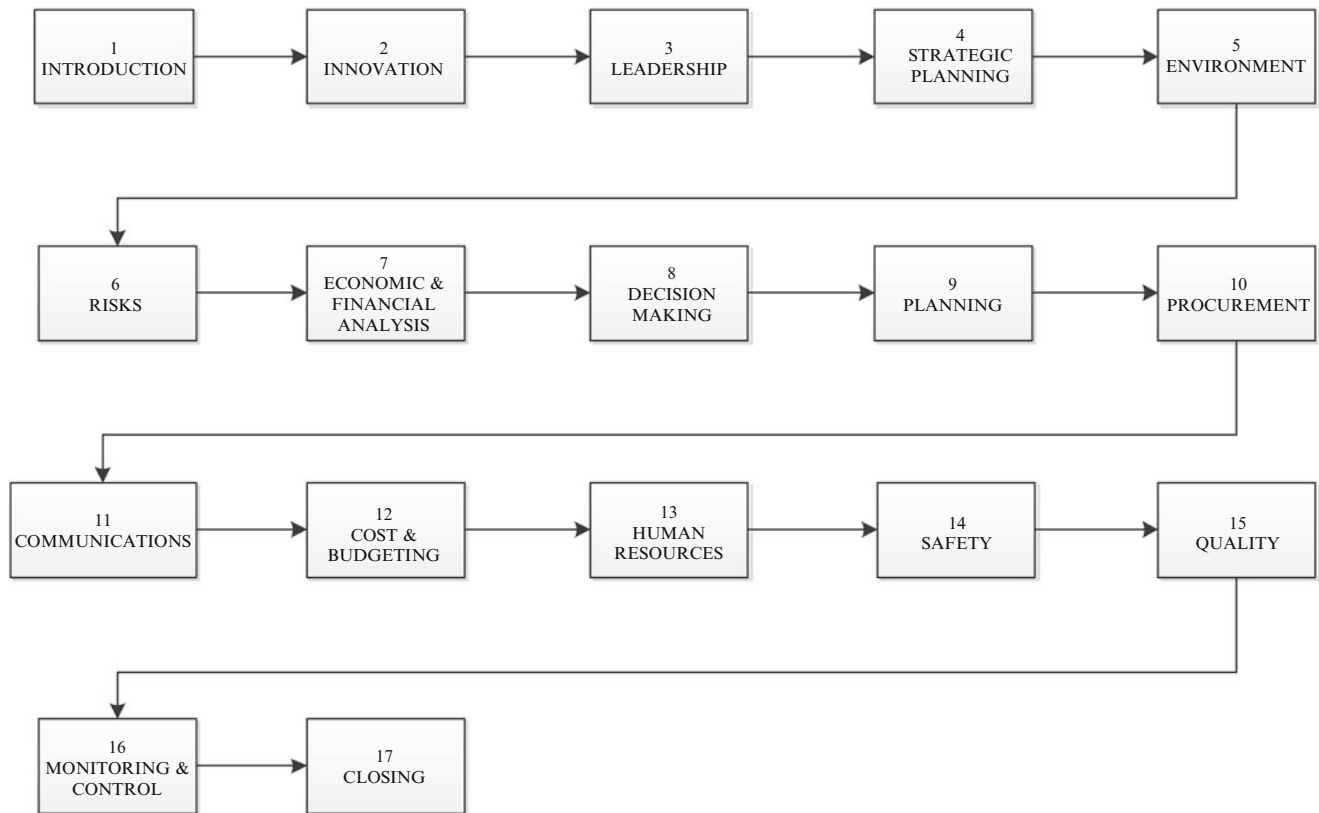


Fig. 1.2 Sequence of project management steps

periods, reporting if there are variances, in both costs and time. If these variances are significant, the control group, together with the Project Manager (PM), contractors, suppliers and other intervening parties, study measures to correct deviations. Again this information is passed on back to both the planning group and the initiation group, which must be kept informed of everything that can affect the project in one way or another.

When the work is completed, the closing group prepares all the necessary documentation for formal acceptance by the owner, provides all technical documentation pertaining the project, such as the ‘*as built*’ drawings, prepares the memory and closes the work, albeit leaving the project open until the warranty expires, as a post-project task.

1.4 Sequence of Processes in the Project Life Cycle

Figure 1.2 sketches the steps and ‘sequence’ in project management; numbers correspond to the chapter where each process is addressed.

The reasons for a company to set up or *Introduce* a new project it its strategic plans may obey different drivers,

which could ‘kick off’ the construction of an industrial plant, develop a new software, expand an existing facility, launch a new product, or start a mining complex. For instance a company may have discovered that there is a niche in the market for a product that they have been developing just at laboratory level, and then they think that it would be profitable to build a plant to produce it, or perhaps there is an opportunity in a project akin with the company expertise in large construction undertakings.

It could also be an *Innovation* – such as were Google, Facebook or iPad – that the company considers profitable and achievable. Whatever these sources the ideas reach a stage that merit consideration by the Board of Directors, which after rough estimates can give the green light to spend some money in a more profound research. Somebody with enough skills and expertise is needed to take the helm of the new potential undertaking, and then appears the necessity of *Leadership*, which materializes in the person of the Project Manager (PM).

The PM, together with other high level staff probably begins in thinking about policies, phases and ways of actions to develop the project, whatever it might be, i.e., he needs a *Strategic Plan*, that defines a strategy based in organization, procedures and methods to execute the project, considering

its strengths and weakness, and that will allow him to realize what aspects and things need to be considered, in order for the company to be where it wants to be in the future, at least regarding this specific project. For instance, the idea could be attractive, but will its impacts on the **Environment** be acceptable? What about its effects on society? Which are the **Risks** that this project can encounter and more important, safe and economically afford? Therefore, he needs information from sources about these two issues, and once he has them, he must analyze in detail their consequences. Assume that environment issues and risks can be, if not completely eliminated, at least reduced considerably, and for both he must establish some acceptable thresholds.

What about financing the project? Most likely at this stage, the PM possesses enough information as to have a rough idea regarding the order of magnitude of the required investment for the project spanning its Life Cycle, including both the construction and the operations period. Most probably the PM will not be responsible for the execution of the **Economic and Financial Analysis**, which surely will be in the hands of the Accounting and Financial Departments, but he/she must be able to furnish the information and calculations that these departments might require, and to do that he must be knowledgeable on the meaning and the importance of the information requested, and especially about their accuracy and reliability, since the execution of the project or its rejection by the Board of Directors greatly depend on this analysis.

Most projects do not have a unique course of action, since more often than not there are different alternatives or options, each one with their costs (economic, social and environmental), with impacts or consequences in the same areas, as well as their inherent technical difficulties and risks. Therefore the PM must usually play the role of a Decision-Maker to propose the higher echelons of the firm, the selected alternative that conforms most of stakeholders. This leads to the analysis of the project using **Decision-Making** techniques, and although it is not necessarily expected that the PM be an expert on this discipline, he must at least have an idea of how it can help him, in making the 'right' decision.

Consequently, knowing the selected option, the technical data and environmental constraints, estimated risks (and tolerances), and resources available, his/her² people can now start with the **Project Planning** stage, detailing the tasks and activities to perform, relationships between them,

their timing, and the necessity or not to call for contractors, suppliers and hire new personnel.

According to the nature of projects they often depend in large measure on material and equipment deliveries coming from suppliers and manufacturers, therefore the **Procurement** activity is essential. In addition, if the project is a complex one that will be developed in different places simultaneously, the PM must examine the existing **Communications** system in the company and determine its adequacy or lack of it, and also considering to what extent the stakeholders want to be informed about the developing of the project.

Well, at this stage the project manager is fully conscious about the complexity of the venture, and probably he has most of the elements he needs to compute **Costs**.

Once they are estimated, preparation of the project **Budget** follows, (not necessarily in Dollar or Euro values, for it can also be in manpower), i.e. to determine how much money the company needs for pursuing this project and perhaps more important – when it is needed – and verify if it coincides with what the Board of Directors has in mind or can afford.

Assume that this is accepted; now the PM needs people to manage and to execute this project, a resource that perhaps the company has, and if not, must get; that is he consults **Human Resources**, naturally furnishing information about the positions to be filled and the qualifications required for each of them. Of course he also points out specific aspects of the project such as **Safety** for the personnel working in the job site and **Quality demands** of the job, and how to control them. The PM is aware that the project has to be finished on time and within budget, therefore he must establish a rigid control not only on these two subjects but also on environment, risks and procurement. Then a **Project Monitoring and Control Sub-system** must be established.

Once the project planning is near completion, the PM has one final "*closing of the loop*" responsibility: completion of the issue and deliverance of **Closing** out documents. These documents include a project history, data, tables, sketches, such as built drawings, etc, that have been used in the project. The purpose of this documentation is to capitalize on lessons learnt, as well as to preserve information about particular aspects, problems and situations that can be used perhaps for other projects in the future, and also to leave a clean track record for anyone who might need to know in the future how the project was developed. These documents should also include a post-evaluation of the complete project as well as an assessment of how well or completely the result complied with the goals established, difficulties encountered and aspects that were not considered in the initial plan. If the project did not attain the preset goals there must be an explanation of why it did not.

²In order not to make the reading repetitive the pronouns 'he', 'she', 'his', 'her', will be used randomly in one gender or in the other, considering them as interchangeable and with the same meaning.

1.4.1 The Five Essential Functions in Project Management

These functions are: Planning, Scheduling, Execution and Overseeing, Monitoring and Control (PSMC), and Closing. They are the core of project management, which can be considered a system, since it receives inputs in form of information, materials, and labor, all of them interrelated, and injects this data into the system. The system processes them in building a factory, constructing a ship or developing new software, and delivers a product, which is the goal of the project. Alike any other system, project management uses a lot of feedback, making adjustments, changing the scope, deleting or adding activities, modifying labor, etc, and the results of these changes must be analyzed, and actions taken if necessary. In reality a critical component of PSMC, 'project controls', acts as a continuous feed-back mechanism, in an effort to keep the project on the right track, that is to finish it on time, under budget, with the highest quality standards, and to the entire satisfaction of the owner or promoter of the project, whoever it may be.

Naturally, all other functions such as financing, safety, environment, etc, are not only very important, but essential too, and no project can be successful without them. However, execution and PSMC, are the backbone because everything is structured around them. The latter is a complex issue since it involves many different procedures, a variety of techniques, many internal characteristics as well as usually unpredictable external influences. It requires using many different tools and very important, to keep stakeholders informed about the developing of the project.

Project management is indeed a rather confusing business because of the interrelationships between the different components. For this reason it is believed that a graphic deployment in a flow chart may be useful to practitioners. An example flowchart is depicted in Fig. 1.3.

It depicts the interrelationships between the different processes and within them. Naturally, it would be quite impossible to represent all possible connections, and because of that, it only shows the most significant. One important aspect to consider is that a project is not an independent entity within a large organization, it is part of a system, because it must be related with other departments within the company such as for instance Human Resources or R&D and then these areas, and others, must be incorporated in the whole process. One of the reasons for this link is that the project must aim at owner satisfaction, and from that point of view usually some departments not directly involved in the project are more in contact with the client and even can anticipate his/her wishes. For instance when an A/E consultant³ working for a client in a construction project

approves the schedule submitted by the main or general contractor, it is wise to consider also the owner's technical staff point of view, because they can have different ideas regarding some aspects of the schedule.

1.4.2 General and Useful Points to Take into Account

In considering a new project it helps to bear in mind the following general aspects:

- Establishing the objective.

It starts with the nature of the project, for it can refer to a product manufacturing, a construction project, a gadget design, or a consulting service to be rendered. If the objective deals with a new product or service, such as a new engine, a residential housing development, a new car model, a new book, an improvement on an existing product, etc., make sure that it will not hurt sales of another company's product of similar characteristics or purpose.
- Think about an appropriate brand name for the product to be manufactured by the project. (*Hint*: If the product will sell overseas make sure that its name does not have a negative connotation in another language). For instance, a famous case in the auto industry is that of a carmaker who produced a car under a name that meant '*Not good*', in another country's slang. It was no doubt for that reason, that the model did not enjoy a commercial success in said country, which was an important market.
- Estimate sales potential according to market and price.
- Evaluate competition, if any.
- Estimate potential risks, in all orders, that is in personnel safety, performance and skills; in delays, costs, suppliers, raw materials availability, transportation, weather, quality, etc.
- Estimate sales procedure, that is defining the marketing sales plan.
- Think about product presentation, that is packaging, if pertinent.
- Evaluate company's capacity for this undertaking, considering personnel availability, accessibility to funds, cash flow, and company expertise.
- Evaluate financial position of the company, and determine the influence that expenditures for this project may have on other ventures, that is make sure that developing this project will not compromise others.
- When examining availability of staff and workers for this undertaking, estimate the influence that their commitment to the new tasks might have on other current or potential projects in the portfolio.
- Appoint a project manager.

³ Architectural and engineering consultant.

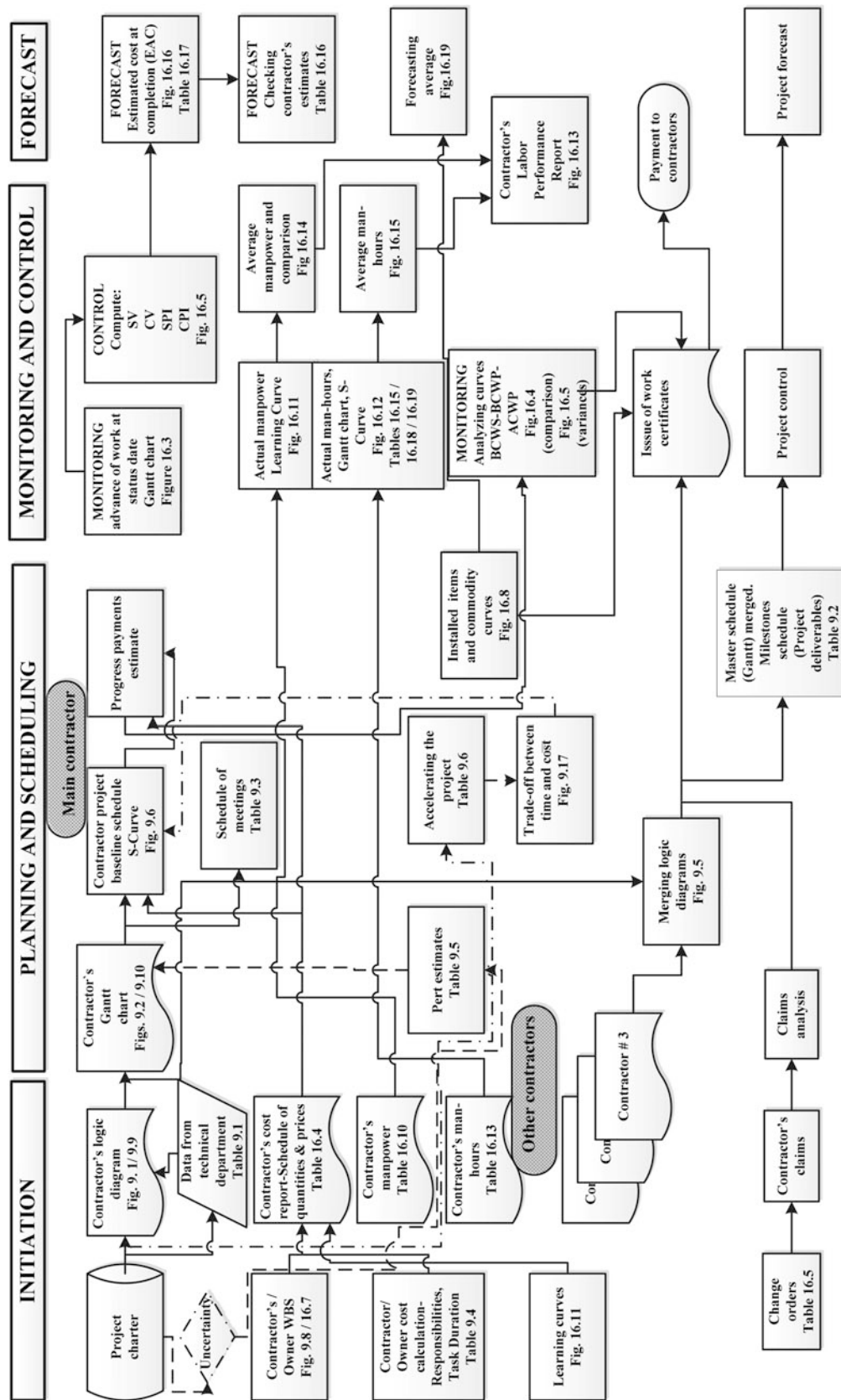


Fig. 1.3 Main relationships between components of a project life cycle

1.5 Chapter Structure

The five groups from PMBOK have different headings in this book, and it uses Tables 1.1, 1.2, 1.3, 1.4, and 1.5 to examine, comment and exemplify them. Each table has two columns and the information that it provides is sketched in Fig. 1.4.

The *left column* lists numbered actions whose execution is considered necessary in order to achieve the group objective. However, these actions are neither listed in a rank nor in a mandatory sequence, because it is almost impossible to consider them as a series of strictly progressive steps, since there is not a clear cut between them, and more often than not, they intrude into one another or generate loops.

This column also indicates which chapter or chapters contain detailed information about the activities selected in the right column, that is, methods to apply and process to follow for performing an action or actions, most of them with applications in real life examples. Examples include descriptions and applications of dedicated software necessary to manage some topics as well as procedures for their use.

Considering the large diversity of projects it is obvious that ‘*action*’ is a very extensive notion, however, it is assumed that actions listed within a group are common to a large set of different projects. Naturally, projects may be small, medium, large or very large, but it is understood that the nature and size of the project should dictate which actions must be used and which should no be considered. For instance, for a small project it may not be very important to analyze how the resources of the firm will be compromised. Other projects could be of easy realization and without foreseeable technical difficulties, and therefore some actions can be neglected.

The *right column* lists the different kinds of activities which furnish the information needed, as well as a summary description of methods, tools, calculations, processes and software to use in order to fulfil the corresponding action.

These tables constitute a large body of information and can also be used as an index. They guide the reader to where he/she wants to be, notwithstanding the subject sought, and all of them are organized in the same way, with one table for each group. Once a group is selected, its objective is immediately depicted.

To have a general view of the project management processes see Fig. 1.3 that shows interrelationships between different groups and within each one.

The suggested procedure is as follows:

1. Select the group of interest.
2. Determine in the left column which actions are to be performed according to the nature of the project.

3. Determine in the right column procedures and methods appropriated for each action, as well as techniques and tools that can be used for their compliance. Also find here where to look for examples.
4. Once a tool, method or software has been chosen, find a brief description of its theoretical aspect and examine cases of practical applications, which can be used as a guide to tackle a particular problem.
5. Look into the company structure and find out which department might have information and data for each action selected.
6. Proceed to the corresponding chapter to get detailed information and know how.

Three main words are used here, whose meanings are:

Action: Things done to achieve a particular purpose (Merriam-Webster Learner’s Dictionary). In this case the purpose of an ‘*action*’ is to match the group objective.

Activity: Something that is done as work or for a particular purpose (Merriam-Webster Learner’s Dictionary). In these tables the word ‘*activity*’ is related with different methods to perform and action.

Task: A usually assigned piece of work often to be finished within a certain time (Merriam-Webster Learner’s Dictionary). In these tables the word is applied in the same sense.

1.6 Tables for Performing Actions in the Different Groups

1.6.1 First Group: Initiation

Objective: Collect, analyze, refine, and study available information regarding a project to be able to make an educated decision on the convenience of pursuing it.

Refer to Table 1.1.

Left column: ACTIONS – Description

Action # 1. Possible origins, causes and reasons that support the initiative, that is, it gives the grounds for considering the execution of this project.

Action # 2. Company’s abilities to accomplish the project regarding funds, personnel, equipment, transportation, working in remote places or in a harsh environment, etc.

Action # 3. Special difficulties related to the project and its location, such as:

Regarding the project:

- Uncertainties inherent to the project (for instance, it is not known at this time how to eliminate radioactive debris from a contaminated site).
- Lack of complete information (such as related to the nature of the soil in a certain segment of a tunnel).

Table 1.1 Actions to be performed in the initiation process group

Initiation group	Information on corresponding activities and where to find applicable methods and examples
Actions	
<i>This column lists: Actions to perform to conform group objective</i>	<p><i>This column is concerned with intelligence aimed at pursuing the action mentioned at left. It refers to chapters where a complete description and example is given for each concept described, and includes:</i></p> <ul style="list-style-type: none"> • <i>Information about origin or source of data needed for a specific action,</i> • <i>Comments about real life situations,</i> • <i>Tools and methods to execute the corresponding activity,</i> • <i>Brief background explanation of tools and methods, as well as real life applications using these tools and methods,</i> • <i>Modus operandi is detailed for each activity and suggestions given.</i> <p>In addressing this group, and because of its wide scope, it is found convenient that comments consider certain types of undertakings – the most complex – since simpler ones will be then included. For that reason, this table refers to <i>large construction jobs</i> such as highways, chemical plants, tunnelling, hydroelectric projects, water transfers, railway construction, mining, etc., or to big <i>manufacturing plants</i>, for instance energy generation, automobile factory, blast furnace construction, and other <i>large undertakings</i> such as sizeable land use projects, pipelines, etc.</p>
<p>1. What are the reasons to consider a project such as this one? <i>See Chap. 1</i> <i>See Chap. 2</i></p>	<ul style="list-style-type: none"> – Local market demand – International markets demand – Third party proposal – Short and long term predictions about demands and prices for products or services that can be produced by the company – Merging with another company – Successful bidding for construction, developing, studies, etc. – Remediation or/and special projects, for which the company’s expertise is rather unique. <i>[See example in Sect. 9.10 ‘Uncertainty in High Valley remediation project’](Chemical plant)</i> – Innovation and design of new products <i>[See example in Sect. 2.4 ‘Developing a tool for decision-making project’ (IT product)]</i> – New government plans and projects benefiting company activities <i>[See in Sect. 8.1 remarks on benefits and subsidies offered by some local governments to lure investors to establish in their area]</i> – Convenience to take advantage of the company dominant position in the market – Detection of a new niche for a new product or service – Production and R&D departments, project feasibility from the company point of view – Some innovation that is worth developing
<p>2. What are the company’s abilities for this undertaking? Find out about company’s abilities for this project execution regarding expertise, experience, workforce, quality management, financial resources, etc. <i>See Chap. 7</i> <i>See Chap. 10</i> <i>See Chap. 13</i></p>	<ul style="list-style-type: none"> – Financial department, advises about funds availability for this project – Production department informs about the need to acquire dedicated equipment for certain operations to manufacture a new product. In this case, cost of new equipment and installation. – Production department, informs about present-day enough and adequate equipment without compromising actual plans – Planning department informs about the availability or not of enough equipment, considering present day resources usage, or the need to acquire additional equipment, or the necessity to replace some existent machinery with larger ones with more capacity or faster output, etc. – R&D department, finds if the proposed method to fabricate a good is the most convenient process, or if it possible to use another way to reduce production costs. – Personnel department informs about personnel availability for this undertaking, or the need to incorporate more people. – Board of Directors, analyses Company’s structure for this project. – Board of Directors, analyses company’s quality standards – Internal communications, evaluation of existing procedures to communicate with client and suppliers <i>[See example in Sect. 11.3 ‘Diagnosis in an enterprise and proposal to install the ERP’ (Cosmetic products)]</i>

(continued)

Table 1.1 (continued)

Initiation group	Information on corresponding activities and where to find applicable methods and examples
Actions	
3. Learn about difficulties inherent to this project and its environment	<ul style="list-style-type: none"> – Planning department makes it known about how to deal with difficulties (such as the need of constructing access roads, or to improve those in poor condition to a jobsite in hilly country, or the necessity of reinforcing bridges with low load capacity for heavy trucks traffic, or lack of a nearby harbour, or difficulty in getting skilled workforce in the project site, etc). <i>[See example in Sect. 7.5 ‘Civil construction project-(Copper concentration plant)’] (Difficulties).</i> – Uncertainties are very often inherent to projects, and in these cases provisions must be taken regarding execution times, poor geological rock conditions in the jobsite, or unknown results from performing an action. <i>[See example in Sect. 9.10 ‘Uncertainty in High Valley remediation project ‘](Chemical plant).</i>
4. Perform a gross estimate of success	<ul style="list-style-type: none"> – Marketing department, for a trend estimate of market share – Marketing department, notifies about own product advantage over competition – Marketing department , if it believes that the product is something badly needed – Sales department, on forecasting increasing demand and estimates of how the new product will be received in the market – Forecasting of sales figures from marketing – Production department, about potential of installed production capacity to manufacture a new product – Human Resources, about good chances to get skilled personnel – Finance department, on expectations about a healthy cash flow – Existing regulations as how they can affect the product <i>[See example in Sect. 4.4.2 ‘Commercialization and distribution of an imported food product into the USA market’] (SWOT analysis)</i>
5. Perform a gross estimate of failure	<ul style="list-style-type: none"> – Marketing department, for updated estimates – Marketing department, regarding people reaction to a new product – Sales department, forecasting for steady or decreasing demand, or because it may collide with existing legislation, etc. – Production department, if in doubt about installed capacity to meet requirements – Human Resources, on difficulties in getting skilled personnel – Finance department, on doubts about a healthy cash flow. <i>[See example in Sect. 4.4.2 ‘Commercialization and distribution of an imported food product into the USA market’] (SWOT analysis).</i>
6. Gross estimate of costs <i>See Chap. 12</i>	<ul style="list-style-type: none"> – Production department for estimates in workforce, materials, tests, mock-ups, and putting into production. – Budget department, to determine a rough cash-flow.
7. Gross estimate of time needed	<ul style="list-style-type: none"> – Production department, about workforce and equipment performance. – Planning and scheduling department, about staff expertise, physical working space, availability of adequate equipment (trucks, cranes, bulldozers, etc.). – Planning and scheduling department, estimate time for construction, based on local standards, as well as rough conditions, for instance high altitude, underwater work, extreme heat and cold, frequent rains, avalanches, flooding, highly unionized workforce, etc.
8. Execute project financial analysis, contemplating ‘Assumptions’ and corresponding ‘Results’. For instance, under ‘Assumptions’, consider: Working capital provisions, Percent equity, Income tax rate, etc.	<ul style="list-style-type: none"> – Finance department, about range of IRR desirable, considering alternative uses of own capital. – Finance department, about other opportunities for own capital (opportunity cost). – Finance department, about capital cost. – Finance department, about contingency fund. – Accounting department about potential evolution (increasing or decreasing) of working capital during the life cycle of the project, that is computation of current assets and current liabilities ratios <i>[See example in Sect. 7.5 ‘Civil construction project (Copper concentration plant)’] (Financial analysis).</i>

(continued)

Table 1.1 (continued)

Initiation group	Information on corresponding activities and where to find applicable methods and examples
<p>Actions</p> <p>and under 'Results', aspects such as:</p> <p>Project cash flow in a certain time horizon, Earnings per share, Debt coverage, etc.</p> <p><i>See Chap. 7</i></p>	<ul style="list-style-type: none"> – Preparation of financial statements, that is: balance sheet, cash-flow statement, statement of earnings, long-term loan schedule, assets-depreciation and amortization schedule, etc. <i>[Idem]</i> – Financial department, performing sensitivity analysis to analyze how potential variations in certain parameters such as price, demand, inflation, interest rates, capital cost, etc., may affect critical aspects such as working capital, IRR, debt coverage, etc., <i>[Idem]</i>
<p>9. Identify and evaluate risks involved</p> <p><i>See Chap. 6</i></p>	<ul style="list-style-type: none"> – Analyze the project to foresee potential risky areas and make a list of them <i>[See examples in Sect. 6.4.1 about different types of threats for different activities]</i>. – Planning and scheduling department, evaluating effects in the scheduled completion time due to delays in supplies and in construction work, or because of severe work accidents, or due to geological conditions, politics involved, strikes, etc. – Planning and Human Resources department, concerning personnel willingness to follow safety procedures, or because scarcity of skilled personnel, or union problems, etc. – Finance department, due to uncertainties in getting bank loans or hints of high interest rates. – Production department, because of suspected delays in getting inputs and equipment in time, or because there are only one or two suppliers for critical items, or from potential problems in transportation of heavy equipment from factory to the jobsite, etc. – Planning, Engineering departments. Consider the necessity of safeguards, for instance acquiring an emergency diesel generator set in case of failure of electric power, or the construction of a trench to prevent flooding of the working space, or the necessity to provide fruit tree supports to allow a normal sway with strong winds, etc. <i>[See Sect. 16.18 about additional safeguard activities needed to protect wild life]</i> – Legal department, to analyze potential violations to existing regulations, for instance construction on certain sea beaches, or extracting aggregates from no-authorized sites, etc. – Legal department, to analyze the existence of potential points of conflict with people that might be affected by the project. <i>[See in Sect. 4.6.8 remark about resistance of people affected by a project]</i>
<p>10. Identify stakeholders</p>	<ul style="list-style-type: none"> – Board of Directors. Contacting potential participants in the project or partners willing to participate – Board of Directors. Contacting people who will be directly or indirectly affected by the project. <i>[See in Sect. 4.6.8 remark about resistance of people affected by a project]</i>
<p>11. Refine financial aspects</p>	<ul style="list-style-type: none"> – Finance department, from contacts with financial institutions to find out about chances for soft loans and conditions. – Finance department, for the most convenient financial sources <i>[See in Sect. 8.2.2 remark about different sources for financing bridge repairs and subject to ownership]</i> – Board of Directors, from government (related with possibilities of subsidies and taxes rebate, or tax deferral) – Analyze diverse financial needs for the different alternatives or project were
<p>12. Refine firm capability</p> <p><i>See Chap. 1</i></p>	<ul style="list-style-type: none"> – Board of Directors, about assessing company's strengths and weakness – Production department, concerning personnel skills and availability and need of dedicated equipment – Planning and Scheduling department, about appropriate use of company's resources – R&D department, producing standardized forms, reports, presentations, communications, etc. to improve efficiency – Board of Directors, from analysing project structural organization – Planning department, furnishing minimum size of plant <i>[See Sect. 12.1.7.1]</i> and production volume as well as break-even point information on sales volume and selling price <i>[See Sect. 7.6]</i>

(continued)

Table 1.1 (continued)

Initiation group	
Actions	Information on corresponding activities and where to find applicable methods and examples
13. Consider environmental issues associated with the project <i>See Chap. 5</i>	<ul style="list-style-type: none"> – Environment department, furnishing analysis of project impacts – Legal department, with information on legislation on environmental impacts – Environment department, with determination of impact on society. If they exist, then an evaluation is necessary – Environment department, investigating life cycle for the project with recommendations to decrease impact
14. Consider social issues associated with the project <i>See Chap. 9</i>	<ul style="list-style-type: none"> – R&D department, with information about the social cost of project – R&D department., with information from consulting affected people
15. Make analysis of competition regarding the product to be manufactured, service to be rendered, or in bidding for a construction project	<ul style="list-style-type: none"> – Marketing, from analysis of main differences with competition [<i>See example in Sect. 15.10 ‘Case study: Launching a new portable music player’</i>] – Sales and Marketing departments, supplying information on performance of competition product [<i>Idem</i>] – In projects with repetitive tasks such as in construction consider bidding with knowledge of productivity (for instance man-hours/m³ of concrete poured), using the learning curve if there is former experience [<i>See example in Sect. 16.3.2 ‘Learning curve applied to the construction of a subway tunnel’</i>].
16. Perform economic analysis regarding profitability of undertaking <i>See Chap. 7</i>	<ul style="list-style-type: none"> – Accounting department, about how the project can improve company’s profits – Accounting department, about influence of the project in the balance of payments of the country [<i>See in Sects. 7.5.8 and 7.5.9 examples of financial indicators</i>] – Accounting department, about inflation forecasting and trend
17. If necessary, perform alternatives selection <i>See Chap. 8</i>	<ul style="list-style-type: none"> – The Project Director, as a decision-maker. <p>In many opportunities, a project may have several alternatives, all of them feasible, but most probably with different cost, scope, risk, or environmental constraints; for instance the existence of three different locations for the construction of a textile plant. Other times, a firm can have a portfolio of projects and, similar to the selection of alternatives, must decide which of the projects is to be executed. A team involving the decision-maker, stakeholders and analysts does this, helped by different methodologies and corresponding software.</p> <p>The problem lies in the fact that the different alternatives or projects, have to comply with both a set of criteria and a set of objectives, and the quandary is then to find out which of the alternatives or the different projects must be chosen considering the different objectives and criteria at the same time. [<i>See example in Sect. 8.1 ‘Finding a location for an industrial plant’</i>]</p> <p>This same methodology can be applied to select contractors as well as suppliers of heavy equipment [<i>See in Sect. 8.6 remark for vendor selection</i>]</p>
18. Write the project charter 19. Develop master schedule <i>See Chap. 9</i>	<ul style="list-style-type: none"> – Board of Directors, from information gathered from different sources – Planning department, with information from the Board of Directors, Legal department, and Client, can establish the definite scope of project – Planning and scheduling department. With information given by the Board of Directors, Client, Suppliers, Main contractor, Subcontractors, etc., regarding scope, key completion dates, agreed start and finish dates, resources, agreed calendars, etc., can build a Master schedule. <p>This is a very compressed graphic document, which shows time-wise the development of the whole project, regarding execution periods for each main task. Naturally, it is not detailed, and therefore a large and complex activity such as ‘<i>Construction of powerhouse</i>’, lasting 26 months, is shown as a single horizontal line (Gantt bar), and of course in a detailed working schedule it can have thousands of tasks to execute in those 26 months. Together with the lines for other major activities or even areas, they constitute the <i>Master Plan</i>.</p>

(continued)

Table 1.1 (continued)

Initiation group	Information on corresponding activities and where to find applicable methods and examples
<p>Actions</p>	<p><i>[See example in Sect. 9.3 ‘Master schedule’].</i></p> <p>This document also indicates <i>milestones</i>, which are dates when certain key activities must be finished, normally when the work done by one contractor must be released to another contractor. Some of these dates are often incorporated in the contract with the owner, with penalties in case of unjustified delays <i>[See examples of milestones in Sects. 9.3.1 and 10.2 ‘Uncertainty in the High Valley Remediation Project’]</i></p> <p>For instance, in a building construction, there is a milestone at the date when the civil contractor has to finish excavation, foundations and civil work. This milestone indicates that the building has to be handed over to the electrical contractor for wiring at that date. Naturally, there is another milestone for the electrical contractors indicating the date it has to finish.</p> <p>Then other contractors take over the building for plumbing, heating and cooling, with other milestones at the respective activities end dates. In turn, when these contractors are done, the paint contractor comes, and so on. Therefore, milestones are very important dates, and constitute an excellent tool for monitoring compliance regarding time.</p> <p>The master schedule, even with its lack of detail, is a very useful and fundamental tool, because it gives a whole idea of a complex project; it is also used in high-level discussions and negotiations with owners, promoters, stakeholders, and financial institutions that are not interested in details such as tasks, but in the general compliance of main activities which govern the development of the project. <i>[See example in Sect. 9.3.1 ‘Master schedule from merging networks from different contractors’]</i></p> <p>The master schedule can be prepared for any project, and milestones placed for any main activity, as for instance, ‘<i>Finish motorcycle helmet design</i>’ (for a firm manufacturing sporting equipment). ‘<i>Finish effects on erosion studies</i>’ (in a dam construction project). ‘<i>Reception of red LED aviation obstruction lights</i>’ (in an airport expansion project). ‘<i>Finish installation of a beer bottling machine</i>’ (in the construction of a beer plant project), etc.</p>
<p>20. Develop project strategy <i>See Chap. 4</i></p>	<ul style="list-style-type: none"> – Board of Directors, must develop parameters for strategic planning – Board of Directors, prepare strategic planning for this project <i>[See example in Sect. 4.4 ‘Commercialization and distribution of an imported food product into the USA market’]</i>
<p>21. Choose a project manager <i>See Chap. 1</i></p>	<ul style="list-style-type: none"> – This person will probably come from the enterprise’s staff or may be through a contact from outside. It is advisable that the project manager be selected as soon as possible, and even able to contribute to the development of the project charter, not only because the advantage of his/her participation in the project under discussion, but also as it may benefit from his/her experience from other projects which can greatly contribute to the present one. His/her position is of maximum authority, and this person is the main responsible for the development of a good job, in time, under budget, with high quality, and accountable to the Project Director. – Board of Directors; establish required conditions for the position, besides his/her technical background and knowledge. <p><i>TIPS to consider by the project manager if work is performed in another country or in far away places, considering welfare of workers.</i></p> <ul style="list-style-type: none"> – Check with the Planning and Human Resources departments about measures taken if the jobsite is located away from cities, and, if personnel have to live in construction camps, verify accommodations and working conditions, – Make sure to learn about water purity, kitchen facilities and medical assistance, at the jobsite, – Make sure that no especial medical conditions exist for working in the site – for instance high altitude – as well as if it is an age limit,

(continued)

Table 1.1 (continued)

Initiation group	
Actions	<p>Information on corresponding activities and where to find applicable methods and examples</p> <ul style="list-style-type: none"> – Determine with Human Resources which regime will be established for rest and recreation (R & R) schedules for personnel working in remote camps, as well as travelling facilities to their places of origin. Keep Human Resources informed about these arrangements, because it is their job to hire personnel, – If necessary, plan daily transportation to worksite for workers living in the campsite, – Make sure that safety procedures are implemented, and instruct safety people to verify compliance by personnel entering tunnels or into confined spaces, or when there are scheduled blasts, – Ensure that provisions are taken for safety equipment to be handed over workers, – Be knowledgeable about customs in the host countries regarding for instance female presence in camps and their working relations with the rest of workers, as well as dressing. This is an especially sensitive matter in Muslim countries, – The project manager has to discuss with his/her superior about procedure in case of attempts of bribes offers for carrying certain activities, as for instance to grant ‘import permits’ or assurance of ‘fast dispatch’, to equipment that have complied with all import requirements, and paid all duties, – Check with your embassy in that country about the existence of political unrest in the region where the work is located, – Ensure to contact health authorities to learn about sanitary conditions in the host country and necessity of vaccinations, – Make certain that somebody in the staff is able to communicate fluently in the host country language. This is also necessary in the home office when preparing manuals, drawings, and specifications that have to be read by people speaking another language, – Make sure that certain people is computer literate and that have a sound knowledge of computer programs that will be used in the jobsite, – Be careful with equivalence between units of measures with those used in the host country, for instance from metric system to the imperial system, – Confirm about the feelings of people in the host country or at any other place about the nature of the undertaking. Work and life can be very difficult if local people oppose the work for whatever reasons, and can inclusive stop it [<i>See in Sect. 4.6.8 remarks about this issue</i>]. – Agree on the type of communications between camps and central offices, as well as frequency of reports to promoter, owner, sponsor, or stakeholders [<i>See Sects. 9.4 and 11.1</i>]

Table 1.2 Activities to be performed in the planning process group

Project planning group	
Actions	<p>Information on corresponding activities and where to find applicable methods and examples</p> <p><i>This column lists: Actions to perform to conform group objective</i></p> <p><i>This column is concerned with intelligence aimed at pursuing the action mentioned at left. It refers to chapters where a complete description and example is given for each concept described, and includes:</i></p> <ul style="list-style-type: none"> • <i>Information about origin or source of data needed for a specific action,</i> • <i>Comments about real life situations,</i> • <i>Tools and methods to execute the corresponding activity,</i> • <i>Brief background explanation of tools and methods, as well as real life applications using these tools and methods,</i> • <i>Modus operandi is detailed for each activity and suggestions given.</i>

(continued)

Table 1.2 (continued)

Project planning group	
Actions	Information on corresponding activities and where to find applicable methods and examples
	<p>In addressing this group, and because its wide scope, it is found convenient that comments consider certain type of undertakings – the most complexes – since simpler ones will be then included. For that reason, this table refers to <i>large construction jobs</i> such as highways, chemical plants, tunnelling, hydroelectric projects, water transfers, railway construction, mining, etc., or to big <i>manufacturing plants</i>, for instance energy generation, automobile factory, blast furnace construction, and other <i>large undertakings</i> such as sizeable land use projects, pipelines, etc.</p>
1. Project charter	<ul style="list-style-type: none"> – It is a listing of work that must be done for a project under a contract. It specifies deliverables, as well as detailing partial deliveries and their dates and milestones. The tasks are expressed in different units such as m², m³, US\$, etc. with pricing for materials used, as well as workforce by category and amount and type of equipment. The scope of work (SOW) may be for installation only, in which case the components for each task are furnished to the contractor by the owner or from third parties, or else it could be complete, that is with those elements provided by the contractor. Sometimes, especially in large projects where there is a main contractor, he is also made accountable for coordinating his work with other contractors or subcontractors in relation with his own. The project charter also includes peripheral items such as accommodation for the contractor's personnel in construction camps as well as food, and contractor's obligation to adhere to regulations regarding safety, environmental and other issues, such as scheduled meetings, and obligation to submit regularly updated reports on work status in an appropriate format (for instance Gantt charts), showing comparison of work actually done against scheduled and also comparison between man-hours and man-power scheduled against actual and by categories of labourers. <p>Additional information provided include:</p> <ul style="list-style-type: none"> – Structural organization for the project, – Procedures for relationships with the client regarding frequency of meetings, agenda for such meetings, durations, frequency of reports, content of technical and weekly reports, etc., – Name of the client's representative as well as that of the firm's representative, – Information that has to be provided by the client and its schedule, – In a production project establishes the main requirements for manufacturing, quantities needed, schedule of deliveries (although not in detail), quality, forms of payment, etc., – Methods of control and acceptance by the client of partial work performed, – Agreement with the client regarding form and timing of payment, – Copy of contract signed with the client
2. Define work breakdown structure (WBS) <i>See Chap. 9</i>	<ul style="list-style-type: none"> – Divide the whole job into '<i>packages</i>' and assign a coding to each one using a hierarchical order <i>[See example in Sect. 5.5 'Construction of a dam for a hydro electric project']</i>. <i>[See example in Sect. 9.4.5 'Developing the basic engineering for an automobile plant']</i>. – Make it as detailed as necessary for control
3. Define tasks <i>See Chap. 9</i>	<ul style="list-style-type: none"> – Make a numbered list of tasks needed to execute the project involving all processes and affected departments of the firm <i>[See example in Sect. 9.1.3 'Planning a water supply system to create a water park']</i>. – If the company has several locations and people from some of them are intervening in this project, indicate that
4. Establish tasks sequencing and build an arrow diagram <i>See Chap. 9</i>	<ul style="list-style-type: none"> – Establish precedence between tasks, indicating for each one which tasks need to be completed (or partially done) before starting it. – Translate these precedence into an arrow or logic diagram linking sequentially all tasks in series and in parallel. <i>[See example in Sect. 9.1.3.2 'Building an arrow diagram']</i>.

(continued)

Table 1.2 (continued)

Project planning group	Information on corresponding activities and where to find applicable methods and examples
Actions	
5. Determine duration time for each task <i>See Chap. 9</i>	<ul style="list-style-type: none"> – Determine a unique unit of time (days, weeks, months, etc.) and use it in all tasks. Consider only working days, and indicate holidays and weekends in the software used. Just put the time needed to complete a task with the standard number of people and equipment it requires. In doubt, consult budget manuals for standard times and equipment. Assume that all material will be in quantity and on time, since for a certain task such as ‘pouring concrete for slab’, there must be a precedent task in the arrows diagram that must consider supplying concrete [<i>See example in Sect. 9.1.2 ‘Water supply system’</i>]. – <i>Durations are determined by various means [See Sect. 9.1.3].</i> – In many cases it is difficult to establish durations because uncertainties due to a number of factors such as no background information about a task, doubts about these durations, the duration of a task depends on studies being done, etc. In these cases it is convenient to use the Pert method, which assigns three different times to each task and then works with a probabilistic average [<i>See in Sect. 9.10 determination of durations under uncertainty</i>].
6. Establish resources needed to execute each task <i>See Chap. 12</i> <i>See Chap. 9</i>	<ul style="list-style-type: none"> – This is of course related with establishing a completion time, but here it is also necessary to detail it for each task trade and qualification (1 foreman, two carpenters, etc., and the necessary equipment other than hand tools, such as air compressor, 1 front loader during 1 h each, etc.) [<i>See example in Sect. 16.4.3 with discrimination of trades</i>].
7. Materials management <i>See Chap. 10</i>	<ul style="list-style-type: none"> – It was mentioned above about procurement for manufacturing. Here we refer to procurement of materials, equipment and raw materials for construction projects, whatever its nature. However, a distinction is made when the firm, say a construction company uses its own equipment, and when, especially in large contracts, different contractors supply the material and equipment they need. In both cases, this is a delicate process involving a rigid control, which usually extends beyond the physical limits of the construction site. If this equipment comes from purchasing or manufacturing, quality control during manufacturing must also be included in planning, as well as delivery time by truck, ship, railway, etc., in order to make sure that when something arrives at the site it has been pre-approved by the firm. The final check will take place in the site, at reception, and needs to be considered in the planning process [<i>See Sect. 10.5</i>].
8. Compute the cost associated with each task according to resources used and time estimate <i>See Chap. 12</i>	<ul style="list-style-type: none"> – There are many ways to perform this activity, but possibly the best one is using standards tables. For this, each complex activity must be broken down in its components, or else work with the packages from the Work Breakdown Structure (WBS) [<i>See Action #2 in this table</i>], or use dedicated software [<i>See example from dedicated software in Sect. 12.1.7.4</i>]. Compute for each task the cost from all intervening workers, breaking them down in trades and categories, as well as time to execute the work. For example one foreman (3 h), two labourers (11 h each), one carpenter (3 h) and so on. – Same for machinery: For instance, for task ‘Trench excavation’, indicate <i>type</i> of equipment needed, say a trencher, and the estimated time it will be used, and its unit cost. – In computing workforce, remember that it is generally involves direct and indirect cost. The first is usually by category within a trade. Indirect costs depend of some factors such as: General expenses, vacation time, safety, bonuses, etc. – Once the total direct and indirect costs are determined for each category within each trade and after these values have been multiplied by the time demanded by the activity, we get the labor costs. <p>TIPS when doing work in another country:</p> <ol style="list-style-type: none"> (a) Check for tax condition of expatriates, that is if they have to pay taxes in the host country, (b) When estimating costs, check for taxes for importing equipment and materials unless exemptions are in place,

(continued)

Table 1.2 (continued)

Project planning group	
Actions	<p>Information on corresponding activities and where to find applicable methods and examples</p> <p>(c) It is convenient to contact a labor lawyer and an accountant in the host country. To avoid problems the project manager needs to have a good knowledge of labor legislation in that country as well as taxes and other charges than could exist,</p> <p>(d) When a contractor prepares a proposal usually he does it in his own currency, say Euros; however, many proposals are requested to be submitted in another currency such as US\$, which is usually specified in the call for tenders. Make sure to perform the corresponding exchange when submitting the proposal that is from € to US\$. This looks evident, however, this author knows a job that a consultant company lost, because this conversion was over sighted, violating the bidding conditions. The sad fact was that the company's offer was the lowest when converted to US\$ and could have easily won.</p> <p>(e) In computing time for activities it is convenient to be assessed about working conditions in said country not only related with holidays but also with ways and speed in doing things, as well as for the existence of religion practice that make provision for some praying time during the day. Also take into account that efficiency for performing an activity in a country does not necessarily replicates in another one.</p>
<p>9. Schedule the whole job, that is placing the execution of tasks (or activities) as a function of time <i>See Chap. 9</i></p>	<p>– Planning and scheduling is normally done by using the '<i>Critical Path Method</i>' (CPM), which can be solved by hand in small projects and with few tasks or by dedicated software for large projects with many tasks. Section 9.1.1 details all necessary steps to use this method, and Sect. 9.1.3 proposes an example which illustrates how to solve this problem by hand, using an arrow or logic diagram [<i>See example in Sect. 9.1.3.1</i>].</p> <p>Floats are determined for every non-critical task [<i>See example in Sect. 9.1.3.2, Fig. 9.1, of how floats are computed 'Planning a water supply system to create a water park project'</i>].</p> <p>– Usually the results from the CPM are represented in a bar chart called the '<i>Gant chart</i>' which indicates the time when a task must be executed, that is its scheduling [<i>See example in Sect. 9.2 for a bar chart construction</i>].</p> <p>– Knowing the duration and the components elements of each task allows for determining its cost, and fixing its starting date permits to learn when money is put into its execution. Summation of costs for all tasks performed in a certain interval, usually a month, allows for determining the amount of funds that must be invested in that period. The figure thus computed for a certain month is added up to the corresponding figure for the precedence month, therefore, in each month there is a cumulative value of costs.</p> <p>– Linking with a line all these accumulated values permits the construction of the '<i>S-curve</i>', or '<i>Baseline schedule</i>', or '<i>Budget Cost of Work Scheduled</i>' (BCWS), for the whole project; which is then taken as a yardstick for checking the advance along time [<i>See example in Sect. 7.5.2 of the S-curve construction using accumulated investment for a copper concentration plant project</i>]. [<i>See example in Sect. 9.2.1 of the S-curve construction for a water supply system project, using man-hours, in lieu of costs</i>]. [<i>See example in Sect. 9.4, Fig. 9.10, for the S-curve construction for a basic engineering project, using percentages of completion, in lieu of costs</i>].</p> <p>– If there is uncertainty regarding the duration of tasks or because other reasons, then it could be convenient to use the Pert method that works with probabilities. [<i>See in Sect. 9.10 a description, explanation and application of the Pert method, and an example in Sect. 9.10.2 for a remediation project</i>].</p> <p>– In a large project where many different contractors participate the working schedule is prepared in such a way that all intervening contractor's schedules are linked. [<i>See example in Sect. 9.3.1, Fig. 9.5, of how different projects are merged</i>].</p>

(continued)

Table 1.2 (continued)

Project planning group	
Actions	<p>Information on corresponding activities and where to find applicable methods and examples</p> <p>– Using dedicated software such as MSProject[®], or Primavera[®] for complex projects, or others for simple ones. Imputed data includes project start date, daily working hours and holidays (calendar), and for each task, planning unit (m, m², m³, man-hours, Km, etc.), sequence, duration, work breakdown structure (WBS) codes, resources needed, cost, responsible person, department in charge and location, etc., as well as milestones. The software will do the calculations, i.e. will compute the total duration of the project, as well as determining floats and start and finish dates for each task. This type of software is an essential tool in practically all projects, since it is quite impossible, problematic and prone for many errors to attempt to process a network by hand.</p> <p>In addition, the software will graphically depict the development of the whole project, with all tasks linked and indicating sequencing, by means of an arrows diagram or logic network. This visual report is very useful to detect errors in sequencing, and for the analysis of conflicts. <i>[See example in Sect. 9.4.12, Fig. 9.8, which shows a logic diagram drawn by computer using the Project[®] software for developing the basic engineering for an automobile plant].</i></p> <p>The software will appropriate resources to obtain an even and balanced use as possible, and will deliver the completion date. I will also show a series of tasks in series and/or parallel that must be executed without any delay. This series of activities is the ‘Critical Path’. <i>[See in Sect. 9.1.3 the explanation about how to determine the critical path].</i></p> <p>If requested, the software can also depict a ‘hammock’ that is a horizontal bar which may included dozens of tasks. This is very often used in the master schedule <i>[See example in Sect. 9.3 of a hammock activity].</i></p> <p>Additionally, the software will generate a Gantt chart or Bar diagram derived from the arrows diagram. The Gantt chart is a very convenient way to show the work because it puts on view at a glance the situation of the different activities as a function of time. It is still more useful in the control stage for it displays a second update bar for each activity, which clearly reveals if the corresponding work is going on, behind or ahead of schedule. <i>[See example in Sect. 9.4.12, Fig. 9.9, which shows a Gantt chart drawn by the computer using the Project[®] software for developing the basic engineering for an automobile plant].</i></p> <p>Normally, and for clearness reasons, relationships between contractors are not apparent in the Gantt chart (albeit they can be shown if so desired, as in this example); nevertheless consider that these charts are obtained after the logic diagram has been prepared and computed, and then the software draws the Gantt chart starting with the information provided by the logic diagram, where all contractors are linked. In this way, if for whatever reasons a contractor is delayed in finishing his part of the project, this information is imputed into the logic diagram, and from there a new Gantt chart is prepared showing this change and how it influences other contractors’ plans. Of course this is vital information not only for the stakeholders but for other constructors too, who can consequently adjust their own schedules.</p>
10. Risk management <i>See Chap. 6</i>	<p>No project is without risk and consequently, many types of risk exist, for instance:</p> <ul style="list-style-type: none"> • <i>Delay risk</i>, meaning that a project could not be completed in time. Delays have many different reasons such as postponements in equipment supply, failures in construction or production equipment, below than rated personnel performance, accidents involving interruption of work, nature events, etc., • <i>Financial risks</i>, such as not having the funds required when needed (cash flow), • <i>Geological risk</i>, for instance, the risk of flooding because of coming across underground rivers in an excavation, • <i>Sabotage risks</i>, such as when for whatever reasons a pipeline is built in hostile country, • <i>Strike risk</i>, when there are reasons to expect labor problems,

(continued)

Table 1.2 (continued)

Project planning group	
Actions	<p>Information on corresponding activities and where to find applicable methods and examples</p> <ul style="list-style-type: none"> • <i>Nature risks</i>, for example, potential hail that can ruin crops, or strong winds that can damage trees, or earthquakes, floods, etc. • <i>Personnel risks</i>, for instance assuming an inexistent level of proficiency in the execution of a task, or by difficulties in getting agreement, etc. [See example in Sect. 6.7 ‘Software development project’]. – In general, risks derive from both external and internal factors. That is, it is necessary to consider risk from causes outside the project, such as delays by suppliers, variation in demand, prices, yields, etc. Regarding internal risks, these are inherent to the project, for instance personnel problems, more difficulties foreseen or found in construction than normally presumed, more failures than expected, as for instance the breakdown of drill rods in oil drilling. – Three elements are to be considered: The <i>existence</i> of a risk, the <i>consequences</i> its occurrence may produce, and the <i>probability</i> of that occurrence. For instance, in an underground coalmine exists the potential risk of an explosion because the release of methane. Which could be the consequences of such event? Probably catastrophic. What are the probabilities of this happening? Nowadays, possibly small. – In general, in this way, a risk can be evaluated as very high, high, moderate, tolerable and negligible (or whatever other convenient scale), and a value attached to each one of these qualifications. On the other hand, another three factors intervene in estimating risks, which are <i>resources</i>, <i>complexity</i> and <i>uncertainty</i>. The first one is related with the available means to decrease risks, the complexity is linked with the project itself, and the uncertainty is linked with the external conditions. – The standard method considers two main categories, which are the ‘<i>Intrinsic Risk</i>’ and the ‘<i>Effective Risk</i>’. The first is the risk when nothing is done to decrease it, and the second corresponds to the case when certain measures are taken to decrease it. The computation may be done by hand, but it is better to use dedicated software if one wants to analyze different alternatives, considering that reducing a risk usually means spending more money. The knack is then to decrease the intrinsic risk to a level where we are comfortable, and playing with the different safeguard mechanisms [See Sect. 6.4.6], to do it at the least possible cost. A threshold value of risk is normally established, which constitutes the assumable or acceptable risk. If the effective risk is below this threshold, there it is called residual risk. – Use of Pert: This is essentially the CPM method but using three estimated time durations for each activity. Then the standard deviation for each alternative is computed using a simple formula. The square root for the summation of individual squared deviations gives the standard deviation for the whole project. [See in Sect. 9.10 explanation of the Pert method for a remediation project].
11. Prepare the budget for the whole project, that is determine how much funds are needed and when. Generate the ‘S’ curve <i>See Chap. 12</i>	<ul style="list-style-type: none"> • With the information input, the software is able to produce, on demand, the accumulated values – at a certain date (status date) – of all expenditures for the project (the ‘S- curve’), also called ‘<i>Baseline</i>’ or ‘<i>Budget curve</i>’, sketched below. <ul style="list-style-type: none"> Thus, it tells us how much is the accumulated money spent at that date. [See in Sect. 9.2.1 explanation of how the S-Curve is built].
12. Determine the critic chain	<ul style="list-style-type: none"> – While the Critical Path Method (CPM) is oriented to find the length of time for a project from start to finish, based on duration of activities in an arrow diagram, the Critical Chain has a similar concept; however, it relies on the fact that, according to its creator, Eliyahu Goldratt, duration times in CPM for tasks are usually overestimated. In so doing, he holds that people feel very confident thinking that there is enough time to do the job, allowing time to pass and then when the task is initiated, it is too late. It works with a time buffer at the end of the project, from which time is debited when needed, and with intermediate buffers when there are conflicting bottleneck areas. The methodology was created in 1997 and is thus the newest contribution in Project Management scheduling, and as any other methodology has its pros and cons. [See in Sect. 9.12 and Fig. 9.20 for explanation and example of this method].

(continued)

Table 1.2 (continued)

Project planning group	Information on corresponding activities and where to find applicable methods and examples
Actions	
13. Establish quality control plan <i>See Chap. 15</i>	<ul style="list-style-type: none"> – A quality plan must be installed for any project. Paramount in this issue are the Norms and Procedures established by international institutions such as the Standard Organization for Standardization (ISO). This not-for-profit organization, based in Geneva, set up norms and procedures for enterprises to follow to launch a quality plan. They guide about what to do, but not how to do, because it depends on each firm. Most known publications are ISO 9000, and ISO 14001 aiming the first one to products and processes quality, the second to environment and the third to human health. Therefore, the design and implementation of a quality plan must be included in planning and of course in control. <i>[See in Sect. 15.4 a description of the most important norms for project management]. [See example in Sect. 15.10 ‘Launching a new portable player’].</i>
14. Environment <i>See Chap. 5</i>	<ul style="list-style-type: none"> – This is an area present in all projects, for any human action affects the environment. More often than not environmental activities and tasks have to be included in planning, and not strictly related with the projects or its process, but just to prevent damage to the environment or the ecosystem. Environmental protection comprises a myriad of activities that in way or another contaminate, and it can be so diverse as: <ul style="list-style-type: none"> – In <i>municipal projects</i>, for instance when preparing the site for a landfill, – In an <i>industrial project</i>, for example in a car manufacturing plant, the design must include devices to neutralize emissions to the atmosphere from the paint shop, – In an <i>airport</i>, the noise contamination produced by approaching, landing and departing planes could not only upset people living nearby, but disturb wildlife in a nearby forest area too, – In <i>service projects</i>, such as construction of an automobile service station, the potential leak of fuel into the soil stored in underground vessels, forces to take extra protection measures and to install control mechanisms, – In an <i>energy project</i>, it is necessary to design the exhaust system as to decrease or eliminate NOx emissions that produce acid rain, especially for coal burning power plants, – Sometimes, the damage could promote the necessity of replacing something, such as when trees are logged to make room for a project <i>[See in Sect. 12.1.1.1, remarks about costs].</i>
15. Establish safety plan <i>See Chap. 14</i>	<ul style="list-style-type: none"> – In all projects, whatever their nature, workers’ lives protection is a paramount issue as well as protection of what is being built or constructed. For these reasons it is essential for the project to have a safety plan in place and appropriate mechanisms to check and enforce its compliance. The safety plan must contemplate every aspect related with the project such as fire fighting equipment, protection from operating mechanisms in movement such as fork lifts, cranes, construction equipment, electric wires, etc. <p style="margin-left: 20px;">From this point of view, the first thing to do in a project consists in listing potential sources for accidents to occur and then make provisions for their prevention through measures such as training personnel, acoustic and visual signals, protection against falls, etc. This plan must contemplate guidelines for every possible circumstance as are for instance working on tunnels, measures to adopt when blasting, electric work, work in confined spaces, workers appropriate attire (hard hats, reinforced boots, reflective waistcoats, protective harnesses, etc. <i>[See example in Sect. 14.4 ‘Evaluation of safety risks’].</i></p>
16. Communications Management <i>See Chap. 11</i>	<ul style="list-style-type: none"> – One of the main problems is some projects is that many departments work more or less independently and in so doing making difficult for others to make use of the information and data that they posses. There is a clear example in production where many times it seems that there is restricted or inexistent information of what production does, or when raw materials or in-progress products enter or leave the warehouse, and the accounting department, which sometimes is not informed of materials movement (and facing an angry supplier complaining about lack of payment). There is no doubt that there must be a clear and fluid communications

(continued)

Table 1.2 (continued)

Project planning group	
Actions	Information on corresponding activities and where to find applicable methods and examples
	between all areas of the firm and that information should be available to people allowed to have it. This is the purpose of a methodology called 'Enterprise Resource Planning' (ERP) which is in reality a unique database where all the information of the company is stored and from where can be extracted and processed <i>[See example in Sect. 11.3 'Diagnosis in an enterprise and proposal to install an ERP']</i> .
17. Develop the project management plan <i>See Chap. 1</i>	– This is an important document; it is a written portrayal describing the project as a whole, objective/s, processes, activities, agreements, conditions, milestones, and all the subjects mentioned in this group.
18. Contracting <i>See Chap. 1</i>	– This is a very sensitive area, and the project manager can play a significant role and at the same time put in practice his/her abilities. <i>[See Sect. 3.2.1]</i> .

Table 1.3 Activities to be performed in the execution and overseeing process group

Execution and overseeing group	
Actions	Information on corresponding activities and where to find applicable methods and examples
<i>This column lists: Actions to perform to conform group objective</i>	<i>This column is concerned with intelligence aimed at pursuing the action mentioned at left. It refers to chapters where a complete description and example is given for each concept described, and includes:</i> <ul style="list-style-type: none"> • <i>Information about origin or source of data needed for a specific action,</i> • <i>Comments about real life situations,</i> • <i>Tools and methods to execute the corresponding activity,</i> • <i>Brief background explanation of tools and methods, as well as real life applications using these tools and methods,</i> • <i>Modus operandi is detailed for each activity and suggestions given.</i> In addressing this group, and because its wide scope, it is found convenient that comments consider certain type of undertakings – the most complexes – since simpler ones will be then included. For that reason, this table refers to <i>large construction jobs</i> such as highways, chemical plants, tunnelling, hydroelectric projects, water transfers, railway construction, mining, etc., or to big <i>manufacturing plants</i> , for instance energy generation, automobile factory, blast furnace construction, and other <i>large undertakings</i> such as sizeable land use projects, pipelines, etc.
1. Team structure	– Assemble your team for project development. – Establish roles and responsibilities, considering abilities and special characteristics of each member. <i>[See example in Sect. 9.1.3 'Water supply system for a water park project']</i> . <i>[See example in Sect. 9.4.10 'Developing the basic engineering for an automobile plant project']</i> . – Develop the work as a team, against individuality. – Establish hierarchical order and clearly defined tasks as well communications between members. – Be prepared to manage conflicts.
2. Select vendors and contractors	– Vendors and contractors are a very important part in project management and selected considering many aspects such as quality, compliance with delivering dates, history of fulfilment of quantities required, speed of response to new orders, service rendered, and even how its personnel works, that is if the company is interested as it should, in corporate responsibility. – In large undertakings it is usual to prepare a shortlist of vendors from where the selected contractor will be chosen. This short list can be made considering aspects as mentioned in the description of action # 2 in this group. However, if the shortlist contains say four candidates, then it will be necessary to select one, and a way to do it, considering the different qualifications from each contractor, is applying the decision-making process, that is using a certain methodology to select the most appropriate contractor. <i>[See example in Sect. 10.7 'Construction of a copper refinery']</i> .
3. Project changes	– Uncertainties in the planning stage for the project can cause that during its execution, changes take place as the work proceeds. For instance, assume the excavation of a tunnel under a river with a TBM (Tunnel Boring Machine), that consistently shows fewer advance per day than predicted, and that probably means a change, because it will delay the commencement of the following tasks, which must reconsider their starting dates. The change can take place also suddenly, if for instance, in the same example, safety people decides to stop the excavation for a while, until safety measures are taken, because there are leaks from the river, which, if increased may endanger the lives of the TBM crew.

(continued)

Table 1.3 (continued)

Execution and overseeing group	Information on corresponding activities and where to find applicable methods and examples
<p>Actions</p>	<ul style="list-style-type: none"> – There could also be changes due to policies. For instance, a developer wins a bidding held by a municipality to buy vacant land in the city and is thinking in building seven high rises on the site. However, because environmental group's pressure, the City Hall decides to change construction regulations for the use of land in that area decreasing the heights allowed of buildings, which undoubtedly affects the developer's plan. Most probably, the developer will try to find a compromise solution or agreement with the City Hall, but that means a re-working of his/her original plans and of course more money spent. – Considering these examples, what can the project team do in any project to ameliorate the impact of changes? There are several options as follows: <ul style="list-style-type: none"> • Establish a procedure to follow in case a change is detected, • Discuss with the intervening people about the necessity of the change, and in case that this is unavoidable, negotiate the best terms for the project, • In the planning stage perform a 'what if. . .?' analysis identifying potential areas for trouble, • Analyse with Planning and Scheduling people the impact of a change on task sequencing and completion time, • Find alternate ways to do a task; • Prepare necessary documentation such as drawings, procedures, etc., as soon as possible to address the change and in so doing decreasing the time impact, • Analyze if the change involves suppliers, equipment or more workforce. – It is also a known fact than in some projects it is the owner who wants the changes, and naturally, if they are feasible, the project manager has the obligation to satisfy the client. However, it is also necessary to let the owner know about delays, additional costs (or not) that proposed changes can produce, and naturally making him/her aware if there could be potential risks, whatever their nature. As an example assume an entrepreneur developing a residential housing complex in earthquake-prone country, and that in the middle of the original project decides to increase the number of houses, using a tract of land on a steep slope. It could be done and the permits were obtained, however there here is a risk of houses collapsing, as history shows for instance in Los Angeles's Santa Monica Mountains. Consequently, the changes must now include technical provisions to minimize that risk. – When considering project changes take into consideration: Impact in the project and in other project, cost of the change, benefit from the change. <i>[See in Sect. 16.2.1 about change orders, as well as Table 16.5 that shows how changes are incorporated by the contractor].</i>
<p>4. Quality assurance <i>See Chap. 15</i></p>	<ul style="list-style-type: none"> – Quality is achieved when firms involved in projects adhere to certain norms and procedures and standards established by an independent organism, which is government dependent in each country, but following international standards known as the ISO (International Standardization Organization). The ISO norms, which in reality are families of standards, such as the ISO 9000, for quality assurance, do not specify how to achieve quality, which would be clearly impossible considering the existing universe of enterprises, types of products and processes, but establishes procedures for each one to follow. Its most known and perhaps applied standard is ISO 9001:2000, dealing with quality management systems. <i>[See in Sect. 15.4 comments on different norms applicable to projects].</i>
<p>5. Information management (Enterprise Resource Planning) (ERP.) <i>See Chap. 11</i></p>	<ul style="list-style-type: none"> – Using the ERP system there is a centralized data bank from where information can be retrieved and analyzed using OLAP (On-Line Analytical Processing), a system that permits examining a large quantity of data. – The information is not available to everybody, but only to some authorized officers. Because the data bank, the high level officers of the company and stakeholders are able to get instantaneous reports on many issues and some reports on a specified period. There is information on every client and recording of all transactions with a customer; the same applies to suppliers. There is instant information about the existent stock in the warehouse and then it is possible to answer immediately if a client requests to purchase some item that the company manufactures. <i>[See example in Sect. 11.3 'Case study for a company, regarding a diagnosis of operations']</i>. – Production is kept updated since every transaction, that is material taken from the warehouse, in-progress production entering the warehouse, deliveries to clients, etc, is registered. Same applies to the status of any purchase order to a supplier or a sales order from a client, as they are stored in the data bank even if the client places an order by Internet, or if the order to the supplier is made by the same means. There is no doubt about the usefulness of this type of information; in addition, all sort of statistics, trends and forecasts can be made with the data readily available, which is invaluable to stakeholders that can constantly keep an eye on the project.

Table 1.4 Activities to be performed in the monitor and control process group

Monitor and control group	Information on corresponding activities and where to find applicable methods and examples
Actions	
<i>This column lists: Actions to perform to conform group objective</i>	<p><i>This column is concerned with intelligence aimed at pursuing the action mentioned at left. It refers to chapters where a complete description and example is given for each concept described, and includes:</i></p> <ul style="list-style-type: none"> • <i>Information about origin or source of data needed for a specific action,</i> • <i>Comments about real life situations,</i> • <i>Tools and methods to execute the corresponding activity,</i> • <i>Brief background explanation of tools and methods, as well as real life applications using these tools and methods,</i> • <i>Modus operandi is detailed for each activity and suggestions given.</i> <p>In addressing this group, and because its wide scope, it is found convenient that comments consider certain type of undertakings – the most complexes – since simpler ones will be then included. For that reason, this table refers to <i>large construction jobs</i> such as highways, chemical plants, tunnelling, hydroelectric projects, water transfers, railway construction, mining, etc., or to big <i>manufacturing plants</i>, for instance energy generation, automobile factory, blast furnace construction, and other <i>large undertakings</i> such as sizeable land use projects, pipelines, etc.</p> <p>It is convenient to clarify the meaning of monitoring and control.</p> <p><i>Monitoring function:</i> Keeps track of work by collecting data about work performance and detects potential problems</p> <p><i>Controlling function:</i> Based on this data analyzes deviations between planned and actual progress and costs</p> <p><i>This column deals with different procedures and means used to monitor and control a project in three main aspects namely: time, cost and performance – It also addresses contractors, procurement, changes, documentation, efficiencies and risk controls, offering guidelines and commenting about tools for each one</i></p>
1. Time monitoring and control <i>See Chap. 16</i>	<p>Refers to checking if work advances in agreement to schedule. This schedule, prepared in the planning phase, was performed by an algorithm called ‘<i>Critical Path Method</i>’ (CPM), that considered all tasks and their interrelationships, as well as resources needed; it starts by establishing all relationships between tasks through an arrow or logic diagram [See example in Sect. 9.1.3.2], and delivers a ‘<i>critical path</i>’. This is a continuous line from the very beginning of the project to its very end, and involves only tasks that do not tolerate any delay in their execution, called ‘<i>critical tasks</i>’. Consequently, the length in days (or in whatever unit of time used) of this line establishes the duration of the whole project. This schedule is a contractual document. [See Sect. 9.1.3 for information about the critical path method]. The critical path can be computed by hand [See explanation and example in Sects. 9.1.3.2 and 9.1.3.3 for a water park project], but in most cases the computation is done using dedicated software [See in Sect. 9.3.1.1 information about dedicated software], which in addition provides information regarding scheduled early start and early finish dates for each task, together with late start and late finish dates. The early start date is the earliest date that a task can be commenced, considering all predecessor tasks; late start date indicates the latest date that a task can commence without compromising the completion date of the project.</p> <p>These early and start dates, together with the duration of a task, determine its ‘<i>degree of liberty</i>’, i.e. how much the task start can be delayed without compromising the project, or how much its duration can be increased. Tasks with this leeway or tolerance, which is called ‘<i>float</i>’, are called ‘<i>non-critical tasks</i>’, since critical tasks have no float. However, if a non-critical task is commenced at its late start date and there is a delay in its execution or it is extended, then it will become a critical task and its delay or extension will affect the whole project, because now it becomes part of the critical path. The same can happens even when a non-critical task starts at its early date, if its duration is extended in an amount of time greater that its float; in this case the available float will not be able to absorb or neutralize this delay.</p> <p>Floats are also important because they are used by the software to schedule tasks in order to level the use of resources.</p> <p>The software produces a report containing all this information, and it usually has both a tabular and a graphic format. [See Fig. 9.9 in Sect. 9.4.12, that depicts a tabular and graphic report for ‘<i>Developing the basic engineering for an automobile plant</i>’ project]. In this example the information is scarce because its purpose was to show another aspect. The information produced may be as complete as wished, including time, floats, critical activities, responsibilities, etc., since all information is in a data base.</p> <p>The <u>monitoring</u> is then done by comparing actual advance of work with the planned advance at a certain date, considering as a base line data from the above mentioned schedule. The results can be tabular and/or graphical.</p> <p><i>[In Sect. 16.1.3.1, Table 16.4 shows amount scheduled in one column and earned (that is performed) to date in the following column]</i></p>

(continued)

Table 1.4 (continued)

Monitor and control group	
Actions	<p>Information on corresponding activities and where to find applicable methods and examples</p> <p>Once the actual values are registered they are imputed into the system and the software run again. Both, a new table or a Gantt chart will indicate if there are deviations, their magnitude and where they are. As a function of the actual data inputted, a new set of early and late dates is produced, and then it can be appraised if the work is going in schedule, or if it is ahead or behind, and the corresponding correction measures can be accordingly taken. [See Fig. 16.4, in Sect. 16.1.2.2, which is a graphic report of <i>advance of work in form of a Gantt chart</i>].</p> <p>Considering this information, controlling is done by taking adequate measures to correct a deviation, if any, by using more resources (manpower, equipment, additional funds, extra time, etc.). However, this is not always possible, because sometimes it is not feasible to increase resources. Assume for instance that it is necessary to excavate for foundations in a small place; it could very well be that there is only room for the operation of one excavating machine, and then it is not possible to accelerate the job by using another machine, although perhaps it can be accelerated by working extra hours. Other solutions can perhaps be implemented such as accelerating another critical task in order to compensate for the delay, or may be looking for an alternate way to perform a task.</p> <p>Other option could involve analyzing the successor critical activities and try to reduce some of them, or perhaps the planning department can help with the established sequence if a critical task can be done in parallel with another one.</p> <p>[In Sect. 16.1.2.2, Fig. 16.5 compares three curves, which are: <i>The work that should have been done at budget costs at a certain date (BCWS). The work actually done valued at budget cost (BCWP), and the work actually done valued at actual costs (ACWP)</i>].</p> <p>The Gantt chart, that as stated in Action # 9 in the planning group, is a product of the arrow diagram processing, is in general the tool or instrument very often used to illustrate the advance of the work in meetings and discussions with the client, contractors, suppliers, etc. Simultaneously, the corresponding arrow diagram is also used to show the effect that a modification in a certain task, either in its duration or in its sequence, or the addition of a new task, may have in the whole project.</p> <p>There are many brand names of software available to perform this important and complex analysis, however, the most used nowadays and suitable for complicated projects are MSProject® and Primavera®.</p>
2. Time and cost monitoring See Chap. 16	<p>The Gantt chart displays in scale, in horizontal bars, as a function of time, the different tasks that are to be executed. If the whole duration of the project is divided in intervals, say months, it is possible, using a linear interpolation, to compute for each task the accumulative amount of work (for instance in m³) that must be performed up to the end of each month. As the budget cost of each task is known, it is then possible to compute for each month how much will be valued in budget dollars the accumulated work. If this calculation is done for each task, the summation of these products will give the total money to be spent in each month for all activities that are scheduled in said interval. This can be represented in a coordinate system that has months in the horizontal axis, and accumulative expenditures in dollars/Euros in the vertical axis. Joining the set of accumulative values produces a curve line, called the 'S-curve', because its shape resembles this letter. This is the base-line budget usually known as 'BCWS' (<i>Budget Cost of Work Scheduled</i>). This is a contractual document and specifies the completion cost of the project and the total cost at each interval [See in Sect. 9.2.1 the S-curve construction].</p> <p>Once the project starts, work is performed and money spent. Then it is possible to compute for each period how much is valued in budget dollars the accumulated <u>work actually done</u>. Using the same procedure as commented above a line can be drawn joining these values and generating an S-curve known as the 'BCWP' (<i>Budget Cost of Work Performed</i>).</p> <p>For the same token plotting the values corresponding to the successive <u>actual amount</u> of work performed yields a third S-curve called 'ACWP' (<i>Actual Cost of Work Performed</i>)</p> <p>Cost control for a project is based analyzing the values of these three curves at a certain date (status date). [See Sect. 16.1 for this analysis].</p>
3. Contractor's control See Chap. 16	<ul style="list-style-type: none"> - Regarding cost, follow the same procedure as above; however, control is performed on the contractor's schedule. In this case, work performed is from certification for payment issued by a contractor, and approved by owner. Again, it is necessary to check that the work done (for instance in lineal metres) at that date relates with the budgeted unit cost, (US\$/m), unless that there have been special provisions stipulated in the contract, such as labor costs correlated with the cost of living index. - Regarding scheduling, it is important to check if a delay here affects another contractor's activities, and also to verify if said delay is related with tasks on the critical path or pertaining to a milestone. If they do, measures have to be taken immediately since this delay will reflect in the completion date of the project. If they do not affect critical tasks, but affects a milestone then the schedule control people must discuss with the contractor which is his/her next steps to compensate the delay. If for whatever reasons the delay is unavoidable in the short time the study of the master schedule will inform which contractor or contractors will be influenced by this delay, for them to be aware of this circumstance [See Sect. 9.3 about master schedule]. Also [See Case study in Sect. 9.7 and Fig. 9.11 which portrays status after updating].

(continued)

Table 1.4 (continued)

Monitor and control group	
Actions	Information on corresponding activities and where to find applicable methods and examples
	<ul style="list-style-type: none"> – This control also applies to resources in personnel utilized by a contractor as well as equipment in the job site. Actual figures are compared with budget and contractual values [<i>See Sect. 16.4.2.1 for controlling manpower and man-hours.</i>]
<p>4. Procurement control <i>See Chap. 16</i></p>	<ul style="list-style-type: none"> – There must be a schedule on the dates when raw materials, materials, products, equipment, etc., are needed in the construction site and in which quantity. For instance, assume that by June 19, 2010, contractor ‘Apex’ will start pouring concrete for foundations in section 1 of a foundry building. Therefore, we must check that concrete delivery company ‘Universal’ is aware of that, and make sure that he will have his equipment ready at the jobsite, together with enough Portland cement, gravel, sand, water, delivery trucks etc., on or before that date. – When receiving equipment appropriate inspection procedures must be carried out to make sure that the equipment comes complete, without damage, in quantity, and on time. Some large jobs such as large hydroelectric dams utilize Kaplan hydro-turbines that come from a manufacturer sometimes located far away in another country. In these cases, and because fabrication of heavy equipment like this can take months, it is necessary to arrange an inspection schedule in behalf of the owner, to verify not only the advance of construction, but also de construction quality and the results of tests performed in the factory and that cannot be repeated in the work site. This procedure must be agreed in writing, usually in the contract, detailing number of inspections, dates, nature of each test, results, etc. [<i>See Sects. 10.5 and 10.5.2.</i>] – For manufacturing, procurement is usually a complicated issue and the production department must be sure that its suppliers have received in time the necessary purchasing orders. From this point of view, communications via ERP (Enterprise Resources Planning) is a very valuable tool, which allows direct interaction with the supplier [<i>See Action # 16 ‘Communications Management’, in Table 1.2, in this Chap. 1.</i>].
<p>5. Change control <i>See Chap. 16</i></p>	<ul style="list-style-type: none"> – First, evaluate the potential change, – Select available alternatives in case the event occur, as well as select the best alternative, – Have the potential changes approved by a competent authority (the Client) where he recognizes and approves the necessity for the change, – The necessity for the change must be well documented and information furnished about the cost, the delay it produces, and the advantages, if any, that it provides. For instance, assume that costly and sophisticated last generation (meaning not thoroughly tested in actual working conditions) equipment has to be installed but that there is a chance that its delivering could be delayed or that its performance is below expectations. An alternative could be to consider similar equipment from other manufacturer, perhaps more expensive, with proven performance, and with a reliable delivery date. Naturally, if the client does not care too much in finishing the project in time, probably it is worth to run that risk with the first equipment. However, if the finish date is impossible to be postponed even in a single day, like for instance the opening of an international exhibition, or the opening of the World’s Cup, then the alternative could save the project. Consequently, other action to consider is the evaluation of the impact that a change can cause, – Analyze through the arrows diagrams how the change in one task or process will affect other activities or processes. Does the float of the changing task absorb the delayed produced by a new task in the change?, – Does the change affect the contractor’s estimate? If so, and considering the delay and new estimate, is the change worth it?, – Ask the contractor to prepare a new schedule with the proposed change to analyze its effects [<i>See example in Sect. 16.2.3 and Table 16.5 for incorporating change orders in the contractor’s schedule, for a storm water storage reservoir project.</i>].
<p>6. Documentation control <i>See Chap. 16</i></p>	<ul style="list-style-type: none"> – Refers to the issuing of drawings, specs, manuals, technical reports, etc. All construction jobs must have a complete set of approved construction drawings. It is not necessary to have the hundred or thousands of drawings approved for the initiation of the project, only those needed to start the process. Normally, in large jobs drawings are being prepared along the life of the project and according with a certain schedule that is of course, linked with the project schedule, but preceding all tasks. Drawings are very important not only for construction but also because they are legal documents, and need to follow a certain sequence from their inception up to their approval as working documents. Drawings are electronically produced using AutoCad or CAD software. – Be sure that drawings comply with all codes and standards regarding scales, sizing, colours, symbols, labelling, features, references, etc. They are so important that a discipline called Drawings Management has evolved for the construction industry which incorporates a section to follow the complete life cycle of the drawing, as well as its storage and retrieving. – Because their importance drawings must be monitored along their life cycle to check compliance of schedule. In some projects this monitoring takes place at pre-established intervals and finishes when the drawings is stamped as approved as a working document. [<i>See example in Sect. 16.12 for drawings production and also Table 16.18 for drawings control.</i>]

(continued)

Table 1.4 (continued)

Monitor and control group	Information on corresponding activities and where to find applicable methods and examples
<p>Actions</p> <p>7. Efficiency control <i>See Chap. 16</i></p>	<p>Information on corresponding activities and where to find applicable methods and examples</p> <ul style="list-style-type: none"> – This action refers to controlling work advance as a function of work performed and costs incurred. It is done using the ‘<i>Earned value technique</i>’, that is, a system that combines work actually performed (earned value), against actual cost. To do this end three S-curves (BCWS, BCWP and ACWP) are developed [<i>See Action # 2 in this Table 1.4 in this Chapter</i>], and pair-wise compared at a certain date (Status date). – Another useful ratio is between BCWP and BCWS called the scheduled performance index (SPI), that is, how much of the work actually done is regarding the amount of work scheduled, both expressed in dollars <i>[See Sect. 16.1.2.4 where both results are analyzed in an example]</i>. – <i>Calculation of estimate to completion</i> There is interest, at a certain date, to estimate the total <i>cost at completion (EAC)</i> of the project [<i>See Sect. 16.1.1</i>]. – <i>Calculation of contractor’s efficiency regarding man-hours</i> Contractors submit at the beginning of work a report indicating the number of people that they will employ (man-power) and the number of man-hours, both by trade. It is of interest to control that these scheduled quantities match reality, since the developing of the project depends on them. [<i>See example in Sect. 16.4.3, Table 16.9 of scheduled manpower contractor’s report by trade, as a function of time, while Table 16.10 reports actual manpower</i>], then comparisons can be made. Same applies for man-hours [<i>See Tables 16.11 y 16.12 for man-hours</i>]. – <i>Contractor’s efficiency</i> Combining man-hours or manpower with amount of work done gives a value about contractor’s efficiency, that is a <i>labor performance factor (LPF)</i>, using a formula [<i>See Sect. 16.4.2.4, formula 16.7</i>].
<p>8. Risk control <i>See Chap. 6</i></p>	<p>In the risk area there are two phases to consider.</p> <p>Phase 1: Its objective is the identification and evaluation of potential risks, as well as devising strategies to ameliorate or eliminate them <i>[See ‘Action # 9’ in Sect. 1.6.1]</i>.</p> <p>Phase 2: Its objective is double, because in this stage</p> <ol style="list-style-type: none"> (a) There is a checking of the safeguards established in phase 1, and (b) Foreseeing or detecting new risks that not were originally contemplated
<p>9. Safety control <i>See Chap. 14</i></p>	<p>Zero violations must be allowed on this issue and offenders must be heavily disciplined.</p> <ul style="list-style-type: none"> – For starters verify that the initial list in all possible areas of safety risks (falls, electrocution, equipment rolling over, traffic accidents, burnouts, etc.), are covered with appropriate safety measures [<i>See Sect. 14.4, Tables 14.1 and 14.2</i>]. – Check strict compliances for safety such as personnel wearing goggles, reflective waistcoats, safety boots with steel toe caps, harnesses, hard hat, gloves, etc. and according to the nature of the work [<i>See Sect. 14.5</i>]. – Verify that procedures are kept when personnel is working in confined spaces. – Check that there exists a control for people working in isolated or remote places such as forests, sewerage, underwater, tunnels, etc. – Make sure that sound signals work, and make certain that all personnel is accounted for and in a safe place in blasting operations. – Check that all personnel, including staff, receive periodic training and possess the corresponding certificate. – Make sure that personnel working in hazardous environments are adequately protected. For instance check the dosimeter for radioactivity when corresponds. – When personnel is working underwater make certain that the decompression equipment works fine and that established procedures are strictly followed. – Confirm that first aid kits are available at different places and that trained first aid personnel are available and according to the number of workers. – Verify the right working order of road equipment such as the backwards warning sound signal for reversing vehicles. – Pay special attention for people working in trenches and verify that the work has the appropriate safety device (shoring system) [<i>See OSHA Technical Manual (OTM) Section V: Chapter 2</i>]. http://www.osha.gov/dts/osta/otm/otm_v/otm_v_2.html – Check the good working order, certifying expiration dates, for fire extinguishers. – Report accidents using an appropriate format (<i>See Sect. 14.6</i>).

(continued)

Table 1.4 (continued)

Monitor and control group	Information on corresponding activities and where to find applicable methods and examples
Actions 10. Environmental control <i>See Chap. 5</i>	<p>Even when in the initiation of the project certain measures were taken to decrease the damage to the environment, these are usually related with the project itself, but not during its construction stage. There is no doubt that any project will leave its mark in the environment, changing the land use, modifying landscapes, altering the ecosystem, using resources, etc. In this control stage, we need to make sure that this impact is under control and also trying to do our best not to further damage the environment. For this reason, it is necessary to exert environmental control, and the following actions, just a sample of course, have proved useful in most projects <i>[See in Sect. 5.1 remarks].</i> <i>[See in Sect. 5.2 and in Table 5.1 factors to be considered in a project for different type of projects].</i> If impacts have been identified in the Initiation Group, make certain that they are kept within the established limits <i>[See in Sect. 5.4 ‘Construction of a dam for a hydro electric project].</i> If the project is large enough there must be an environmental group which mission will be:</p> <ul style="list-style-type: none"> – At the beginning of the project, and if it takes place in a wilderness or away from human settlements, as is normal in many hydro, mining, metallurgical, roads, pipelines, etc. projects, make sure that the number of trees cut, to make room for the undertaking and for the construction camps, is as low as possible, as well as cutting the strictly necessary, and naturally verify that plans to mitigate the damage are underway. – In many cases, water for the construction camps is delivered by trucks, but there are areas where this is not possible. There is no doubt than in this latter case in the planning stage of the project, studies were performed to determine where to get water from. May be there are rivers nearby and in that case water supply is probably assured. However, in another cases, the only solution is to get water from water wells reaching aquifers. If this is the case, the environmental group must perform weekly checks to determine the average volume of water extracted per day. Naturally, this extraction rate has to be lower than the recharge rate of the aquifer. – If the construction camp is large enough and with dormitories and mess hall, forcefully it must have a waste water treatment plant to treat sewage from kitchens and bathrooms, and including cloth washers. The good working order of this plant is something that the environmentalists have to check and make recommendations to improve reliability. For instance, it might be assessed that a degreaser could be installed in the waste water stream from kitchens to help the water treatment plant to work efficiently. – In construction, there are always leaks from vehicles such as oil and diesel oil which naturally falls onto the ground. The environment group needs to stop these leaks, for instance by periodically visually inspecting the working order of construction equipment. – Sometimes, material for excavation is dumped in a specially designated area. This area should be chosen with care because if close to a river, chances are that part of the debris can dam it. – In open pit mining, blasted material (rocks) is transported to the grounding and milling area by large haul trucks which produce a lot of dust. This dust harms people and vegetation along roads and sometimes hinders the photosynthesis process because the layer of dust on leaves. It is usual to wet the road with water tanks trucks to prevent or at least ameliorate this dust, and this is another task than environmental people must watch. – At the end of the project the area used by contractors is left empty, however make sure that not waste is left. – Project contract should include a clause by which all area logged must be reforested, and this applies to land occupied by construction camps. – For the same taken, all asphalted or concrete surfaces, for instance parking lots and internal roads in construction camps have to be removed. The idea is to leave the place as it was found or better. – To check environmental damage in manufacturing <i>[See in Sect. 5.6 ‘The hidden contamination in manufacturing’].</i>
11. Quality control <i>See Chap. 15</i>	<ul style="list-style-type: none"> – Make sure you know what the client really wants <i>[See Sect. 15.8 to apply the Kano Model and Sect. 15.10 to use Quality Function Deployment].</i> – Check compliance of quality tests for material input and installed, such as fresh concrete. – Make certain that right procedures are used such as the right amount of vibration when pouring concrete. – Verify that construction drawings are approved for contraction and not only drawings in process. – Verify compliance of drawings production schedule and approval process

Table 1.5 Activities to be performed in the closing process group

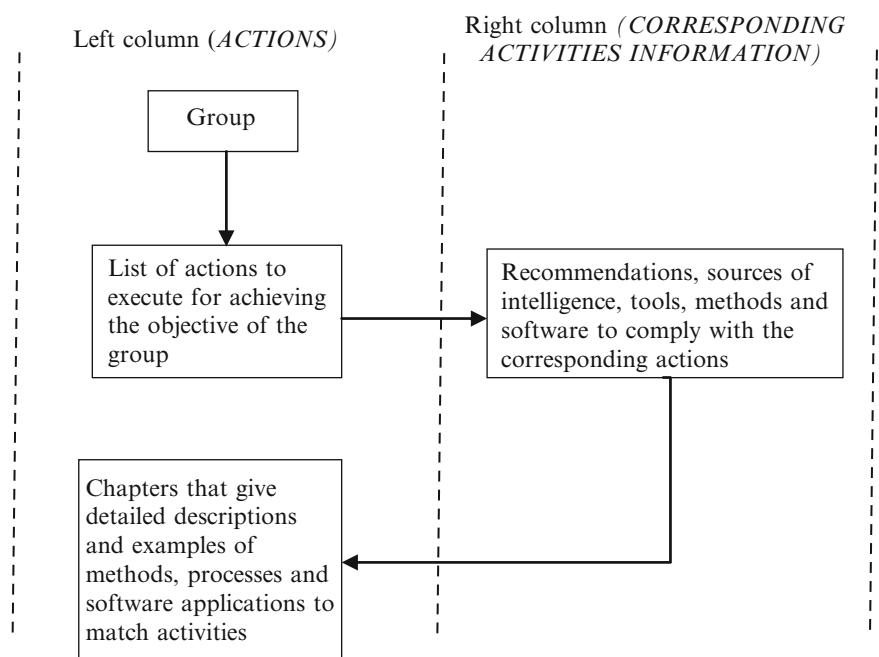
Closing the project group	
Actions	Information on corresponding activities and where to find applicable methods and examples
<p><i>This column lists: Actions to perform to conform group objective</i></p>	<p><i>This column is concerned with intelligence aimed at pursuing the action mentioned at left. It refers to chapters where a complete description and example is given for each concept described, and includes:</i></p> <ul style="list-style-type: none"> • <i>Information about origin or source of data needed for a specific action,</i> • <i>Comments about real life situations,</i> • <i>Tools and methods to execute the corresponding activity,</i> • <i>Brief background explanation of tools and methods, as well as real life applications using these tools and methods,</i> • <i>Modus operandi is detailed for each activity and suggestions given.</i> <p>In addressing this group, and because its wide scope, it is found convenient that comments consider certain type of undertakings – the most complexes – since simpler ones will be then included. For that reason, this table refers to <i>large construction jobs</i> such as highways, chemical plants, tunnelling, hydroelectric projects, water transfers, railway construction, mining, etc., or to big <i>manufacturing plants</i>, for instance energy generation, automobile factory, blast furnace construction, and other <i>large undertakings</i> such as sizeable land use projects, pipelines, etc.</p>
1. Closing the project	<p>This is another action where the project manager is heavily involved.</p> <ul style="list-style-type: none"> • The project is completely closed when the whole work has been delivered to the owner and accepted. • Different project components such as equipment must have been tested, and in case of production equipment a checking must be performed to verify that it delivers the contractual output. All the testing and results must be documented and added to the closing documents. • Also consider some deliverables such as spare parts for equipment, working manuals, instruction manuals, manufacturer warranties, etc. • If the original contract contemplates maintenance of the work for a certain period by the consultant or contractor, indicate so in the closing report, and the corresponding availability of that service. • If work includes not only the supply, but also the installation and start up of some equipment, for instance a large centrifugal compressor, make sure to include the final report of the technician who installed it and the results of all the tests. Also indicate, if needed that the technician will stay in the site for a period in fulfilment of the contract signed. • In case that equipment has been installed and needed municipal inspection or certification about some characteristic such as the composition of the flue gas from an industrial incinerator, make sure to add the original document of approval from that organization, keeping, of course, a certified copy. • In every case the reception of the work by the client or owner must specify his/her agreement with what is received, albeit usually a warranty clause is established, lasting a certain period, to guarantee against hidden defects, albeit there is some payment withheld by the client as an assurance against these defects. Anyway the owner usually is granted some time to accept the final documents once he/she have had the time to inspect the quality of the work, checking the good working order of all equipment, good finishing in concrete structures, output delivered as stipulated, etc. • It is a good practice to also prepare a dossier, memory or project review about what happened during the project's cycle of life which can be a very valuable tool for future similar undertakings. • Of course all the administrative procedures must come to an end. All departments of the construction or consulting firm must receive a memo letting them now the end of the project and urging them to close all files and report back to the project manager. The ERP system is a good mechanism to do this [See Sect. 11.2]. • Make sure that all project records are put into binders, duly labelled and classified and kept in a safe place. They can be invaluable in the future if there is necessity to check something. It is really frustrating to look for information that one knows exists and not finding it, hence the need of a good classification. Of course this keeping of information also applies to electronic records which must be copied in appropriate devices and kept in a safe place. • Naturally, all written communications with the client must be also kept and especially those who pertain to periodically owner's approval for work done. • O&M manual. • As built drawings [See example in Sect. 17.1, Fig. 17.1 for a powerhouse structure]. • Complete and gather documentation. • Make sure that there are not loose ends.

(continued)

Table 1.5 (continued)

Closing the project group	Information on corresponding activities and where to find applicable methods and examples
Actions	
2. Closing the contract	<p>Very important document which certifies that all the contractual obligations have been met at client's satisfaction. If nevertheless this is not the case, an end of the contract must be agreed upon detailing all the aspects that have not been satisfactorily met</p> <p>The US Government uses a check list for closing out projects. Federal. As a useful guide [See http://www.ncmantxchap.org/Meetings/Check-list.pdf <i>Contract Close-out Procedure and Check List</i>].</p> <p>This check list comprises a series of forms posing some specific questions and each one with three boxes labelled 'YES', 'NO', N/A. The forms address amongst other subjects:</p> <p>Program control office: Refers to complete completion of all tasks.</p> <p>Property: Refers to customer property and residual materials.</p> <p>Facilities: Refers to shutdown program for space, facilities lent, borrowed or leased.</p> <p>Supply chain management: Refers to subcontracts and purchased orders.</p> <p>A similar procedure can be used by any firm, company or consulting company to closeout a project.</p>

Fig. 1.4 Sketch of a table organization



Regarding location:

- Accessibility (for instance tough access to the jobsite especially in winter time).
- Hazard conditions (if the project is located in a zone prone to snow avalanches),
- Existence of certain sanitary conditions (case of a location in an endemic malaria area),
- Very harsh winters (abundant snow or very low temperatures),
- Political unrest in the job site (such as rivalry between political factions with potential for sporadic fighting), etc.

These difficulties need to be detected and analyzed very carefully because they can affect the project.

Action # 4. Assessment of success regarding finishing in time and within budget for a construction, or reliability about the estimated amount of sales for a new product, or probabilities of capturing a predetermined portion of the market in a specified period for a new product, etc.

Action # 5. Assessment of failure, due to different factors such as: Necessity of purchasing equipment from a short list of suppliers, very tight completion time that cannot be exceeded, or if exceeded subject to a tough penalty, lack of company's expertise for this particular type of project, lack of confidence in the supply chain because the distance to the site or for other reasons, etc.

Action # 6. Cost estimate. Refers to obtaining a preliminary range of costs. This is necessary for determining if it is

convenient (or not) to go ahead in performing a more detailed cost estimate.

Action # 7. Time estimate. Refers to getting a rough estimate of time needed for completing the project, or for recovering the money, or for getting an agreed percentage of the market share, etc.

Action # 8. Financial analysis. Refers to performing a detailed calculation to determine the project financial feasibility and main parameters, or deciding if available funds could be preferably spent in another undertaking considering a better yield, or maybe finding that the project is financially too risky, or to know if the firm can sustain the expected cash flow, etc. The right column suggests a series of actions to be taken to give the Board of Directors information about the financial feasibility of the undertaking, and then enabling them to decide if it is worth it for the company or firm to pursue it.

Action # 9. Detect and evaluate risks involved. Check the different project stages regarding potential and foreseeable risks, such as risks that can compromise completing the work on time (due for instance to potential delays in transporting heavy equipment), financial risks (because there is no certainty of banks support), cash flow risks (considering that payment of work certificates from the project promoter can be delayed), geological risks (for the reason that soil and ground characteristics are not very well known), personnel risks (because of dangerous work, such as working with explosives), weather risks (since poor weather conditions can halt work during some days), political unrest risk (for it can create not only disturbance in the work but also sabotage), disease-catching risks, etc. Most probably the diverse risks will involve some type of protection or safeguards to be considered, which of course will increase the budget.

Action # 10. Identify stakeholders. That is, find out who are the interested parties in this particular project. It will encompass people within the company, such as directors and personnel related to the project, and people outside the company, such as representatives from the owner or promoter, perhaps banks or credit institutions, decision makers, probably suppliers, and people, citizens, groups, community, etc affected by the project. This last category of stakeholders is very important and seldom taken into account. These are the people who, albeit not related whatsoever to the project, will be influenced by its development and further operation. This is significant, since most types of projects, from a chemical plant to an urban road, from a slaughterhouse to an aluminium smelter, from an agriculture development to a harbour construction, will have some impact on people. This impact may be positive when it enhances their quality of life, for instance through the creation of new job opportunities, or by improving life conditions as in a

municipal dwelling plan, or maybe negative, by worsening it, as in the case of noise, odours and contamination generation, or by partially obstructing a mountain view that many people enjoy, because of the construction of a suburban highway.

Another very important 'stakeholder' is the environment that has neither a voice nor a vote. However, if the project severely impacts it, the responsible promoter will hear about it, not only from the environmental groups, but too – which is usually much worse – from the environment itself, in the form of damages produced by acid rain (formed by coal-fired power station emissions), bodies of water contaminated with industrial effluents and no longer able to sustain aquatic life (from paper mills). There could also be climate change (because of CO₂ released into the atmosphere), or a decline in crop production due to lack of water since the aquifer that supplied water is now depleted due to excessive draw, or death of animal and vegetal species, or erosion (as after logging a forest), etc.

Action # 11. Refers to a final financial study when all parameters are known, such as type and conditions of loans (short and long term) that can be negotiated with banks, as well as interest rates, payback periods, grace periods, operative costs, working capital, depreciation, inflation, sales, and prices estimates, probable rate of return, tax deferrals, subsidies, etc. When all this data is known it is possible to prepare projected financial statements and to learn about the financial and economical health of the project.

Action # 12. With information from all the other actions it is possible to refine the firm capability and ability to carry out the project.

Action # 13. Determine all environmental impacts that the project will produce, but not only limited to direct effects but to indirect effects too. Very likely additional money should be considered in the budget for decreasing or ameliorating these environmental aspects.

Action # 14. Social issues. How will the project affect people? For instance, how many people must be displaced to build a hydroelectric dam? Or how will the project impact people's income because of the creation of new job opportunities? What will be the social impact due to the construction of a direct high speed train, by bypassing many little towns now served by a local train service?

Action # 15. What will be the market share of the product produced by the project in the market? Will it be enough to make the project economically feasible in a certain period of time?, or how strong is the competition in bidding for this construction project?

Action # 16. With data from Action # 11, estimate project feasibility and analyze it regarding opportunity cost for other investments.

Action # 17. From R&D, and Production and Planning departments it is now known that there exist several alternatives to execute this project. For instance, there could be different optional routes for laying a power transmission line between two points A and B, or different methods to manufacture an item, or diverse procedures for digging a tunnel, or several options to fulfill a certain electric energy output using renewable sources. This involves a decision-making process in order to select the most convenient project or alternative satisfying the stakeholders. For instance, a highway construction project may have two alternative routes, and each one with different costs, length, and advantages and disadvantages from the economic, financial and environmental point of view. The selection-making process is designed to help the DM to determine which of these two alternatives is the most appropriate considering these different points of view and satisfying the stakeholders.

Action # 18. The project charter. This document summarizes the main features of the project and conditions that apply, that is dates and deliverables, as well as milestones. It is a basic document for a project to start. It details the scope of the project, its planning and scheduling, the costs estimate, risks envisioned, manpower and resources in general

Action # 19. Master schedule. This is a comprehensive document, usually in graphic format where all main activities for executing the project are displayed, and showing the links (precedence), between them. It is not a detailed document but a condensed one, meaning that large and complex activities, encompassing perhaps hundreds of tasks, are represented as a single line spanning two dates, and thus indicating their duration. For instance in launching a new product, a task could be ‘*Develop and construct mock up*’ with a duration of 190 working days. This task is connected at its end with another task such as ‘*Build prototype*’, which in turn is linked with ‘*Start manufacturing*’, and so on. This document does not qualify as a production or construction schedule because of its poor definition; it is instead a contractual document that specifies the length of the project and displays certain dates, called ‘*Milestones*’⁴ that are used for control and sometimes for payments. The WBS (see Sect. 9.4.5) can help in identifying these milestones.

⁴ A milestone from the project management point of view is a date, indicating when a certain task or activity must be completed or scheduled to show an agreed degree of advance, or because its completion is paramount for the initiation of another important task, activity or process. Sometimes, for a large project, a milestone schedule is prepared, mainly used as a master schedule.

Action # 20. Project strategy. A memory that specifies the way the project will be done. The project must be in line with the strategic plan of the company pursuing it. For example, it makes sense if a food company, making ice-cream, wishes to develop a new line of products based in frozen food, because the project is aligned with the main business of the firm, and then it can apply to the new line its expertise in manufacturing and distributing food products. Obviously, a new project for this company such as to fabricate automobile parts is completely alien to the company and it does not have the chance to become a successful venture.

Action # 21: Choosing a project manager. There is no need to elaborate or to emphasize the importance of this action since the success of failure of a project may depend on the knowledge, ability and leadership of the person filling this position. In general the project manager is responsible for the whole lifecycle of the project, that is from inception to finish, including the warranty period. Normally reporting to him is a construction manager, who is responsible for the construction or execution stage.

1.6.2 Second Group: Planning

Objective: Coordinate all data regarding tasks, times, sequence, resources and costs to develop a harmonic and feasible schedule, establishing a completion date that can be reached, an estimate of minimum costs that can be achieved, and aiming at the best use of available resources

Left column: ACTIONS – Description

Action # 1. Project charter: A complete description of the work to be done, including its scope (SOW), that is the definition of the work, range and description, specifying start and finish dates, as well as boundaries, and implies an exact knowledge of the job to be done. In addition, it specifies acceptance criteria for main deliverables as well as constraints, and key dates known as ‘*milestones*’.

Action # 2. Break the work into parts. This is necessary to have better control and especially for cost control.

Action # 3. Determine the different tasks that must be performed and assign responsibilities and work load.

Action # 4. Sequencing. Tasks must be performed according to a certain order and respecting precedence. Many tasks can be done only when another is complete or semi-complete, that is there is a dependency (for instance we cannot utilize for a subsequent use a concrete slab recently poured, until the concrete has not solidified and hardened enough). Tasks can also be executed in parallel with another when they are independent, as for instance the excavation for foundation for heavy equipment and

at the same time pipe lying for electric power to this equipment.

Action # 5. Duration. The time than in normal conditions takes to complete the task using the required personnel in quantity and quality and with the appropriate equipment and tools

Action # 6. In addition to manpower and materials, the use of other resources must be thoroughly contemplated, especially those shared between several tasks, mainly construction equipment such as backhoes, load and haul equipment, bulldozers, cranes, etc.

Action # 7. Procurement tasks. Except from own equipment it usually involves acquiring everything such as raw materials (sand, gravel, Portland cement, water, etc.), elements and equipment incorporated into the project (steel beams, cladding, steel frames, for an industrial building), (hydro turbines, dam gates, ancillary machinery, in a hydro power plant, (blast furnace, centrifugal blowers), in a steel fabrication project, etc. It also incorporates dedicated equipment for construction such as a TBM (Tunnel Boring Machine), shotcrete equipment, etc, for tunnelling, etc.

Action # 8. Costs. Involves computing direct and indirect costs for the execution of each task.

Action # 9. Scheduling. It means determining when a task must be executed, and this point in time is generally not related with its duration. That is, a task with certain duration can perhaps be performed at different times, and even interrupted and completed in parts, but it also has to comply with the precedence relationships (it might be preceded by one task, by several or by none) that might exist. Its position in time is also related with the availability of resources it shares with other tasks, and with its 'float', which means that the period allowed for its execution is larger than its duration. Say for instance that task 'excavation' has duration of 5 days; however the allowable span of time to execute it starts on June 19 and finishes on August 14, therefore, clearly, the task has a wide span of time to be executed.

Given task duration, its precedence relationships, resources needed (in personnel, materials, equipment, funds, etc.), using an appropriate technique called 'Critical Path Method', and a dedicated software, it is possible to determine when the execution of each task can start and finish as well as the amount of its float, if any. The software uses this float for levelling shared resources. When a task has a float, whatever it might be, it is called 'non-critical', while if it has no float at all, it is called 'critical'. Obviously, critical tasks are the most important in the project because any delay in any of them produces a corresponding delay in the final completion date for the project. The series of critical tasks constitute a continuous line, a path, from the very first day of the project to the

very last, and it is called the 'critical path', which defines the duration of the project.

Action # 10. Whatever the nature, span and type of a project there is always a risk involved. Risks cover a wide variety of situations and can produce serious accidents, delays, cost overruns and considerable losses. Reduction of this risk, whatever its nature, involves spending more money, amount that has to be added to the project cost and budget.

Action # 11: Project budget. A project involves a series of tasks that are to be executed along a certain period. Consequently, when the cost of each task has been determined, it is necessary to know when this expenditure will take place. To do this, all scheduled costs in a certain period, for instance in a month, are totalled, and the resulting figure added up to the value found for the precedent month. That is, in each month, there will be an accumulated amount of money that should be spent. Plotting these accumulated values as a function of time, and linking them with a continuous line, generates a curve called 'Budget Curve' or S-curve. This curve is the baseline of the project expenditures, and graphically displays the scheduled progress. This is a very important contractual document since is used as a yardstick to relate, at a certain date, the accumulated work actually done with the accumulated money spent at the same date. The precision of the S-curve to represent the whole process depends in the degree of desegregation.

Action # 12. The critic chain is a different methodology which claims that reduces the time needed to complete a project.

Action # 13. It deals with controlling the quality of the work done, as well as with the compliance of the quality plan that must be established.

Action # 14. As mentioned before the environment is the 'silent partner' in a project, however, it must be taken into account, and as matter of fact, in many countries a project surpassing a certain investment amount, is not approved for execution by the corresponding approval office at national, provincial or city level, if it is not accompanied by an environmental impact assessment (EIA) produced by a reputable governmental or a registered private agency. This EIA in many cases is responsible for an increase in the original budget due to modifications or safeguards that must be incorporated in the project and that were no originally considered.

Action # 15. Safety. This is a very important area and some large projects have a team devoted to safety control. Its importance, besides affecting human beings, is so large that generally, together with environment, it is one of the few aspects with enough authority to legally stop a project during execution.

Action # 16. Communications management. This is a significant issue because quality communications is fundamental between people participating in a project, especially in large ones. There is at present sophisticated software to help in this matter and for classifying the kind of information that each stakeholder, department or agency is allowed to receive or request. The system usually involves people outside the firm such as vendors and clients, feature especially useful in projects concerning manufacturing and distribution, since a client, say a supermarket, can connect directly with a vendor system and place electronically an order. This way there are neither delays nor lost or 'forgotten' orders or misunderstandings. In large systems information in real time is furnished whenever the authorized people request it.

Action # 17. The project management plan is an abridged document describing the whole project.

Action # 18. Contracting. It refers to negotiations and pertinent documentation between two or more parties related to the project. In this case it is between the owner or representative and suppliers, or contractors or personnel.

1.6.3 Third Group: Execution and Overseeing

Objective: Execute the job following as close as possible the master schedule, aiming at the highest standards for quality and keeping stakeholders informed of the project development.

Left column: ACTIONS – Description

Action # 1: Team structure. It refers to the assembling of a work team if the project requires it; this is an important action and carefully consideration should be given. Members of the team are usually self-directed, normally each one within his/her own capacity and knowledge, since usually the team is constituted by a multi-skilled group, but they must work together, with a common objective at sight, whatever it might be. However, it is understood that there must be somebody controlling the team, perhaps the project manager himself, but giving wide latitude to the members of the group.

Action # 2: Selecting vendors. Vendors must be considered part of a project, for very often the compliance of the completion date rests on a vendor responsibility and efforts to honour his/her deliveries commitment. This category includes hiring contractors and subcontractors, and in so doing special consideration should be taken about their past performance, either because the firm or the promoter has worked with a particular contractor in the past, or by examining the constructors' histories.

The following list describes some criteria that can be used for this evaluation purpose.

- Will the project be developed under IMS⁵ approach?,
- Years in business,
- Number of engineers,
- Number of other specialties (geology, transportation, etc.),
- Numbers of workers that will participate in this project,
- Quantity of m² built in the last 3 years,
- Expertise in this project area expressed in number of projects completed,
- Percentage of own equipment to be used in this project,
- Average age of equipment,
- List of ISO standards such as:
ISO 9001:2000 (Quality),
ISO 14001:1996 (Environment), ISO 10006:1996 (Quality management in projects), and ILO/OSH: 2001 (Occupational health and safety), that the contractor uses or has been certified for,
- Number of projects finished in the last 15 years,
- Number of projects delayed more than 10% of initial schedule, in the last 15 years,
- Number of times taken to court in the last 15 years for job related issues,
- Number of suits won,
- Amount of working capital for this project in millions of Euros,
- Liability insurance in millions of Euros.

Action # 3: Project changes. There is seldom a project without changes along its execution, and statistics show that a high percentage of work takes place as re-work, therefore be careful about changes. Changes can derive from several sources such as client's new specifications, reductions on work contracted, or expansions. They can also derive from variations of external factors such as uncertainties, or else by internal factors pertaining to the project, such as modifying a design. Therefore, changes are a reality in any project and the project management team must be prepared to face them with the objective of minimizing the impact on time, money, safety and environment. Changes affect contractors as well since they generally produce an increase on the original budget and may be a modification of contractor's schedules and scope of work.

Action # 4: Quality assurance. Modern quality assurance not only means the quality of the product being manufactured

⁵ Integrated Management System. Linked with ISO guidelines especially with ISO 9000 and ISO 14000, requiring for a company to have manuals and directives regarding safety, quality, finances, etc.

or the project being executed. Quality assurance involves the whole company and also the client and suppliers. The client is involved because a company works with him/her in order not only to fill his/her needs but also trying to anticipate them. Same with suppliers, for the company works with them to develop a new product or in ameliorating a product being manufactured, and this is a continuous activity.

Action # 5: Information management. This is a relatively new aspect to consider in large projects and its appearance has been possible due to the progress made on informatics and the development of dedicated software. Information management is now somehow imperative in large projects, where intelligence about its development must be known in real time by stakeholders, and besides screened in such a way that everyone receives only the information that he/she need, that is, it can be accessed only by determined personnel and thus not available to anybody. The system has many advantages not only for the information provided at any time but also because all decisions and documentation such as purchasing orders, type and quantity of goods in progress, material and equipment stored in warehouses and dates of their arrival, working capital cash-flow, etc. are registered, and then indicating who was or is responsible for a certain action. However, it is expensive and requires a previous study to determine what a project or a company really needs, and besides it is not adequate to some firms or projects because for instance, the size, importance or complexity of the undertaking does not justify its implementation.

1.6.4 Fourth Group: Monitoring and Control

Objective: The main goal is to control the project for finishing it in time, within schedule, with expenditures as scheduled (that is on/under budget), and to the owner's satisfaction. It is also important to monitor quality in all stages and tasks, monitor that safeguards for risk work adequately and foresee new potential risk areas.

Critical areas for monitoring are time to complete the job, cost at completion, risk and environmental controls.

Definition of *monitoring*: The action of collecting, analyzing, recording, and reporting significant and relevant information considering a project performance.

Definition of *controlling*: The action of working with information from monitoring to establish degrees of compliance of planned activities, and if needed take the necessary steps to match planned with actual performance.

Left column: ACTIONS – Description

Action # 1. Time monitoring and control (that is monitoring and controlling the project schedule). This is a fundamental action which purpose is to ensure that the project is developing according to schedule and perhaps most important, that it will be finished on time. In some projects that need to be completed exactly at a certain date this action has a capital importance; for instance a project for organizing a large event such as the World's Cup, with many subprojects developing simultaneously and where the completion cannot be altered because it has been established years before, with many aspects, ceremonies, travels, and official acts tied to this date.

Other projects can perhaps be less demanding but nonetheless a delay in the completion date can cause the loss of economic benefits, as for instance the construction of a large mall when all commercial spaces are taken, merchandise ordered, advertisement in progress, and people hired to start working at a specific date. In some cases, if it is true that a delay can be accepted, it could also imply financial problems, for instance when payments due to banks for construction loans are contingent to sales of the product manufactured by the project. It could also produce substantial economic damage when the start up of a new facility is contingent to the finishing of another one, as could be the starting of an aluminium smelter which depends on the operation of a high voltage transmission line, also under construction, since it cannot work without electric power. As was commented in Action # 5, duration, in the Planning group, in these cases it would be perhaps convenient to have planned the project using the Pert method. Control may be done in the same way as the CPM method.

Action # 2: Time and cost monitoring. Even thou project cumulative expenditures may be aligned at certain dates with what was scheduled, that is not a guarantee that the project is running within budget. The reason for this assertion is that money effectively spent must be tied with work effectively done. If these two factors coincide with what was planned and scheduled it is possible to assert that the project is running within budget and on schedule, otherwise, probably it is not. This is precisely the purpose of work and cost monitoring and hence its importance; in addition, it is necessary to remember that costs overrun at the end of the project mean that a larger investment that planned was necessary, and this can influence the profitability of the project.

Action # 3. Contractor's control. It is related with several issues namely:

- Work quality,
- Manpower,
- Man-hours,
- Production,
- Efficiency.

- Action # 4. Procurement control. Refers to input to the project in any form.
- Action # 5. Change control. Refers to changes, due to several causes and that always occur in a project.
- Action # 6: Documentation control. Refers to documents that support the projects, such as drawings.
- Action # 7: Efficiency control. Related with contractor's performance.
- Action # 8: Risk control. Every project is subject to risk, This control aims at checking that appropriate measures are taken and maintained.
- Action # 9: Safety control. Relates with verifying that safety measures are taken, that safety equipment and devices are working properly, that workers follow safety instructions, etc.
- Action # 10: Environmental control. To make sure that the environment is disturbed as little as possible, and, in case that this is unavoidable, check that restoration proceeds as scheduled.
- Action # 11: Quality control. The aim is to build or produce something with the highest quality standard to satisfy the client.

1.6.5 Fifth Group: Closing

Objective: Deliver the project and get final acceptance by owner, as well as the handing over in time of a dossier with data and all documentation regarding the project, including guaranties established.

Left column: ACTIONS – Description

Action # 1: Closing the project. The project is delivered to the owner.

Action # 2: Closing the contract. A contract is terminated.

1.7 Project Charter

This is the document that constitutes the authorization to commence the project and that also serves as of the project's basic reference. It is also very important because its context must reflect everything related with the execution of the project, therefore, it is a reference document. There is not a standard format for it, however it must contain at least the following data and information, but not limited to:

- *Vision and aims or objective* of the project,
- *Description of the project* establishing its boundaries, that is where it commences, what its scope is, and where it finishes.
- *Environmental factors*; that is the main internal and external factors that may influence the project. Examples

of internal factors are the firm's capability to undertake the project, *experience, facilities, personnel* skills, etc. Examples of external factors are market conditions (such as a large international demand for soybean meal pellets, copper), new government measures, etc.,

- *Stakeholders identification* and their function, with roles and responsibilities,
- *Name of the Project Manager*, together with the Board formal appointment and his/her range of authority and responsibility,
- *Detail of deliverables* to the client as well as milestones schedule,
- *Acceptance procedures* and criteria for partial and final deliverables,
- *Organization structure*,
- *Project budget*,
- *Known risks* assumed,
- *Ways in which the environment* is protected.

To facilitate the preparation of this document there are commercially many templates available. An example of a template is found in 'Treasury Board of Canada (2008)'.

1.8 Project Management Plan

This is a document normally prepared by the Project Manager explaining the way the project will be executed, how the monitoring will take place and measures taken to control the work. It includes, but is not limited to:

- Staffing,
- Staff training,
- General procedures for materials management,
- General procedures for frequency and type of communications and reports scheduling,
- Procedures to be followed for changes in the scope or in the original plans, either by reducing or enlarging a task, or adding new ones,
- Units of measures to be used (metric or imperial system), as well as currency (Euros, Dollars, Yens, etc.),
- Language to be utilized in reports and communications,
- Procedures to be followed for inspections and issuing of progress payments to contractors,
- Techniques and tools to be used, for instance CPM (Sect. 9.1.3), CCPM (Sect. 9.12), the Gantt Chart (Sect. 9.2), Earned Value (Sect. 16.1), etc.,
- Frequency of monitoring and tests (for instance for steel hardness),
- Hardware and software to be used for different aspects, such as for quantities take-off, planning and scheduling,

communications, materials management, financing and accounting, etc.

- Quality and safety plan.

Commercial templates are available for this function. See for instance Wiegiers (2007) for shareware form.

1.9 Organizational Process Assets

We use the Project Management Institute (2008) definition that states that organizational project assets are ‘Any or all process related assets, from any or all of the organizations involved in the project that can be used to influence the project’s success’. This is an important concept related with the undertaking because it considers the company elements that can benefit the project. For instance, it is obvious that if there is a team of skilled people to do research for a new development in an organization related with the company, it is an asset that can be used. It could also be that the firm has an adequate structural organization, flexible enough to adopt for a new project. Or perhaps there is a new large overseas project that requires a degree of freedom from the mother company due to the necessity of a potentially risky joint venture with a local firm; in that circumstance it could be convenient to form a temporary company. If the mother company can supply the necessary skilled staff without damaging its own activities, this is an organizational asset, which without a doubt will benefit the project.

1.10 Statement of Work (SOW)

This is a different document from the project charter. The SOW is only related with the product to be delivered and the corresponding work to be done; it points out its scope, stipulates who will be in charge of its execution, in what location, and provides a detailed planning and tasks and activity schedule as well as estimated associated costs, consequently it is abundant in technical information.

1.11 Conclusion of This Chapter

It is naturally impossible to cover all necessary activities for a project, let alone the myriad of activities for a wide variety of projects. This chapter has intended however to grasp in general the whole idea and offers a comprehensive list of actions that are common for most projects disregarding their nature, and adding what it is believed to be a valuable help for the experienced practitioner as well as from the beginner in the form of activities to be performed. This help will be found in hints about the sources from where the necessary data and information can be extracted. There are besides, in some cases, directions to cases and examples from where the reader can reinforce a concept or become aware of the ‘right’ technique to use.

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Some unfortunate remarks from scientists and people who 'knew':

This 'telephone' has too many shortcomings to be seriously considered as a means of communication. The device is inherently of no value to us.

Western Union internal memo, 1876.

Heavier-than-air flying machines are impossible.

Lord Kelvin, president, Royal Society, 1895.

There is not the slightest indication that nuclear energy will be obtainable.

Albert Einstein, 1932.

Abstract

This chapter is related with the origins of ideas with enough merits and advantages for considering them as potential projects. With that objective sources other than those normally examined are analyzed, but most especially projects that come from innovation. A case study for the development of software is proposed detailing the necessary steps that take into account existent competition and state of the art.

Keywords

Project origins • Innovation • Inertia • Life-cycle • Continuous process

2.1 Definition

Innovation is possibly best defined as the exploration and exploitation of new ideas in pursuit of a competitive advantage (Kavanagh and Naughton 2009).

From here it is obvious that the innovation concept is opposed to the 'standard' or 'routine' concept since innovation means 'change' that is to abandon old ideas, practices and devices and look for new ones. This also means that project management must look for new forms and methods to do things, new techniques for planning, for costing and budgeting, for monitoring and control, even for closing out a project; in other words innovation is a concept that must be embedded in project management. Innovation can also mean detecting, analyzing and meeting needs, as expressed in the case study of Sect. 2.4.

One way to accomplish this aim is to promote the generation and presentation of new ideas, discussing proposals and

suggestions, and encouraging improving them when possible. For instance it could be the proposal of a new way to check – other than the usual visual inspection – that there are no more air bubbles in freshly placed concrete being compacted with an immersion vibrator. In research projects there are sometimes unexpected results, which should not be immediately discarded because they do not meet requirements; a closer examination could reveal some potential for another purpose or for filling an unpredicted niche in the market. There are many examples of inventions that are the outcome of research that began with another goal in mind.

For instance 'Post-it-Notes'[®], the small colored self-stick used as page marker or notepaper for short notes or messages, was, according to 3M a "solution without a problem" (3M 2011). A company researcher was looking for strong glue and in so doing developed a new chemical formula, which instead produced very weak glue; however, he did not reject it, albeit not immediate use was found. Later, somebody else became aware that this product was

exactly what he was looking for as glue for page markers, with its qualities of being weakly attached to a page, so it could be easily removed without a trace. Today it is one of the most popular office products. This example also illustrates the argument that innovation is sometimes a stepping stone process until reaching its final goal, which is sometimes unknown!

2.2 Projects Origins

The idea of developing a project may have many different origins or sources such as:

- Fill a void in the market for an existing product, for instance the need to develop a small electric two-seater car, for urban displacement, or an e-bike with a fuel cell,
- Increase the capacity of a plant, as in the case of enlarging a biofuel factory,
- Entering the market taking advantage of the international high price and strong demand for a product. For instance, building a copper refinery, or reopening an old mine that was closed years ago because a low yield, when actual prices make the exploitation economically feasible,
- Improving an existing and credited product, for instance a music record player with new features, advantages and capacity,
- Creating a brand new product with technical features that greatly improves existent ones, such as the invention of the digital camera replacing the old ones,
- Import substitution, for instance manufacturing locally a drink that is imported from Europe,
- Taking advantage of some special conditions that nature offers, for instance the construction of a wind farm in a windy region, or building a plant to produce fruit juice concentrate in a Central American country, or building a new resort in a new unspoiled beach, area, etc.

In all of these examples there is direct or indirect prior experience. However, in this chapter we are examining projects whose origins come from research and innovation with no prior experience. There are plenty of modern examples such as the iPod[®], e-books readers, GPS used for navigation, new pharmaceuticals and their presentation, new computer languages, etc.

Why are they considered different? Because, in addition to research, there are other activities and procedures to perform not usually found in business projects. Some of these differences are:

- Developing a new product, a new concept, a new mechanism that was never thought of before, that is, there is no prior history,
- Even when the project is in its early planning stages, there could be aspects that were not considered, however they popped-up and need to be addressed. For instance, what could be the potential users' reaction if they have to

change their minds about traditional ways of doing things, especially considering that in general there is inertia, that is people do not want to try new ways since they are comfortable with what they know, or because they are afraid or reluctant to make changes.

The appearance of the first automobile is a clear example; many people saw them as a novelty that would soon die away, and because they could not conceive that a vehicle could move by itself and not be drawn by horses as human-kind had been doing for centuries. This was a revolutionary new idea only comparable with the invention of the railway. As a known example, it is worth remembering what a president of the Michigan Savings Bank advised to Henry Ford's lawyer (Cerf and Navasky 1984) when consulted about investing in car manufacturing. He said:

The horse is here to stay, but the automobile is only a novelty – a fad.

The three remarks reproduced at the beginning of this chapter and selected amongst many others, dramatically demonstrate people's reaction, even from famous scientists, to new ideas.

This inertia is not exclusive of old times, for it is also frequent in ours, and actually takes place for instance each time that a software company launches a new and improved version of its platform. Most users complain that they have to learn again, when they are at ease and confident with the platform that they have been using.

- Some new characteristics and defects of a new product are discovered along its life-cycle. For instance c.1885 the electric fan was invented (using brass blades), with not very different appearance from today's models, however it did not have a protective wire cage, something that apparently was considered not necessary at the beginning, and neither did it have different speeds. These were step innovations, and something similar happens with each invention (railways, airplanes, cars, computers, TV sets, record players, etc.).

Frey (2003) points out the main features in developing innovation projects when talking about their differences with ordinary business projects, which are replicated here.

- *Innovation projects tend to start with loosely defined, sometimes even ambiguous objectives that become clearer as the project proceeds. The processes used are more experimental and exploratory and seldom follow strict linear guidelines.*
- *Teams need to be more diverse and have a higher level of trust as they explore new territory where failure is a possibility.*
- *With failure as a built-in possibility, innovation teams are more actively involved with risk management and need to learn to fail fast and fail smart in order to move on to more attractive options.*

• Also, innovation projects generally need to be sold to project sponsors and funding committees, a responsibility usually not required from normal project teams.

It is generally accepted that innovation is a continuous process based in small advances which in turn are the responses to what customers want, such as a laptop with more battery life between charges, a car with less fuel consumption, graphics software with enhanced capabilities (for instance allowing materials takeoff), a medium to disseminate information, such as the Internet, etc. As an illustrative example of innovation in project management it is suggested to consult Bourne (2010).

2.3 Innovation and Project Management

The history of project management is marked by a series of successive innovations commencing perhaps with Frederick Taylor,¹ and Henry Fayol² and their works on administration and efficiency, followed by such landmarks as:

- Henry Gantt³ and his célèbre Gantt Diagram or Bar Chart, for work scheduling (see Sect. 9.2),
- Risk management, for contemplating potential risks in a project at the same level as its main components (see Chap. 6),
- Program Evaluation and Review Technique (PERT),⁴ for planning projects with uncertainty (see Sect. 9.10),
- Critical Path Method⁵ (CPM), for planning all tasks of a project (see Sect. 9.1.3),
- Earned Value Analysis (EV),⁶ for cost monitoring and control (see Sect. 16.1),
- Critical Chain Project Management (CCPM),⁷ for planning and managing floats (see Sect. 9.12),
- Work Breakdown Structure⁸ (WBS), for decomposing a project into components (see Sect. 9.4.5),

¹ Prominent American engineer considered the founder of the scientific organization of work.

² Renowned European engineer, who looked for ways to increase efficiency, using scientific administration principles. He developed the concept of establishing basic functions in any enterprise.

³ American engineer, worked with Taylor and Henry Ford in the scientific organization of work. He is amply known by the diagram that bears his name and that is extensively used in projects and programs scheduling.

⁴ Invented by Booz Allen Hamilton Inc, for the US Department of Defense (DOD).

⁵ Developed by DuPont Corporation, USA.

⁶ It is a part of the Pert methodology.

⁷ Developed by Eliyahu M. Goldratt, USA. See Goldratt (2004).

⁸ Developed in 1957 at the same time as Pert and for the same Department (DOD).

- Project Life Cycle⁹ (LCA) or Project Life Span, for analyzing the whole life of a project (see Sect. 5.6.2),
- Economic Input-Output Analysis,¹⁰ for determining project contribution to contamination (Carnegie Mellon University Model), (see Sect. 5.6.2).
- Multicriteria Decision-Making Models (MCDM), for selecting alternatives or projects (see Sect. 8.1),
- Material Management models (see Chap. 10),
- Information models (see Chap. 11),
- Quality Models such as The House of Quality,¹¹ for adapting engineering to client's wishes (see Sect. 15.10),
- Total Quality Management (TQM), for managing quality in a project (see Sect. 15.12),
- The SWOT¹² analysis, for determining company or product characteristics (see Sect. 4.4.2)
- Etc.

2.4 CASE STUDY: Development of a Tool for Decision-Making

2.4.1 Background Information

The decision process consists in making an educated assessment regarding what alternatives in a project should be pursued, or in choosing which project – amongst a series of projects in a portfolio – is more convenient to develop, considering restrictions such as funds availability, access to resources, environment constraints, political reasons, economic grounds, limited capacities, etc.

It is a tough problem and is explained in Chap. 8. Various mathematical algorithms have been developed to solve this quandary, which looks for a solution or selection that best satisfies stakeholders. It is applicable to all kind of situations where decisions must be taken.

This proposed case concerns a company in the IT business that thinks that Linear Programming (LP) – a branch of Mathematical Programming (MP) – is the ideal tool to solve this problem because it allows for the construction of representative mathematical modeling of complex situations, which albeit imperfect, offers a more realistic description

⁹ It started aiming at optimizing energy consumption. Its first study was performed in 1969 at the Coca Cola Company by Harry Teastley (PricewaterhouseCoopers 2010).

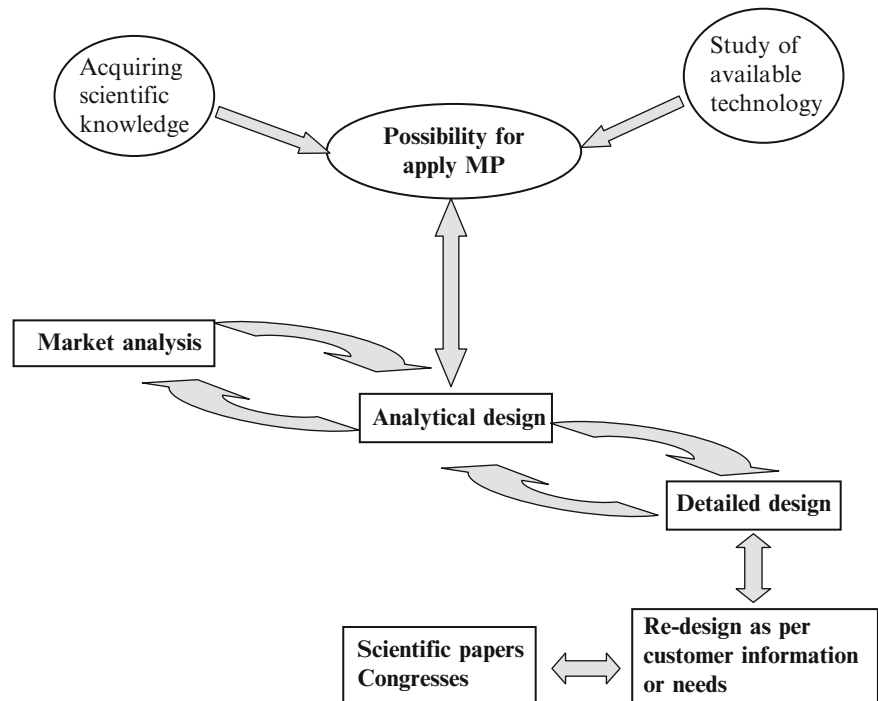
¹⁰ Developed by Vassily Leontieff to study industrial interaction. See Leontief (1951).

From the point of view of its application to projects see Carnegie Mellon University (2003).

¹¹ Developed by Mitsubishi Heavy Industries, Japan, in the early 1970s.

¹² It is attributed to Albert Humphrey from Stanford University, USA, around 1970.

Fig. 2.1 Sequential procedure for innovation – Development of a tool for decision-making



of an actual situation than existent models. The treatment of complex problems such as the analysis of river basins to decide what type of a series of projects of different nature to undertake, considering technical, economic, and environmental issues, as well as other difficult undertakings, constitutes an unexploited niche in the market. Here is the innovation, to develop something that was never made before, that is, considering many different objectives as well as all kinds of restrictions, that is qualitative and quantitative, as is normally the case in most problems.

2.4.2 Research

The new tool is grounded in a very well-known algorithm developed in mid twentieth century, which works with matrix algebra and finds a solution for the problem applying a proprietary procedure which is the innovation proposed. The steps for this research are sketched in Fig. 2.1.

Let us analyze these components:

Acquiring scientific knowledge on Mathematical Programming (MP)

It is necessary to search and read the literature about this discipline to determine if it is possible to use it for this project's purpose. There is a lot of information on this field and indeed attempts have been made in the past to try to use it for solving this problem, resulting in new algorithms that unfortunately did not match expectations.

Study of available technology about existent methods for decision-making

Obviously it is necessary to research the existing methodologies to learn about their weak and strong points, and to confirm if it is really meaningful to look for alternative ways, or if the gain would be so negligible as to render it worthless to this project. Main methodologies researched were AHP,¹³ ANP,¹⁴ Promethee¹⁵ and Electre.¹⁶

Possibilities for applying MP

With the two concepts above defined it is now time to investigate the feasibility of using MP to attain a desirable objective. Actual systems are systemic in the sense that they interrelate with the decision-maker but are influenced by his/her subjective evaluations. The objective of this work is to present an innovative system as a result of research that, in addition to reducing uncertainties, works intensively with the decision-maker in a feedback system until a satisfactory solution is reached. From this point of view SIMUS – the name of this proposed software – provides a final result, that is a selection according to stakeholders wishes and as a function of data and

¹³ Analytical Hierarchy Process, developed by Thomas Saaty (1980).

¹⁴ Analytical Network Process, developed by Thomas Saaty (1996).

¹⁵ Promethee (Preference Ranking Organization Method for Enrichment Evaluations), developed by Jean-Piere Brans et al. (1986).

¹⁶ Electre (Élimination Et Choix Traduisant la Réalité), developed by Bernard Roy (1968).

the interaction with the decision-maker, in other words a 'satisfactory solution'.

Analytical design

This is the mathematical analysis that is the core of the project. Once it has been completed it is necessary to test the procedure in actual cases, and may be compared to results with those reached by existent methods.

How is the analytical design performed? One answer could be: *Looking for a way of using and improving, through innovation, existent methods and adapting them to needs.*

Market analysis

Information about the potential market is the first phase, since needless to say, if no demand or necessity is envisaged for this kind of procedure or algorithm there is no point in its development. The method must offer at least the same advantages attributable to the existent methods, however, this is a lower limit, since the procedure must provide additional benefits such as increased reliability, less subjectivity, a better representation of the actual scenario, and the possibility of a full 'What if...?' analysis. From the marketing point of view many questions must be posed such as:

- *Is there a potential market or it is only a nice academic work?*

In this case there is indeed a market because many researchers and Project Managers (PM) are not confident with the results obtained from the existent procedures. There is certainly a potential market as a consequence of the relative absence of subjectivity that Simus offers, and because it can provide solutions that are transparent, debatable, reproducible and obtainable by anybody, since results are independent of personal appraisals and wishes.

- *Is there in reality a niche or it is simply an aggregate to something existent?*

There is certainly a need since at present time the mathematical modeling of many actual projects does not represent reality, even approximately, when for instance no relationships between projects, or existent capacities or available funding are considered.

- *What is the method's best feature?* In this case the new method's best feature is the production of more reliable solutions because it does not have as much subjectivity as existing models.

Detailed design

Once we are convinced of the goodness of the new method it is perhaps possible to refine it to make it easier for the user to understand. It implies creation of an analytical design by

analyzing the different aspects that may pop-up. Extensive tests have been performed to detect the goodness of this product modeling and solutions, comparing final results with those from 44 cases taken from the Internet for simple cases and in another 22 for more complicated scenarios.

Redesign as per customer information, needs and feedback

The customer must be consulted about what he/she needs, listening to his/her demands and problems. There has been a redesign of the tool, for since its first versions the opinion and feedback from the decision-maker and stakeholders were taken into account.

Scientific publishing, conferences

This is the way to make the model known to the scientific community.

The model has been published in specialized journals and has been applied to diverse problems from around the world, as well as discussed in several international conferences.

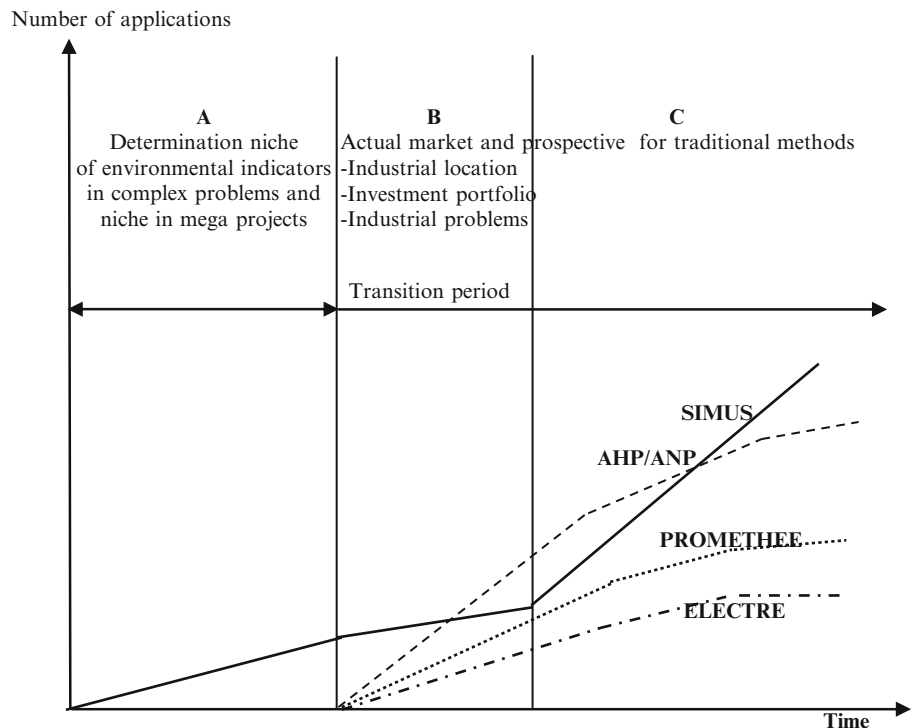
2.4.3 Fundamentals

The proposed new tool is based in a very well-known algorithm called 'Simplex' and developed by George Dantzig (1948). It works with matrix algebra and applies its own rules to solve the problem. However, its main drawback is that it gives an optimal solution only when working with a sole objective, and it is unable to cope with subjective restrictions. Unfortunately most actual problems involve many objectives, especially the complex ones. The innovation consisted in completing the Simplex algorithm with a mathematical procedure in order to overcome the two mentioned drawbacks; it is a necessary step to determine if indeed there is a niche.

2.4.4 The Next Market

An innovation has an economic goal that consists in looking ahead of the discovered niche, considering the paradigms from the Earth Summit held in Rio de Janeiro in 1992. From this event a worldwide effort was launched to protect the environment with the goal of attaining a larger sustainability. This fact in turn placed an enormous burden on the decision-making process, since now many environmental restrictions as well as social constraints are to be incorporated into the model, which complicated the problem even more. Figure 2.2 shows these two sectors in this process, the first one taking advantage of the existent niche, and the second one regarding the actual market and future of methods.

Fig. 2.2 Interpretation of SIMUS development and disruption of existing market – Development of a tool for decision-making



2.5 Conclusion of This Chapter

The innovation concept has been defined and exemplified with different illustrations, aiming at showing the importance of this concept that as said must be embedded in project management programs and actions. The case example has tried to depict the successive steps in developing a new tool pointing out the aspects that must be considered.

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Nolberto Munier and Fernando Jiménez-Sáez

Abstract

This chapter deals with two main subjects which are dealt in two parts (a) Part one, Project Manager qualities or competencies and (b) Part two, Negotiations and contracting. The first one relates with leadership, that is the ability to manage the most important assets a company has, people.

The second deals with the negotiation as part of the task that any project manager will face as a professional. It starts by defining key concepts that will be used to explain the negotiation process. Further, it examines the process structure analysing main characteristics and depicting those elements that will define the final deal. Finally an example is provided where different aspects of the negotiation process are shown. The goal is to give the reader some key elements that define the negotiation process in projects as a social activity, and to show the many different paths the process can follow without pretending to indicate a single and correct model of negotiation.

Keywords

Outline of a Project Manager • Leadership • Roles • Attributes • Abilities • Negotiation styles • Influencing styles • Negotiation climate • BATNA • ZOPA • Bargaining power

3.1 Part One: Leadership

By Nolberto Munier

3.1.1 Project Manager Attributes

The following sections comment about the features that most researchers think a Project Manager (PM) must possess.

N. Munier (✉)
Teamic International Canada, Canada
e-mail: nolmunier@yahoo.com

F. Jiménez-Sáez
Universitat Politècnica de València, Valencia, Spain
e-mail: fjimenez@ingenio.upv.es

3.1.1.1 Outline of a Project Manager (PM)

It is understood that a first-quality project without a good PM will probably run into many problems. Considering the technical point of view this individual faces a complicated task, which can be possibly efficiently managed by his/her subordinates; however, it is generally more complicated from the human and organizational point of view; here the attributes for the PM can be challenging, most especially in those projects with construction camps, many times in the middle of nowhere, where he/she is the primary authority, and where conflicts appear every day, from the quality of food, fights, violations of camp regulations, and not a little task, in relationships with contractors and the client. In these situations, it is essential that the PM possesses a capacity to take decisions and certain qualities for effective management which are commented on here. The PM function is in general a solitary position and must be entrusted with responsibility and autonomy to perform properly.

The PM normally walks on a high-wire when he has to relate with both his personnel, mainly engineers with their particular technical thinking and experience, and the client with his/her own ideas, expectations and time requirements. Both goals should be the same, of course, but this is rarely encountered. However, a middle point can be found when the project team aims at performing a good job and to the owner's complete satisfaction, while the client tries to understand the difficulties, uncertainties and the different aspects always present in a complex project. To be able to perform his duties efficiently the PM must possess a series of attributes that are suggested to consider when selecting a candidate for such a position.

3.1.1.2 Attributes of a PM

It is difficult to synthesize the characteristics inherent to a PM because of the large variety of projects, situations and problems that are normally associated with this function. However, there are some traits that hold for any project irrelevant of its nature. These are (Barry):

Participation

An effective PM must understand very clearly where he wants to go and how to get there. However, a leader can do nothing if he does not have adequate people, but for that it is also necessary for him to instill in his personnel the feeling that each one is important and with a real participation in achieving the proposed goal. The PM must be persuasive and convincing in transmitting this idea

Good Communicator

It is often said that ability to communicate is one of the most important qualities for a PM. This communication must not be limited to technical issues, since it must also be effective in informing people about goals and objectives of the project (It is very difficult to work and cooperate when one does not know the purpose of his own work).

A person must know about his position in the hierarchy and what his responsibilities are (It is frustrating not knowing to whom to report.)

A person must also be informed about his performance (it is good to learn how well one is doing the job), and also about his prospects within the organization (The work may be very interesting but it is also important to know about the opportunities for advancement in the hierarchy.) In addition, take into consideration that it is normally important and rewarding for any individual to know the result of a job that he did in the past, or how it contributed to the success of a project or in achieving the goal. In other words, the applause usually given to a good musical performance is also nice to hear regarding a job well done. People are normally eager to improve even more, or continue doing a good work when the result of their effort is recognized.

Integrity

Leadership also means an ability to compromise and to establish an ethical working behavior; it is very difficult to demand moral integrity if the leader is not a probity model.

Enthusiasm

Enthusiasm is contagious. An optimistic PM, with a craving for doing, with innovative ideas, with clear and precise objectives and with the ability to transmit these values to his subordinates is something really important. In every project there are moments when everything seems to go astray; it is then when the PM must show optimism, trying to see the positive side and plainly rejecting the negative approaches, and at the same time finding other alternatives, attitudes or actions to improve a situation.

Empathy

Probably one of the most important aspects; the team is formed by human beings, not robots. As every member of humankind we have our moments of joy, frustration, sadness, anger or pain. Most emotions are inevitable, and if it is true that it is not expected from the PM to share these feelings with his subordinates or that act as a consolation partner for everybody to transfer his problems, the least that a person can ask is for sympathy and understanding. That is, for a person to learn that he is supported and understood by his superior in any situation is something extremely important. As Barry quotes *"It's nice when a project leader acknowledges that we all have a life outside of work."*

Competence

It is very difficult to work – and there is abundant experience to back up this assertion – under a person who does not know what that work is. It is frustrating not only because it generates endless discussions, but also because work of the team members is dislodged, which in turn generates discussions amongst them, which imply waste of time, enmity and the loss of the team spirit. Consequently, a PM must be technically prepared for the position he holds. Nobody can pretend that the PM must be more knowledgeable than each member of the team, but what is expected is that he possesses the necessary technical knowledge to understand a problem, accepting or rejecting solutions proposed and be able to intelligently and knowledgeably debate with his subordinates.

Possibly one of the most important ways to show this capacity is related with the implicit knowledge of the project, that is, overcoming the difficulties of information transmission and explanation, with as La Femina (2002) puts it *"the knowledge that we have without knowing we know it"*.

Sometimes, instead of taking norms and regulations as guides many people follow their 'gut feeling', which appears to be the summation of a series of factors, such as prior experience with a product, similar situations, knowledge of

a particular subject, etc. which would seem to address an issue through a methodology, process or determined conduct. Of course, it is not acceptable that a PM insists on following his gut feeling, however, it is something that helps and especially it can motivate the team members to look for new alternatives or solutions.

Ability to Delegate

This is something so logical that it appears superfluous to even comment on it, however, it is something that many persons just do not understand or cannot do. Some PMs feel that they need to be constantly on their subordinates, instructing them – even with good manners and with some reasons – about what they must do and how. For them, many of their subordinated people do not have enough capacity to make decisions, analyze situations or find alternatives. Naturally, with this concept in mind, they question their own capacity, since most probably these people were hired or selected by the PM.

There is no doubt that it is necessary to manage, lead and control, but this can be done without making people feel that they are not able to take a decision, solve a situation or successfully complete a task assigned.

A good PM allows his people to make decisions according to everyone's position; he must be able to discuss with them their propositions, ideas, changes suggested, and ways of action; he must be able to assess, but not impose his own ideas. Needless to say, lack of ability in delegating discourages the initiative of the staff and leads to everybody waiting to be instructed about how to do his own job, and most probably not liking it.

Stay Cool in Difficult Situations or Under Pressure

It is true that to stay cool in such situations depends on a person's character, and this is a very desirable ability in a PM. This has been confirmed in many cases such as, for instance, a shipwreck where terrorized people, frightened by the unknown, in a precarious condition of life, prone to desperation, hear the words of a leader, become tranquil and obey instructions. As Bennis (1997) says *“Out of the uncertainty and chaos of change, leaders rise up and articulate a new image of the future that pulls the project together.”*

Team-Building Skills

As the name implies it is not only the ability to organize but also to keep intact and united the organic fabric of the team as a cohesive unit. From this point of view the PM must not only know the role of each member of the team, but also verify how well the assigned tasks are executed.

Ability to Solve Problems

There is a very much appreciated ability sought in the PM and it is the capacity for problem solving, which is based on experience, self confidence and knowledge; for many an intrinsic quality of the PM is a liking of challenges. Kouzes (2007) to this respect says: *“They have a ‘fresh, creative response to here-and-now opportunities,’ and not much concern with how others have performed them.”* (Cited by Barry).

3.2 Part Two: Negotiation in Projects

By Fernando Jiménez-Sáez

3.2.1 Introduction

3.2.1.1 Approaching Negotiation in Projects

To the question *‘Is negotiation part of the Project Manager's tasks?’* we only can answer that *‘Certainly, it is’*. In fact, negotiation of details in a project permeates almost every role and affects all the people engaged in their various tasks, regardless of the purpose and scope of the project. However, it is certainly most prevalent in the Project Manager (PM) role.

Project negotiations tend to extend far beyond the tactical considerations associated with competitive bidding and a Game Theory approach (Cova et al. 1994). It is widely understood that participants in the negotiation process face great difficulties in negotiating major projects (Cova et al. 2002). Essentially, the interested participants (namely, client and contractor according to game theory characterization) have to deal with the problem of identifying and distributing potential payoffs. Even when a project is awarded through a call for tender, the client and contractor need to make joint decisions in negotiating important details of the final agreement and, very often, throughout the project delivery process.

In general and for any project, a significant amount of joint decision-making needs to take place. In a broad sense, there are three characteristics related to projects and project management that are usually involved in any negotiation process: *‘Discontinuity’*, *‘Uniqueness’* and *‘Complexity’*. These three characteristics contribute to the challenge and importance of negotiations in project business (Murtoaro et al. 2005).

The discontinuity feature may imply that a project delivery is often considered as unique in the sense that the client and contractor cannot rely on stable processes of interaction. Instead, intense negotiations in the project development period determine to a great extent the economic success of each interested participant.

The uniqueness of each project supposes that the final output cannot be considered a standardized good, which the parties have complete information about. Projects may include many issues to be negotiated with multiple options for each one, therefore offering an enormous number of possible agreements. Negotiations are needed to construct the possible contracts, the key interests of the client, the terms of the agreement, and settle disagreements, which may arise.

The complexity, or the number of stakeholders, means that extensive negotiations are needed to distribute payoffs and ensure commitment to the project on the part of all relevant actors. The more parties are involved in the negotiation, the more complex negotiations usually are.

Therefore, project planning and its management regarding scope, resources, scheduling, budgeting, etc. can benefit from good project managers endowed with negotiating skills. Taking this fact for granted, the next step is the determination of those key aspects that will define and delimitate the negotiation process. In addition and, for the sake of the chapter's length we also assume the existence of a conflict. There is plenty of literature dealing with conflicts, its definition, types and solutions, negotiation being one way to solve them so we will not enter this arena though it is closely related to negotiation.

3.2.1.2 Key Definitions and Elements in a Negotiation Process

We find four characteristics common to all negotiation situations (Raiffa et al. 2002; Lewicki 1992; Rubin and Brown 1975), namely:

- There are two or more interested parties,
- These parties can cooperate to arrive at a joint decision,
- The payoffs to any party depend either on the consequences of the joint decision or alternatives external to the negotiations and
- Involved parties can reciprocally and directly exchange information.

Interested parties may refer to individuals or groups of individuals. In negotiations, the interested parties must arrive at a joint decision (Raiffa et al. 2002) meaning that they must jointly select and commit to a common course of action; a jointly selected, common course of action is called an agreement. Zartman (2002) defines negotiation as a process by which contending parties come to an agreement.

An agreement determines a payoff for each party (Sebenius 1992). The goal of negotiations is to jointly select and commit to a common course of action that is superior to any unilateral action for each and every party (Raiffa et al. 2002). Interested parties are motivated to negotiate for payoffs that they cannot achieve without joint behaviour. Negotiation is therefore aimed at either creating something

that neither part could do on their own, or to resolve a problem or dispute between the parties (Lewicki et al. 1999).

Finally, the negotiation procedure is essentially characterized by a communication process, direct or tacit, between individuals who are trying to forge an agreement for mutual benefit (Young 1991). Also Kremenjuk (1993) defines negotiation as a basically purposeful communication between two or more parties. Communication is a process by which information is gradually exchanged between individuals through a common system of symbols, signs, or behaviour (Webster 2005). Therefore, and putting together all these ideas, we can finally define negotiation as '*A social process of joint decision-making where two or more parties communicate to select and commit to a common course of action that is superior to unilateral alternatives*' (Murtoaro et al. 2005).

There are basically two types of negotiation processes: negotiations in which creating joint value is an obvious opportunity. These are often referred to as integrative, collaborative, win-win or creative negotiations (Raiffa et al. 2002; Lewicki et al. 1999; Fisher et al. 1991). Alternatively, negotiations in which the structure presents no or less-obvious opportunities for joint gains are referred to as distributive, competitive, win-lose or claiming negotiations (ibid.). In the project management field the most appropriate way to resolve conflicts of interests among a project's stakeholders is the win-win one, so relationships between the interested parties remain protected. Though the win-lose type may apply under some circumstances to project management negotiations, this chapter will focus on the first type.

3.2.1.3 Negotiation Styles

Since negotiation has been defined as a social process, negotiation styles are influenced by the individual's characteristics and moods, culture, skills, communications characteristics and any other circumstances that may come together during the process, shaping somehow the way an individual faces it. However, the literature (Shell 2006) identifies five possible negotiation styles, namely:

- *Competitive*: Competitive style negotiators pursue their own needs and objectives, even when this implies others may suffer an undesirable loss. Those who use this negotiation style are often assertive people and unwilling to cooperate. They place their needs above others' needs, trying to manipulate the situation in their favour. They are usually more concerned with winning the fight than finding the best solution.
- *Accommodating*: The opposite style of competing, and for accommodating style negotiators, the relationship is everything. Accommodating profiles think that the route to winning people over is to give them what they want.

Individuals who use an accommodating negotiation style tend to be passive as they seek cooperation. They often neglect their needs and want to make sure others get their way. Those who accommodate tend to be submissive, selfless and afraid of conflict.

- *Avoidance*: This is often referred to as 'Passive aggressive'. People who habitually use this style really dislike conflict. Rather than talk directly with the other party about the issue, avoidance styles may instead try to take revenge without you knowing about it. The avoidance style can be a typical reaction to highly competitive negotiators. Avoidance is a style in which neither assertiveness nor cooperation takes place.
- *Compromising*: Compromising is the style that most people think of as negotiation, but in fact is usually just haggling. Compromising often involves splitting the difference, usually resulting in an end position of about halfway between both parties' opening positions. In the absence of a good rationale or properly exchanged concessions, halfway between the two positions seems 'fair'. Between competing and accommodating is the compromising style. Those who compromise try to find a quick solution that benefits everyone involved.
- *Collaborative*: The collaborative profile is about making sure both parties have their needs and objectives met. Collaborative profile negotiators can more easily revert to one or two of the other styles when pushed or when the situation calls for it. They are adamant that their needs must be met and they acknowledge that the other party has needs that must be met too. Those who collaborate are both assertive and cooperative; they are the exact opposite of avoiders.

According to these categories one may wonder whether there is one style that better applies to negotiation processes in project management. There is no single 'best' or 'right' style. All five profiles of dealing with conflict are useful in different situations; however, most of us tend to have one or two preferred negotiation conflict styles that we use unconsciously in most conflict situations, though we are capable of using all five.

3.2.1.4 Influencing Styles in Negotiation

Any negotiation process reflects how the individual tries to impose his criteria in order to obtain the maximum payoff from the other party. Influencing may mean different things to different people. For some it represents persuasion or even negotiation, for others, it is about getting people to see their point of view or using their authority to get people to do something or change something. Despite these different interpretations, we agree on two (three in some cases) influencing styles that may vary in its intensity but not in its approach.

- *Push*: This style is about moving or forcing someone to a change rather than motivating him or her to want to make the change. It tends to involve logical reasoning, threatening punishment, or offering rewards or incentives. It also seeks to increase the 'forces' and rationale for change. Push styles can be effective in achieving compliance but may not achieve commitment. They may bring about quick results.
- *Pull*: It is about motivating the individual to want to change. People using this style tend to involve personal disclosure, involvement and showing the possibilities that will result from change. They tend to work on decreasing the forces or rationale against change. It can be effective in gaining commitment and high quality but they may be slower in achieving results.

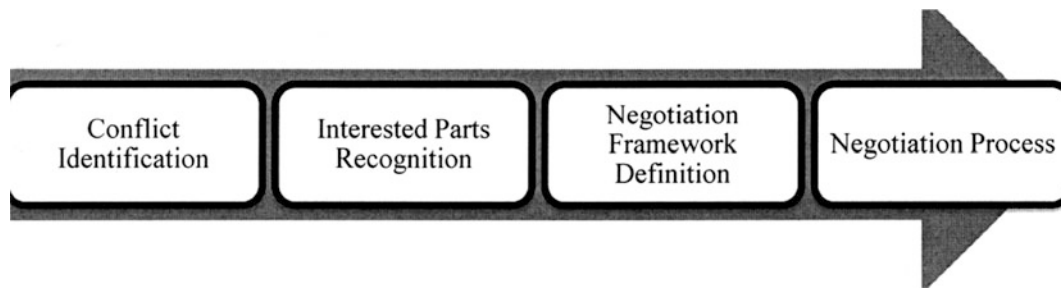
As usual in negotiation processes there is not a right or wrong style to use. It depends on the issue to be negotiated, the sort, quantity and quality of information each party may consider for the process and many other personal circumstances leading to choose one or the other style. Even it might be possible to change from one style to another if the negotiation process may so require. Still there is a third possible position for negotiations: '*moving away*'. In fact it is not a negotiation style in itself but a position to avoid negotiation by deferring or delaying the interaction, decision or bargaining, sometimes in an effort to cause minimal conflict and to affect a more desired outcome.

As we mentioned before, both styles have some use and will be appropriate for different circumstances. For instance, '*push style*' fits into top-down organisations where the negotiation process takes the form of orders; the army is the clearest exponent in this sort of organisations. On the other extreme we find flat organisations where right decisions rely on negotiations that usually require information no matter who provides it. One case involves research institutions where decisions regarding research projects may require a wide consensus from the people involved, hence a '*pull style*' may better fit into these situations. For the sake of any PM it is fair to say that a pull style, when combined with the minimum amount of push needed to achieve compliance, is most effective in searching for commitments and attitude change.

As a result of approaching a negotiation using one style of influence or another, the negotiation climate or tone will be conditioned. In general, push-influencing styles will impose a defensive negotiation climate and pull-influencing styles will prepare negotiations for openness. Main characteristics of a defensive negotiation climate are a push-influencing style, where communication between parties resembles a debate rather than information exchange and dialog, with limited listening and frequent judgments. In contrast, an openness negotiation climate is usually the result of a pull-style of influence, where communication is based upon dialog and information exchange through which each party

Table 3.1 Combination of influencing styles with negotiation climate and style

Influencing style	Own negotiation style	Negotiation climate	Counterpart's possible negotiation style
Push	Compete	Defensive	Compete Accommodate Avoid
Pull	Compromise Accommodate Collaborate	Openness	Compromise/Accommodate/Collaborate Compromise/Accommodate/Collaborate Compromise/Accommodate/Collaborate
Move away	Avoid	Defensive	Compete

**Fig. 3.1** Interrelated elements of a negotiation process

will try to convince the other with reasoning; judgements are limited and listening is the base for the dialog. Therefore there exists mutual trust between the parties. Table 3.1 summarises the most likely combinations of influencing styles, negotiation climates and styles. Needless to say that any further combination might also be possible.

3.2.2 The Negotiation Process

Before analysing the process, we can sum up the previous elements to highlight that negotiation is a social process that can be undertaken in a formal or informal manner, consciously or unconsciously. We usually negotiate to satisfy a need that might be difficult to make explicit if it depends on emotional features. The process itself is affected by each individual's moral and ethical values, therefore it is possible to find people who lie as a negotiation strategy. We have to clearly distinguish between not providing all the information and lying; information will be provided at its due time, therefore there are many elements influencing the negotiation. This fact results in different alternatives for an agreement that will satisfy to a greater or lesser extent the objectives of the interested parts. Consequently, final agreements often retain some degree of uncertainty: the higher the parties' satisfaction upon conclusion of the agreement the better the acceptance of its results.

The elements that define the negotiation process are therefore: *conflict identification*, *interested parties recognition*, *negotiation framework definition* and *problem solving*

process or negotiation itself. These four elements are closely interrelated. Figure 3.1 depicts this process. First, a problem provoking a conflict is identified; second, those individuals who are concerned with the conflict have recognised each other; third, they proceed to establish the framework for the negotiation. At this point the scope of the conflict has to be carefully defined: the higher the conflict level the more difficult the implementation of a negotiation and the search for an agreement will have to be found in other forms such as conciliation, arbitration or even judicial processes.

For the sake of the project it is recommended to set a negotiation framework for the conflict. Any other alternative will result in detriment to the project. Taken for granted that a negotiation process is the first best to solve the conflict and search a solution, this fourth element occurs in different stages. Different authors have usually identified four or more phases. However, the activities related to these phases and the stages presented are basically the same. We will refer to these stages as:

1. Pre-negotiations,
2. Conceptualisation and settings,
3. Closure and follow up.

Next, each stage will be further described in order to characterise the activities involved in each one and to define those key ideas to be developed to carry on the process.

3.2.2.1 Pre-negotiations Stage

The starting point implies that each involved party recognises the need for a negotiation and then the need to identify the counterpart. During this stage each interested

party must evaluate his and the counterpart's bargaining power. The underlying idea of this concept is similar to the one used in Game Theory: it is related to the relative abilities of parties in a situation to exert influence over each other. The extent to which we are able to delimitate this concept will help us to determine our negotiation strategy. The following are some elements that help us delimitate both our own and the counterpart's bargaining power:

- The *actual need for the negotiation*: the more basic is our need to negotiate, the weaker the bargaining power,
- The *need for a relationship between the interested parts*: the larger our need for the relationship, the weaker the bargaining power,
- The *need for an agreement*: the lower our number of alternatives to an agreement, the weaker the bargaining power,
- The *need to actually fulfil the agreement*: the higher this need the weaker the bargaining power,
- The *available time to achieve the agreement*: the less the time to negotiate, the weaker the bargaining power.

During this stage it is also necessary to identify both our own and the counterpart's needs and the objectives that will meet those needs. These objectives act as the spotlight during the negotiation process. In addition, each individual has to analyse what resources are available for him and the counterpart for the negotiation. All this information is combined to define the general issues under negotiation.

Many different issues can be included in a project negotiation. However there are three characteristics in each project, no matter the type, which are also part of the negotiation process and will influence, to a greater or lesser extent, the individuals' needs and objectives: the *project scope, cost and time*. From the perspective of negotiation, these three general elements are actually basic negotiable issues in projects. The scope, cost and time are decision variables on which the parties negotiate a specific level from different alternatives. Only after the parties have come to an agreement on the particular value of scope, cost and time, do these elements become objectives, against which performance can be operationally measured.

This stage is also referred as the *intelligence stage* and it enables to the interested parties to determine their '*Best alternatives to a negotiated agreement*', also referred to in the literature as BATNA (Fisher et al. 1991). Therefore BATNA can be defined as the course of action that will be taken by an interested party if the current negotiation fails and an agreement cannot be reached. Involved parties negotiate in order to better satisfy their own interests through some jointly determined agreement than could otherwise be done (Sebenius 1992). In practically all situations, negotiators have outside alternatives that they can turn to (or BATNA), should they fail to reach an agreement in current negotiations. The payoff of each party's BATNA

determines the lowest level of the payoff that a party is willing to afford in order to continue the negotiation. Taken together, these minimum payoffs define the disagreement point.

The region of agreements beyond each party's BATNA, in the direction of increasing payoffs, delineates the agreements that are individually rational for both parties. Alternatives to negotiated agreement also play a tactical role. The more favourable alternative courses of action negotiators have, the smaller the need for the negotiation and the higher the standard of value that negotiators can expect from any proposed agreement (Sebenius 1992). The set of feasible contracts is called the '*zone of possible agreements*' (ZOPA).

We also can understand the BATNA concept as **the minimum agreement to the negotiation**. Any solution that a party may consider below this point will provoke abandonment of the negotiation process.¹ The following picture illustrates a negotiation process between two individuals.² The region of agreements beyond each party's BATNA, in the direction of increasing payoffs, delineates the agreements that are individually rational for both parties.

Figure 3.2 helps us understand the relative positions of interested parties and how these relative positions are the result of their actual BATNA. The picture reflects a relatively equilibrated negotiation, however, negotiators with more attractive BATNA are able to capture a greater share of the negotiation zone (Chen et al. 2003) and therefore use it to obtain more advantageous agreements.

3.2.2.2 Conceptualisation and Settings

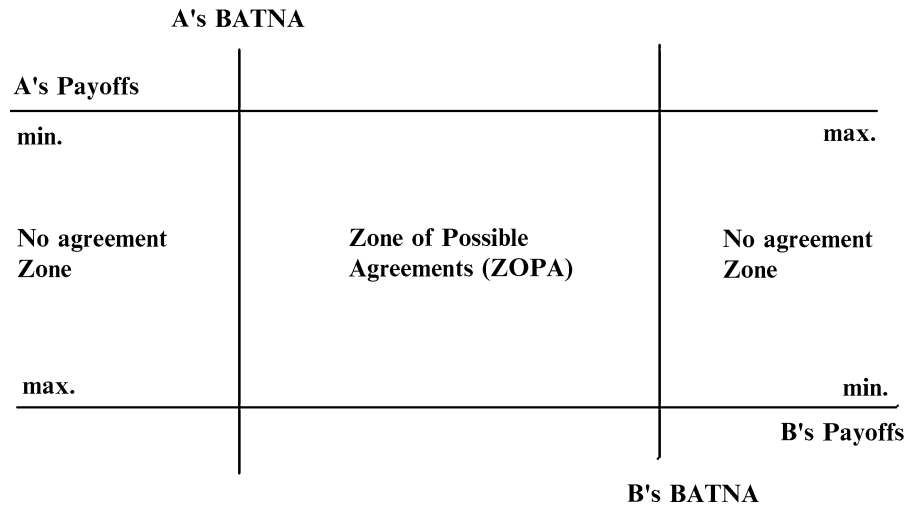
During this stage the interested parties have to define their own interests, determine the set of options for each issue under negotiation and evaluate the possible combinations of options with respect to their interests. Specific tasks involved in this stage are the following:

1. Confirm hypotheses regarding bargaining power of each interested party. If the bargaining power is equilibrated between the individuals a collaborative negotiation style is suggested. Alternatively, an unbalanced bargaining power between the individuals will drive the negotiation process using a competitive negotiation style on one side and most likely an avoiding negotiation style on the other.
2. Negotiation strategy definition. This second task will settle the confidence degree between the interested parts.

¹The concepts of BATNA and ZOPA directly emanate from Game Theory. In fact these minimum payoffs define the disagreement point, an equivalent of the non-cooperative Nash equilibrium concept (Raiffa et al. 2002).

²A more thorough explanation of this picture can be found in Murtoaro et al. (2005).

Fig. 3.2 Visual interpretation of negotiation concepts



As a consequence of the mutual understanding it will be easier to establish an openness climate for the negotiation leading to a collaborative negotiation style. For this case, mutual understanding is not synonymous of friendship or agreement with the other individual's ideas, but deeper knowledge about the counterpart. A balanced situation in terms of mutual understanding and bargaining power will lead to collaborative negotiations based upon mutual confidence and an openness climate. Instead, unbalanced situations will lead to impose (or haggle) under a defensive climate.

3. Provide information progressively. As we stated at the beginning of this chapter, negotiations in projects require fair behaviours, avoiding lies and tricks. The process of providing information represents the bidding phase in which each interested party will communicate to the counterpart what he is able to offer and the limits for that bid. This stage requires time, assertive behaviour on each part and relevant information to advance in the process based on constructing coherent bids, discarding those that do not fulfil expectations.
4. By the end of this stage many different alternatives of agreements will have been explored and compared to each interested part's BATNA contributing to the ZOPA's delimitation.
5. If all this process is carried out under mutual collaboration, creativity and generosity, it will be possible to reach an agreement that fulfil many of the objectives and needs of each party and should provide a common ground of action.
6. Finally this is an iterative process that evolves over time as it is fed with new information, counterparts confirm or reject initial hypotheses, influencing styles change, then producing changes in the negotiation climate and therefore in the counterparts' negotiation style. If the process runs aground at some point, it may be necessary to return

to the previous stage to collect new information. It also be possible to postpone the negotiation process.

3.2.2.3 Closure and Follow up

This is the final stage in the negotiation and it represents the achievement of a common solution: the interested parties jointly select and commit to a common negotiation contract usually found within the delimited ZOPA; and finally implement and control the contract. However, if the negotiation process does not reach a final agreement, this stage represents the need for additional information if the individuals are still interested in reaching an agreement, or the breakdown of negotiation if individuals consider that no agreement will be good enough to improve both individuals' BATNA.

The next figure (Fig. 3.3) summarises the elements that the interested parts will have to consider and the sort of decisions to be taken in each stage to proceed with the process and find a common and agreed solution to the conflict.

3.2.2.4 Final Guidelines

As mentioned at the beginning, there is no unique negotiation method but a set of possibilities shaped by the interested parties. Furthermore the possible route for any negotiation process will evolve according to the information and timing adopted by each participant. However, this process has to be planned in advance to establish possible paths and anticipate responses and behaviours. In short, prior to a negotiation, any negotiator needs to determine his or her first best according to the needs and objectives identified and any possible alternatives that might be plausible and acceptable in case of not being possible to reach the first best.

Negotiation is an ongoing process fed with useful information to bear out or reject initial hypotheses. The goal is to reach a solution satisfying all parts without one individual position's prevailing over the rest. Many agreements that clearly benefit only one party may end up being equally

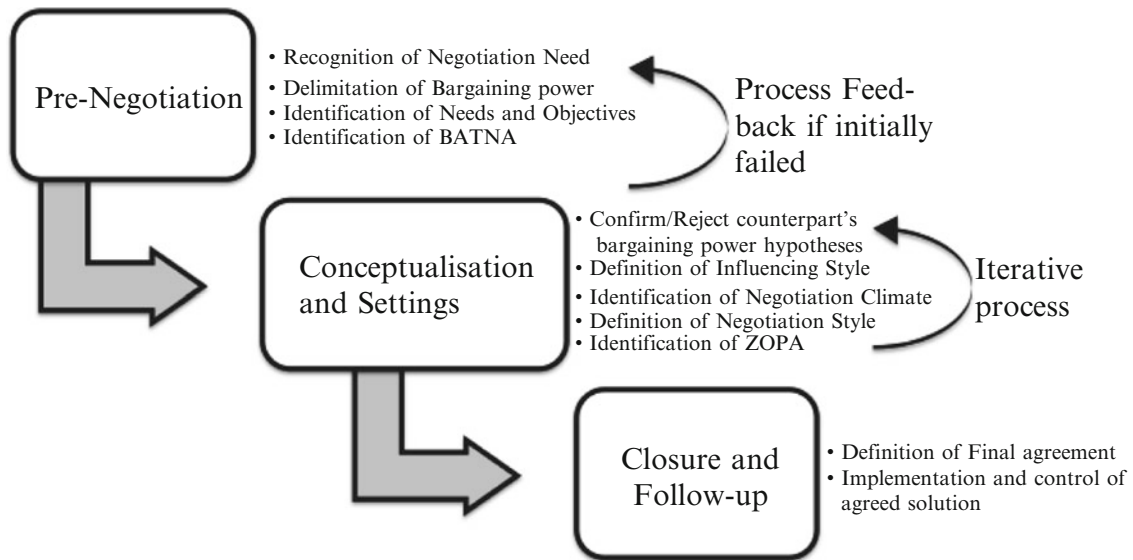


Fig. 3.3 Negotiation process in three stages

damaging to this part due to the counterpart's inability to respond adequately. It is equally negative to unconditionally accept an agreement than to force it

3.2.3 CASE STUDY: Identifying the Problem

These cases deal with different situations that might arise. Each one focuses on one specific issue of the negotiation process: lack of relevant information, unbalanced starting point for the involved parts' BATNA, and a wrong negotiation process from all points of view.

3.2.3.1 The Need of Background Information: Actual Identification of the Problem

This case has been adapted from March and Wu (2006). It emphasizes the need to define and identify the problem. In this example, a sizeable electronics firm faces considerable difficulties with one of its subassemblies. The core of the problem revolved around certain types of fittings and pins that became bent and distorted in the subassembly process. Units already produced suffered damage and were rejected because of imperfections; these discarded components were put aside and re-worked later on in the month.

This duplication of efforts resulted in increased costs as workers had to work extra time to meet their quotas, and these extra costs had not been considered in the manufacturing budget. The manager of this subassembly line did not want to assume these overhead expenses because he felt that it was not his responsibility. Likewise, the manager of the final assembly department also refused to acknowledge the inclusion of the extra costs to his budget since these were a

consequence of poor work from the personnel in the subassembly department, where the problem arose.

The subassembly department manager argued that the parts were in good condition when they left his department and therefore the damage must have occurred in the final assembly department. A solution to the matter agreeable to both parties was worked out some time later since both parties were looking for a long-term solution to this quandary. They were able to negotiate a reasonable solution only when they understood the actual nature of the problem.

It was ascertained that the subassembly workers had some slack time available during every working month. The damaged parts were returned in small batches from the final assembly plant so that the subassembly personnel could work on them during these slack periods. Also, when they examined the problem in detail, the managers found out that some of the personnel in the final assembly plant may not have been adequately trained and may have also been partially responsible for the damaged components. These personnel were identified and sent to the subassembly plant to further improve their training and to learn more about what transpired in that department.

The final solution pointed at the increased cost concerns of both departments. In addition, the extra time was reduced by reallocating personnel to those positions where and when they were actually necessary and finally, because of the enhanced training, the number of damaged parts was considerably reduced.

The lesson to be drawn from this case is that the managers were only able to realise the problem and address a solution when they were able to understand the real issues that lay beneath the conflict as the cause for the increasing costs.

3.2.3.2 CASE STUDY: How to Win in a Negotiation with Constrained BATNA

This case has been adapted from Lax and Sebenius (2006). In the 1960s Kennecott, a U.S. mining company was about to enter into renegotiation over its contract with the government of Chile regarding the 'El Teniente' copper mine. At that time, Chile's BATNA (represented by Eduardo Frei's Government) appeared overwhelmingly strong as the government was inclined to take a strong pro-sovereignty position towards foreign management of Chile's natural resources. The government of Chile was politically well positioned to establish its own power through financial conditions or exert the option of unilaterally declining to renegotiate, getting Kennecott out of the process by simply expropriating the mine. Chile had its own experts who could manage and operate the mine, as well as the processing, and could easily put the copper into the market. Kennecott found itself in the position of either consenting to the contract renegotiation terms dictated by the Chilean government or having the mine snatched.

Realising that their own BATNA was weak, Kennecott executives came up with a very creative negotiation deal which ultimately weakened Chile's position while leveraging Kennecott's BATNA more favourably by creating value for both sides. The proposal made by Kennecott entailed the following six steps strategy, thereby changing the rules of the game:

- The deal consisted of Kennecott offering to sell a majority equity interest in the mining operation to the Chilean government.
- Realising that Chile would not particularly care to divest the funds of the sale into U.S. banks, Kennecott offered to use the funds, combined with an outside loan, to finance the mine's expansion. This allowed Chile to preserve its sovereignty interests and have greater financial gain from future profits. They were able to renegotiate and establish a partnership which was mutually acceptable to both parties.
- Next, Kennecott persuaded the Chilean government to guarantee the loan and have this guarantee subject to the law of the state of New York.
- Then, most of the company's mining assets were insured with U.S. backed guarantees, against the potential expropriation threat.
- Kennecott also negotiated that the copper production from the expansion would be sold exclusively to clients in Europe and North America.
- Finally, the rights to collect from these new contracts would be sold to a consortium of financial institutions based in Japan, the United States and Europe.

This allowed for a greater diversity in the customer base and additional partners. In future contract renegotiations, this would result in a much larger multi-party negotiation

and then Kennecott had to renegotiate on its own. Many of these outside interests would also be engaged in other unrelated negotiations with the Chilean government, thereby reducing Chile's bargaining power in any future contract renegotiations. Therefore, Chile's government would not have too much flexibility to change the negotiation game when they renegotiate their contracts.

Finally, because of the insurance guarantees obtained by Kennecott, even if the renegotiations collapsed, Kennecott had succeeded in protecting many of its interests should Chile opt to go ahead and appropriate the copper mine. Additionally, the company would have new and powerful partners to support its position.

At the end, some years later, the mine was eventually expropriated by Chile, but Kennecott was by far in a better position to renegotiate compared with what it would have had before. Kennecott enhanced its BATNA by making an offer that the Chileans could not refuse, while taking steps to protect their own interests should negotiations collapse.

3.2.3.3 CASE STUDY: It Is Also Possible to Lose in a Win-Win Situation

This case study has been adapted from Seroka (2005). This case is also known as the 42 months war. In January, 1993, management and labor of Bayou Steel in Laplace, Louisiana, were negotiating a new contract. Each side believed that they had built a solid relationship so the process would end up favourably to both sides. The firm's representatives went into the negotiations thinking and believing that if they used a win-win negotiation concept, they would increase and enhance the relationship between the shop floor and management. Even the president of United Steel Workers of America (USWA) did not conceive of the possibility that negotiation would collapse and would lead to a strike, and believed that a negotiated contract would be reached with little or no effort.

Bayou's representatives sought the help of two facilitators from the Federal Mediation and Conciliation Services to guide management through a win-win negotiation process with the workers. The president of Bayou said that the facilitators would help them identify each side's objectives and concerns, and led him to believe that they had in effect resolved 90% of the contract issues.

The facilitators set up an issue by issue agenda. They left the economic issues such as incentives, base pay, overtime, and vacations as the final issues to be negotiated. Bayou's representatives believed that they had correctly addressed the employees' concerns about economic issues. However, union members became suspicious about management's good intentions to take a win-win approach. They began to collectively believe that the negotiation approach was a disguised ploy meant to undermine their position, especially regarding economic issues.

At the beginning, negotiations went relatively well, as predicted. Yet, as the union representatives placed the economic issues on the table for discussion, the situation quickly turned upside down into a hard-nosed bargaining negotiation. Bayou's representatives attempted to stick to a win-win negotiation style, but this no longer was the case with the union. As a consequence union members rejected the negotiation process and went out on a 42 months strike.

By using an agenda to address negotiations, Bayou Steel failed to consider that any single issue could be so divisive. As the economic issues rose to the foreground of the negotiation process, Bayou Steel no longer had leeway in considering trade-offs.

The lessons from this case refer to the need to be able to compare and contrast all the issues collectively, and by order of relative importance. A large set of negotiation issues with few degrees of freedom can hamper willingness and confidence of interested parties. Instead, dealing with issues on a one-on-one basis through a pre-designed agenda can offer a wide span view of the process and the location of each objective and need in the negotiation.

3.2.4 Conclusion of This Chapter

This chapter deals with a fundamental PM task: negotiation. It shows that there are many different issues to be taken into account for any negotiation. However, it is a social process and therefore many additional features may influence the course of the negotiation changing radically the picture. Yet, some general guidelines can be offered:

1. *Information is power in any negotiation*, therefore, good information on the other individuals involved is always a good ground to settle needs and elaborate objectives.
2. *Project management may involve any negotiation strategy* but a collaborative approach facilitates an openness climate and pull-styles on influence.
3. *Negotiation is also a time consuming process*. It requires careful preparation before facing the counterpart, cautious attention, active listening and assertive behaviour in order to progressively incorporate relevant information into the process that may lead to the expected agreements.

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Abstract

This chapter deals with the essential process of strategic planning; it portrays strategic planning as a necessity in any kind of project, and links it with the vision and mission of the company in charge of a project development, whatever it might be, as well as with actions to be taken to reach objectives and achieve goals. It also comments on the stages needed for strategic planning to take place; these are intelligence, gathering, implementation and control, describing methods to fulfill each one. A case devoted to a commercial venture is proposed; it is divided into two parts. The first one is the execution of a SWOT analysis (Strengths, Weaknesses, Opportunities, Threats), and the second part is the development of the project.

Keywords

Strategic planning • Goals • Objectives • SWOT analysis • Internal and external business environment

4.1 Introduction

Strategic planning is the process of identifying an organization's long-term goals and objectives and then determining the best approach for achieving those goals and objectives ([Boston University](#)).

Strategic planning applies to any kind of projects, whatever they might be, like the construction of a high-speed train, the development of a pharmaceutical product, coal mine exploitation, creating a new learning centre, or producing a new type of wine. However, even considering this wide spread of project content the philosophy and procedures are alike for them all, since in all projects the same issues appear.

Given a vision and a mission, considering the present day position, and having decided where the company (or firm, organization, association, institute, etc.) wants to be in the future, its strategic planning indicates *what has to be done* to

attain the established objective. It can be thought as a sort of road map that tells a traveller how to go from where he is now to his final destination.

For a construction company, responsible for a large civil project, the goal could be to finish the job at complete client satisfaction, building at the same time a sound background concerning its expertise and prestige for the company regarding jobs well done, finished in the agreed time and respecting the original budget. For a government committed to the construction of a high-speed train, the goal could be for the country to have a fast and reliable service that will benefit society. For an educational concern, the goal might be to create a business oriented centre, aiming at being in the future one of the best MBA schools in the world. For the wine-maker his/her goal could be to have the best cabernet sauvignon even produced.

Goals are different but steps are the same, and for sure, strategic planning is not a short-term endeavour, perhaps a mid-term, say 5 years from now, but more often a long-term

venture. Thus, strategic planning is not a simple punctual event but a lasting procedure or process, and one of its tasks is goals setting. It is not a detailed or itemized process, but it establishes a framework for a business plan, as well as for tactical actions to take place, that is *how to do* things, *when to do* them and by *who*, and because of its importance, strategic planning is usually the responsibility of the higher echelons in the company.

Strategic planning is not a static procedure, because even when defined and established it does vary. If that were not the case the company could be assuming that nothing will change in the future either within the company, which is called the *internal or endogenous environment*, nor outside the company, which is termed *external or exogenous environment*, and this would certainly be a very naïve way of thinking.

In reality, since it has a dynamic nature, it is quite the opposite, and its objectives are adjusted according to internal, external, or both environment changes. For instance, C.T.W's Supermarkets might have a strategic process in place and mainly regarding client satisfaction. However, due to advances in social sciences there is a new paradigm – related with corporate values – and because of that, its Board of Directors might decide that these values must reflect those qualities which are appreciated by shareholders, clients, suppliers and employees and that also must be long-lasting. Considering that, C.T.W's Supermarkets Board of Directors decide that its strategic planning has to hold and even improve these corporate values, and in so doing make it clear that they are not some transient measures that will fade in the future, but a permanent issue with a large relevance. From here, there will be tactical actions to implement these corporate values.

4.2 Tools for Strategic Planning

One of the main issues in strategic planning is that a company must be aware of its capacities, potential, experience, and skills, but at the same time must be honestly conscious of its shortcomings, that is, like the two sides of a coin. One side relates with the internal environment, that is, attributes within the company products, ideas or plans, which in most cases can be corrected, improved or changed. The other side corresponds to the external environment, meaning clients, political scenario, market conditions, exchange rates, etc., which clearly are facts or aspects where a company normally does not have any influence.

Considering this, it is then reasonable to think that these two aspects are to be considered. This duality poses a difficult problem mainly because uncertainty in the external environment; however, help comes from a tool called 'SWOT', acronym for Strength, Weakness, Opportunities

and Threats; the two first issues match internal attributes and the second ones the external facts. It is then possible to perform an analysis to have a fair appraisal of the company standing project-wise, that is, it will allow determining the probabilities of success or failure in the undertaking.

Another tool to consider is '*Life-Cycle Cost Analysis*', in order to determine not only costs during the project construction period but also through the operation or revenue period, up to the end of the project life, and naturally, escalation has to be taken into account, estimated and applied, as well as discount rates to bring figures to net present values. A project may look very attractive and inexpensive in the construction phase, but can become expensive to maintain. A good example is a project for installing an ERP system in a company (see Chap. 11), which might be expensive to maintain and/or because the company chooses a Cloud Computing¹ approach.

4.3 Elements of Strategic Planning

The elements and stages that constitute the strategic planning process are:

Information or intelligence stage

- Establish goal or goals. Goals are usually long-term endeavours a company wants to attain, and normally are achieved by complying with a set of objectives,
- Establish objectives. Objectives are concrete short-term accomplishments, which are normally associated with ways or tactics to meet the objective,
- State vision. It is where the company wants to be in the long term, that is, asserts the goal to achieve,
- State mission. It establishes the objectives to attain the goal asserted in the vision.
- Project financing

Regarding financing it is reasonable to think that there must be enough money to pursue a project from the *economic point of view* (that is, related with project *cost*). However, this obvious fact is not enough, since the company must also consider the *financial point of view* (that is, related with the *time* that disbursements must be done). The financial aspect can be understood when one considers that the total amount of money to execute the project is usually not available at any moment. It is normally invested, or in form of accounts receivables, or in stocks, shares, etc. If the money comes from bank loans, these are normally delivered by tranches, since it does not make sense to pay interest for 'sleeping' or dormant money stored in the company safe.

¹ System in which company information is stored in a server outside the company which also provides all the necessary software resources that are managed by the cloud server.

Therefore, at certain intervals, the company must count on having enough money to pay for work done by a contractor, or for equipment delivered during that period. These amounts must then match the baseline schedule, or S-curve (see Sect. 9.2.1). Figure 4.1 shows this matching, where it can be seen that scheduled work follows an S-curve, while disbursements follow a step function.

Design stage

- Perform SWOT analysis (see Sect. 4.4.2).
- Develop strategy, that is, determine what to do. For instance Planning, Scheduling, Cost control, Budget control, Communications, Environment, etc.
- Make a sensitivity analysis (*What if.?*) (see Sect. 12.1.3), using relevant parameters, for instance: Demand less than expected, necessity to reduce the sale price, production not up with demand (which can be advantageously used by competition), declining international price for the product created by the project, increases in freight costs.
- Compute break-even point (see Sect. 7.6).

Implementation stage

Includes:

- Implementation of adopted measures in all sensible departments and areas. See Table 4.1 as an example.
- Implement tactics that is actions needed to get the objectives and goals. See Table 4.1 as an example.

Control stage, using key performance indicators.

- Indicators or metrics are needed to gauge the performance of a project, and their purpose is to show how well the strategy works to attain the established goals. Strategic indicators are usually germane to the nature of a project, and for this reason it is difficult to establish a listing of them. However, some internal indicators such as trend of working capital, cash flow evolution, work advance, and others, as well as external, like client satisfaction, sellers and contractors compliance, etc., are common in most projects.

would be an excellent market for this product, where it was not manufactured due to high production costs. However, in order to protect its milk industry the U.S. government had banned import of many milk derivate products, including this milk jam.

Some months ago Dulche initiated procedures with the U.S. Agriculture Department to have the foodstuff approved for import, and succeeded, since it proved that its product was sugar-based instead of milk-based. This government ruling established Dulche as the only company allowed to legally import this product, which was, of course, a very large advantage, until other companies were able to get the same permit.

Dulche planned to export the product to Los Angeles and then to expand to all the south of the United States with a high percentage of Latin Americans, most especially people from Mexican origin (Mexicans are very fond of this product and in fact they manufacture it in Mexico, with another name and using goat's milk). From this perspective the venture looked very promising, which was helped by an affordable pricing. The company also prepared a business plan that allowed it to get loans from banks.

4.4.2 SWOT Analysis

After obtaining the permit Dulche performed a SWOT analysis. It considered internal factors for the product and the company such as '*Strengths and Weakness*', as shown in Table 4.2 and also external factors that could help the venture such as '*Opportunities, and also Threats*' than could damage or alter the scenario, as depicted in Table 4.3.

These tables are only a part of the SWOT analysis; however they show the most important aspects.

As in any project there were ups and downs, and without a doubt there were three very positive aspects that fueled Dulche's enthusiasm:

- (a) The exclusive permit,
- (b) The fondness for this very well known product, and
- (c) The large Latin-American population in the States.

However, a more thorough analysis also showed that it was a risky venture and three members of the Board of Directors voiced their opposition mainly centered on the existent rumors about a potential total ban in the future, and in the very serious fact that no market study was done, and that the venture would only be based on the feelings that the product has all the ingredients for success.

Anyway, the optimistic directors won and Dulche decide to pursue it; financial projections and indicators were provided and approved based on the very optimistic sales

4.4 CASE STUDY: Commercialization and Distribution of an Imported Food Product into the USA Market

4.4.1 Background Information

Dulche SA, an Argentine company, with decades in the food business, manufactures a jam made out of cow's milk (known as Dulce de Leche), which translates as 'Milk jam' that is an extremely popular product in all Latin America although with different names. The company thought that the United States, considering its very large Latin population

Fig. 4.1 Financing the project and net cash flow

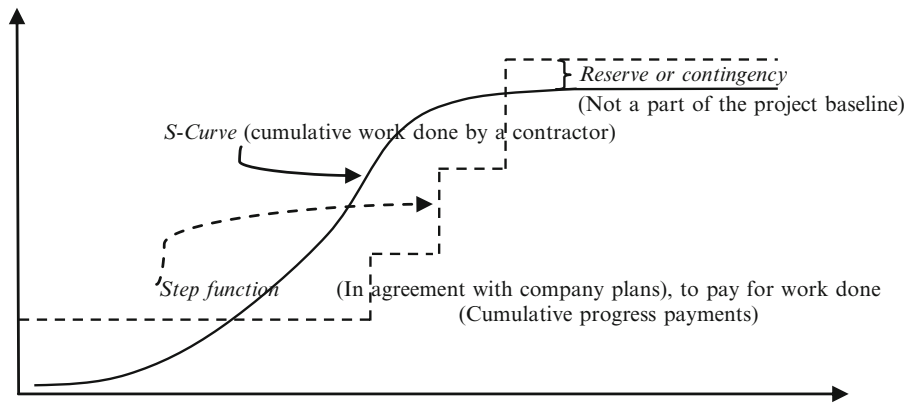


Table 4.1 Implementation of strategic planning in the construction of a large railway tunnel

Knowledge area	Methods	Tools to materialize objectives	Intelligence gathered along the process
(Strategy \equiv Organization)	(Ways or Tactics \equiv Implementation)		Type and extent of information provided by tools as well as results from monitoring
Set of <i>established objectives</i> to attain strategic goal or goals	Set of <i>set up tactics</i> to accomplish objectives along the process	Set of <i>designed instruments</i> , ways, means or contrivances to execute tactics, as well as designation of accountable personnel	Set of <i>dedicated performance measurements</i> such as key performance indicators (KPI), ratios, indexes, and reports derived from job execution
Planning and Scheduling	Critical Path Method Bar Chart	By hand MS Project [®] software Primavera Planner [®] software Kick-off meetings Three-weeks look-ahead schedule Weekly meetings with contractors	Delivers total time to completion Shows the critical path, that is the minimum time for execution of the whole project Determines critical activities, that is those that do not tolerate any increase in execution time Determines floats, that is the allowance in time for non-critical activities Allows checking compliance with established milestones Informs about resources usage such as resources levelling Analyzes budget cost of work planned (BCWP)
Budget control	Earned value	Building the 'S' curve Weekly meetings with contractors Computation of contractor's performance indexes on manpower and man-hours, materials, equipment and machinery at job site Use of performance measurement software. There are many brands in the markets that portray the information through metrics, tables, bars, pie charts graphs, etc.,	Determines budget cost of work performed (BCWP) (<i>see Sect. 16.1.2.2 for definition</i>)
Cost control	Earned value	Building the 'S' curve Weekly meetings with contractors Monthly certifications of work done	Determines actual cost of work performed (ACWP) (<i>see Sect. 16.1.2.2 for definition</i>) Allows determining costs variation
Communications	Electronic link with all departments of the company, client and suppliers	Using Enterprise Resources Planning (ERP.) Weekly progress report	Provides real time information of all activities. Determines people allowed to receive certain information

(continued)

Table 4.1 (continued)

Knowledge area	Methods	Tools to materialize objectives	Intelligence gathered along the process
(Strategy \equiv Organization)	(Ways or Tactics \equiv Implementation)		Type and extent of information provided by tools as well as results from monitoring
Set of <i>established objectives</i> to attain strategic goal or goals	Set of <i>set up tactics</i> to accomplish objectives along the process	Set of <i>designed instruments</i> , ways, means or contrivances to execute tactics, as well as designation of accountable personnel	Set of <i>dedicated performance measurements</i> such as key performance indicators (KPI), ratios, indexes, and reports derived from job execution
Environment	Environment team in charge of checking environmental compliance	Permanent monitoring through: Visual inspection, for instance on: Oil and chemical spills, water contamination, dust, waste, etc. Samples taken if necessary Reports	Checks compliance of environmental Regulations Allows immediate response if needed
Risk	Visual inspection of work detecting potential problems (For instance water seepage in a tunnel) Delays in executing key activities New developments posing new risks, etc.		Checks that expected risks are under control Keep an eye on the potential appearance of new risk factors
Safety	Visual inspection of machinery and personnel equipment Visual inspection of personnel compliance with regulations, for instance using hardhat		Allows checking that safety procedures are kept. Permits computing percentage of accidents and causes Lets establishing prevention measures for new hazards
Logistics	Confronting contracts documents with actual expected delivery dates Keeping track of advances in fabrication processes in manufacturer premises Checking equipment when arriving at the jobsite	ERP. Internet	
Financial and economic evaluation	Cash flow statement Balance sheet Loans statement	Computerized financial statements	Checks if project is in track regarding expenditures, working capital and especially cash flow
Quality	International ISO standards	ISO 9000 – Quality ISO 14001 – Environment ISO 31000 – Risk Etc.	Checks that quality norms are established and maintained

forecasts. The first container with the product was shipped to Los Angeles. The company had already relocated a high level officer in Los Angeles to manage the distribution of the product. After arriving in the States, the foodstuff was offered, with wide acceptance, to many small Latin American outlets in the Greater Los Angeles area, and in two large supermarkets chains catering to the Mexican population. The product was taste-tested in these two supermarkets and was prized very competitively, albeit there was some competition from a smuggled similar product from Mexico.

The product sold well although at a low pace, however the South American company decided to close operations after 14 months because of very low profitability, if any. When one

considers that it was a good and palatable product, at the right price, aiming at a very large Latin population, with a definite advantage since it could be legally sold, and that an affective advertisement took place, one wonders why it failed.

Marketing expenses were correctly appraised and considered fairly stable since apart from the manager with a fixed salary, there were only two employees with a fixed base and commissions, using their own vehicles, and occasionally a couple of ladies taste-testing the product in different outlets; therefore personnel monthly expenses were almost fixed. There were no surprises either with operating costs such as rentals (office, warehouse and living accommodation and transportation for the manager), and telephone.

Table 4.2 Strengths and weakness – Commercialization and distribution of an imported food product into the USA market

	Strengths	Weakness	Comments
Known product	The product is very well known in all Latin American countries, albeit with different names and presentations	Because the different denominations it will take some time for people to identify the product with what they know	There were neither budget nor an estimate for advertisement other than taste-tasting in supermarkets Therefore it is difficult to evaluate how long it will take to let the product be known
Taste	Because the use of cow milk the product has a more delicate flavor than the similar made with goat milk	It is impossible to know how people will react to this slightly different taste	A short product testing was performed in three cities of three different states and the results were satisfactory taste-wise
Price	The product will be priced competitively which is interesting considering the higher price of cow milk compared with goat milk	The profit margin will be low, and economic feasibility of the project is based in its sales volume	The company decided to distribute the product and not to trust it to established distribution companies, in order to reduce operating costs, and with distribution personnel using their own cars and working on commissions
Composition	The product is made with cow milk, with a very rich flavor	However, there is a movement in the USA against consuming food with high calories	It is believed that this fact will not have an effect in Latin-American population, but certainly will influence other people, especially native Americans who appear to be more mindful about high calories products
Aiming at the childrens market	Cow milk is three times more nutritious than goat milk and this is an argument that will be used for promotion, being especially suitable for children	Goat milk is by far more popular and used than cow milk and easier to digest, and very close to human milk, which is an argument used by some producers in Mexico	
Sales potential	Considering the huge Latin American population in the United States it is assumed that the demand will be considerable. Sale points will be some large Mexican supermarket chains and also in hundreds of small shops patronized by Latin Americans in Los Angeles, and other with high Latin American population	The Latin-American population in the States is mainly concentrated in the South and on the West Coast that is in California. However, no serious market analysis has been performed and then it is unknown if the population can afford to buy a minimum of five flasks a month, which is the quantity estimated for break-even with an estimated sales of 6,000 flasks a month	This is probably the weakest point since sales is presumed to reach a certain level, based in conversations with some Mexican supermarkets in Los Angeles, Tucson, San Antonio and San Francisco, as well as studying the composition of Latin American families in the States and the former consumption of the product, when it could be imported from Mexico

Table 4.3 Opportunities and threats

	Opportunities	Threats	Comments
Import	At the moment of this study the import of milk product is prohibited in the States in order to protect their own milk industry. However, the company has obtained the only existent permission to import the product because it demonstrated that the product is not milk based, but sugar based (not by content but by dollar values), and sugar is not banned	There are rumors that perhaps at some time in the future the import regulations would be changed, because it is considered that using dollar values for a certain product masks the actual percentage of each component, since it depends on the respective price of the commodity in the country of origin. However, nobody in the Commerce Department or in Customs could confirm the rumor	The exclusivity to import is by far the most important argument to go ahead with this business, since there is definitely a great advantage in being the only product to be approved for import. Not too much attention was paid by the company to the rumors
Competition		There are also rumors that at least one company based in Florida on the East Coast is thinking to produce locally a similar product mainly oriented to the huge population of Cuban origin. However the taste and presentation is different because the Cuban custom is to consume the product as a candy bar instead of a jam as this product is	Not too much attention was given to this rumor
Cash flow	It was thought that considering the work of a team of sellers working on commissions and because of the large quantity of small shops marketing the product, there will be a reasonable flow of funds enough to cover operating expenses	Unfortunately not many shops cancel their obligations on time, which make it necessary to extend credit time and then compromising the cash flow	During preliminary conversations with some retailers and just as a sample it was known that normally payment is within a month after delivery, and on this assumption cash flow calculations were done
Managing the business		Members from the Board of Directors voiced their concern on the fact that Dulche did not have international experience and especially in the very difficult and competitive US food market	This argument was contested because Dulche will appoint a seasoned commercial manager and because some member of the Board thought that ' <i>business is the same everywhere</i> '

Then, again, why did the project failed? Was it the product that failed or the culprit was poor strategic planning? Let us examine the following list that a good strategic plan should have pursued and try to determine the cause of failure.

4.4.3 Analysis of This Case

The main culprit was the low demand as commented on in 'Sales potential' in the SWOT analysis.

Considering the three stages of Strategic Planning, namely, intelligence, implementation and control, it is obvious that the company failed because of lack of intelligence, or may be they did not pay enough attention to signals from the external environment, which were clear. It is however believed that the company performed well in implementation and control, for they very quickly developed a customers network and were wise enough to quit before losses were too big. Let us analyze the case:

In general, the project objective was OK, but the company failed because:

- (a) Lack of expertise on overseas sales even with a good project manager, because the Board of Directors did not appraise correctly the existent situation for importing food products into the USA, especially milk foodstuff. In addition, they did not pay too much attention about the possibility of potential regulations that could be enacted to change the norms, as it happened. Therefore, a correct diagnosis of the situation was absent amongst other aspects because lack of intelligence regarding import regulations was a main culprit on this critical issue.
- (b) There was a cash flow problem because they did not realize the delays in payments either from large supermarkets or as well as from small outlets. They should have realized that these small outlets are usually cash-strapped, and even when they usually pay (which was usual), they do that with a considerable delay. Information should have been collected regarding modality of payment and it was not.
- (c) A sales projection was done based on information from a succinct and poor marketing. However, this basic information was flawed because Dulche did not realize that the Mexican equivalent product had a different taste because it was made with goat's milk, and that people were used to that taste.
- (d) The Board of Directors should have known that it is very difficult to succeed, especially in a foreign and competitive market, with only one product, and did not recognize that in their home country they had diversification through a complete line of food products. True, when poor revenues showed them this error, they tried to amend it by importing new food products but it was

too late. Therefore, the strategy should have considered diversification.

In reality, if it is true that all the above circumstances contributed to the fiasco, it is believed that factor (c) was the most responsible, which in turn affected the cash flow. The second most important flaw is attributed to marketing that did not realize the cultural aspect, and what is really sad is the fact that marketing was aware that import regulations were under study, consequently, even if the product would have been a success it really would have had a very short life, until the new legislation was in place. They lost the comparative advantage they had in introducing the product legally in the country.

4.5 Conclusion

There is no doubt that even if Dulche followed the three steps of strategic planning they were not performed correctly. They performed a SWOT analysis but failed to interpret its clear signals. Therefore procedures were followed but not understood.

4.6 Suggested Procedure for Strategic Planning

There now follows a series of procedures that a good project strategic planning should perform. They mainly apply to the examined case because it is believed that some framework is convenient to exemplify them, but in reality, their applicability is common to most projects.

4.6.1 State the Goal and Analyze Diverse Factors and Potential Risks

- What is the goal of the project?
Most probably, the goal is to enter in a huge market and be a dominant force in this activity, and of course, make a profit, but how good is that potential profit considering actual investment? Can the company afford the risk especially if the investment money comes from loans?
- Analyze in all honesty the strength of the company for this business.
Does the company have the necessary expertise, or is the lack of it one of its weaknesses?
- What are the opportunities envisioned for this development?
Are they long lasting or just fleeting and ephemeral opportunities?
- What are the threats?

For instance, think what would have happened if the product remained in the market, but when import regulations changed, the product was no longer able to enter the country, or if the tariffs and import duties rates rose sharply? Would the product be still saleable?

- Establish a commercialization period, after which it can be decided to continue or to quit the business. In other words, how much is the company willing to lose?
- Compute the potential earnings, but more important, consider the cash flow needed for operations.
- Make an approximate economic projection based on potential demand from the market study and average cash-collection periods, and compare results with direct and indirect operation expenses, which usually cannot be deferred. Consider a buffer to take account of delayed payments from clients.
- Select some critical external variables affecting the project or the product made by the project, and perform a sensitivity analysis, that is finding out what can happen if these variables change in the future, and also considering several scenarios for each one. A very good way to perform this action is using the financial statements prepared for the project, which usually are a part of the business plan. Since the different statements such as the *Balance Sheet*, *Cash Flow*, *Earnings*, *Long Term Loan schedule*, etc., are related, a change in an external variable such as *Revenue from Sales* will immediately reflect in the *Project Analysis* statement affecting metrics such as *Project Return*, *Shareholders Return*, *Earnings per Share*, etc.

Read about a sensitivity analysis in Sect. 7.3.

4.6.2 Consider Other Strategies

- Study potential spin-offs from this project. For instance, a blast furnace construction project will produce a residue, called slag (scrap iron). This slag can be used to produce Portland Blast Furnace Slag Cement which is extensively used for hydraulic work. Even when the primary purpose of the project is to obtain iron, the company may consider expanding its activity in the future by producing that kind of cement,
- Integration. A company, producing blister copper can think of a vertical integration to produce anode copper,
- Study the feasibility for potential diversification. For instance a large candy manufacturer with plants and distribution centres in several countries develops a project to manufacture cardboard to make boxes for packing its products; this product, not related with the main activity of the company, was also sold to other companies.

4.6.3 Perform a Market Study and Analyze Potential Variations

(Common to all cases but exemplified in the just analyzed case)

Coming back to our case study:

- Determine existing competence, regional or local tastes, geographical areas of interest, potential demand, and segment of the market the product addresses.
For instance consider transportation costs plus insurance to other far away regions in the States, such as Texas, with a large Latin population.
- Study dietary trends.
It could be that people are becoming reluctant to purchase sugar products.
- Analyse potential selling outlets for the product,
For instance, should the product sales concentrate on small Latin retailers or also investigate supermarkets, considering mark up and charges from the latter?
- Prepare adequate literature in English and Spanish.
Make sure everybody can understand what this product is, because it is known with different names in Latin American countries.
- Study advertisements, and food tasting campaigns in supermarkets.
This is a good tool but also very expensive, since large supermarkets require a fee to allow taste testing on their premises.
- If the company plans to sell only one product make sure that the operation is profitable, or if there is necessity to incorporate more products from the very beginning or in successive steps. Compute the break-even point of sales.
- Determine presentation of the product (size, weight and label).
Also study differential prices or discounts for different outlets based in volume purchased and modality of payment.
- Make sure that labelling text is in accordance with local law.
Be careful in labelling. The product could be banned if its label does not comply with existing regulations regarding percentages of sugar, fats, calories, salt, etc. Have the label approved before using it, because re-labelling can be very costly.
- Make a sensitivity analysis especially focused on demand and price variation.
This is important as demand can vary according to economic conditions, and it could become necessary to lower the price in order to promote sales.
- Study the competition, from which a lot can be learnt.
For instance try to find out if there was in the past a similar attempt from a competitor.

4.6.4 Study Custom Laws and Taxes

- Find out if the product is included in the Harmonized Tariff System for import rates.
- Analyse if there are import regulations of its content (sugar, milk, etc.), and find out how this content is measured. Sometimes they are based on percentage and dollar value.
- Analyse sales tax law in place of distribution. Remember that regulations and taxes can vary from state to state.
- Learn about amount of wages and salaries paid to employees (direct and indirect).
- Learn about documentation needed for contracting people and depositing their contribution to retirement and social services.
Very important. Remember that there are minimum wages to be paid and mandatory tax and social security forms to file.

4.6.5 Think About Facilities

- Analyse adequate warehouse availability especially for refrigerated products.
Make sure to consider pallets to store merchandise and that the facility has appropriate decks for loading and loading trucks.
- Study potential locations of the company headquarters (offices, warehouses),
- Find out about potential for short-term arrangements regarding rentals, warehousing, distribution, etc.

4.6.6 Operations

- If an executive of the company will be based in the USA, make sure that he/she gets proper clearance from the Immigration Department with a licence to work in the States, as well as income taxes to pay.
- Make sure to know existent regulations for tamper proofing.
- Make sure to know local regulations about handling conditions for further packing the product into flasks, or boxes if from its origin it arrives in bulk bins.
- Are bank loans available to the company? At what interest rate? Is there any grace period offered by the bank? If there is one, remember that even if there is an allowance for payment, interests are still running.
- Analyse about average collection time in the industry, otherwise it is possible to run into cash-flow problems.
- Negotiate purchasing and shipping the product.

- Consider getting a good theft insurance and also for damages suffered by the merchandise during the sea trip, and other transportation from the sea port.
- Most probably, the company will need food product liability coverage, which normally is very expensive. Find out about regulations, conditions and costs.
- Find out about fees charged by large supermarkets for taste-testing the product.
- Establish a company at destination for import, packing, distribution and hiring employees. Find out about regulations regarding minimum wages and salaries, as well as taxes withheld.
- Establish a distribution mechanism.
- Establish procedures for collection and further daily fund deposits in a bank.

4.6.7 Monitoring and Control

- Monitor the development of the project by establishing indicators to control how the strategy is working.
- Think about alternative strategies to promote the product in case the planned strategy is not producing the desired effects,

4.6.8 Final Comments

The case just described was analysed in some depth to point out the importance of good strategic planning in carefully analysing all the aspects of a project. Out of the three aspects of strategic planning, i.e. intelligence, implementation and monitoring/control, it appears that the first one was almost completely neglected, and consequently, the project was based on inaccurate, incomplete and misleading information. However, the implementation worked as planned, although with some changes, for instance, it was not known that taste-tasting promoting the product in supermarkets carries a hefty fee; again there as no prior information about this modality.

The monitoring also worked well since using as indicators the monthly volume of sales, the average days for collecting amount receivables, and especially the trend of working capital needed, translated into cash flow that was reaching dangerous levels and that prompted control actions such as importing a new line of products, participating in fairs and increasing advertisement, but that finally called for closing out the project.

True, it pertains to a complicated case especially because it dealt with a food product trying to enter in a very promising but also very difficult market, as the USA is. However, there are unfortunately many examples of failure

because of lack of sound strategic planning in many other areas, where some evident actions were not considered, or perhaps taken lightly. For instance, and these are also actual cases:

- Construction of a hydroelectric dam, managed by a consulting engineering Canadian company. In this case, the strategic plan failed to duly appraise the difficulty in dealing with official regulations and customs in a developing country (external factors).
- Same as above for another multinational American consulting firm trying to build a copper concentration plant in another developing country (external factors).
- There is a sad example, involving a large aluminium company, of stopping a huge hydroelectric development in Canada after hundreds of millions of dollars were invested, because native people's opposition to the project was not duly considered (internal and external factors).
- In another case a multinational mining country had to stop operations for gold mining because of people's resistance to the project, on the grounds that it would contaminate their potable water source (external factors).
- The oil spill ecological disaster in the Gulf of Mexico speaks of British Petroleum's 'negligence' according to James Hackett, chief executive of Anadarko Petroleum (BBC Mobile 2010). Apparently, a huge safety valve located at the top of the well (called a blow-out preventer) failed to operate. At the time of this writing there is no conclusion about the reasons for this failure, but nonetheless, and considering that said risk exists, it appears that the strategic planning did consider it safe enough, and did not find necessary a back-up mechanism (internal factor).

4.7 Strategic Planning in Remedial Work

It differentiates from other projects in the sense that generally these are unique undertakings such as cleaning up contaminated soil, evaluating worthiness of some structures like bridges, decommissioning chemical and petrochemical plants, cleaning up rivers, etc. In these cases each project is different, with its own objective, characteristics and demands, and normally there are a lot of tests to be done and procedures to develop, for instance how to treat a quarry contaminated with radioactive water, or to clean up a marsh, or how to save endangered animal and vegetable species. Sometimes there is a lot of uncertainty because one does not know what to do, for instance in cleaning up a river with very contaminated mud; it could very well be that it is safer not to disturb the mud because of the danger of contaminants

dispersion. Therefore, there are risks here that have to be carefully evaluated. Quality assurance is also very relevant in this type of project especially in data and measures taken, that because they are not usual, need to be carefully checked.

4.8 Conclusion of This Chapter

The necessity of planning a project strategically is evident; without a proper strategy, without knowing what our objectives are and the ways to reach them, it is quite impossible to succeed. This chapter examines this issue and supplies the tools for strategic planning and its elements, as well as an example of the very important SWOT analysis. The case study is an actual case that exemplifies the consequences of a poor or inexistent strategic planning.

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Unfortunately our affluent society has also been an effluent society

Hubert H. Humphrey¹

Abstract

This chapter addresses the paramount issue of the effects and impacts that a project can cause on the environment, the society and the economy, which is imperative nowadays to consider. Aspects such as land use, impact on the environment, emissions of noxious or harming gases to the atmosphere, contamination of soil and water amongst others, are briefly analyzed.

Keywords

Factors • Impacts • Sustainability • Damage minimization • Carrying capacity of the environment • Indicators • Social impacts • Economic development

5.1 The Environment Importance in Projects

Every project, whatever its nature has effects on the environment, the atmosphere, the soil and water bodies. These effects are impacts that alter in a greater or lesser degree the environment. For that reason nowadays it is mandatory in almost every country that a project – does not matter its nature – must submit an environmental impact assessment (EIA) to get the approval from a competent organism. Most projects assess these impacts considering how much they alter the environment, however, since it is impossible to produce zero impact, it is normal to establish parameters, or thresholds measured in contents of a pollutant in m³, grams, litres, etc. That is, there is always a tolerance that must not be surpassed. There is abundant information in all countries regarding admitted contamination therefore, a project that will produce a certain amount of say SO₂ can be accepted if its emissions are below this limit.

However, there are also projects whose main objective is to improve the environment per se, or to correct something

that has produced damage to the environment. To this category belong projects such as the creation of a new forest when an original one has been swallowed by the rising waters behind a dam. There is a similarity with the enormous effort made to save the Abu Simbel temples that were threatened when the Aswan Dam in Egypt began filling the reservoir. From the environmental point of view there were several huge projects such as the rehabilitation of the Rhine River, or massive projects to restore heavily contaminated areas in the U.S.A. Projects to select indicators to control the status of the environment also belong to this category, as well as projects developed by City Halls all around the world, but especially in Europe, to develop sustainable cities. See the Aalborg Commitments (Aalborg+10).

Most projects are special undertakings with potential environmental damage attached, and comprise a large variety of problems from ship building to cities rehabilitation, from hydroelectric plants to high-rise construction, from manufacturing to universities, and many others. However, in all of them there is a component related with the environment, which in these cases plays the role of a ‘silent partner’ in any discussion.

¹ Vice president of the United States 1965–1969

The main problem in this kind of project is to identify the impacts that a project will generate on people, wildlife, the environment (air, soil and water, forests), buildings, erosion, landscape alteration, etc. The range of impacts is large; air pollution, soil and water contamination, noise, climate change, destruction of heritage, massive migration of people, migration or disappearance of wild life, forest logging, etc. Unfortunately, examples are abundant; large contaminated plains in Kazakhstan, the retreating Caspian Sea, the almost depleted Ogallala aquifer in the USA, and many others bear witness to how humankind has managed to destroy the environment; the first mentioned is because of nuclear tests, the second due to a huge cotton development, and the third one because too much water is being extracted.

Of course, nature may be a silent partner in these events; though it has neither voice nor vote, it manages very well in demonstrating excesses to humankind, through the melting of the poles and rising ocean waters threatening to swallow some countries, or in the ozone hole producing serious effects on humans and animals because there is no longer protection against the sun's radiation.

Some projects address social issues like rehabilitation of derelict areas in cities, elimination of shanty towns, social programs for unemployed people, measures to decrease accidents, etc., but in all of them the environmental factor is always present, exhibiting damage to the environment.

Many industrial projects, roads, railways, energy conservation, forestry, oil drilling, etc., in addressing economic issues largely affect the environment, but many people view them as an unavoidable requirement, since they provide the means for people to earn a living. True, and probably nobody can think in terms of not creating new job opportunities because of damage to the environment; but the opposite is also true, in the sense that humankind must not be allowed to destroy the only planet it has. That is, many people view the issue as a dichotomy between economic growth and sustainable development,² an example of 'it is this or the other' similar to the results in throwing a coin; it is heads or tails.

Many believe that this is not the case, that the possibility exists of having it both ways, provided that equilibrium is reached. That is, we can get an economic or a social benefit in developing a project, while we also know that we are damaging the environment; a logical question is '*Since economic growth is necessary, how possible is it at the same time to preserve the environment for future generations?*' One answer is '*By minimizing the project's impact on the environment, and by taking remedial actions to counteract in*

some measure the effects of such impacts'. And this is a capital and central issue in all kinds of projects.

Can we do anything else? Yes, we can, by trying to 'compensate' for damage to nature by enhancing as much as possible the environmental conditions existing before the project begins, such as planting more trees than those removed, by increasing the amount of rain water directed into the soil (for instance through the construction of rain water ponds), by establishing strict limits for commercial fishing, by removing weeds from lakes, etc.

As a bottom line it is believed to be mandatory that these two apparently antagonist concepts must be considered when analyzing a new project from the environmental point of view, that is, any project, independently of its technical considerations, must be framed by these two concepts, and besides, special care must be taken in not surpassing the carrying capacity of the environment³

The main purpose of this chapter is to make the project manager aware, especially in new projects, that environmental issues, besides of those purely technical, must be considered.

5.2 Detection of Impacts Produced by a Project

For each project it is essential to establish the different impacts that it will generate from the environmental point of view. One way to determine these impacts is to break-down the project into its component elements or main blocks. Then, it follows the analysis of the consequences, demands or impacts that each component and subcomponent will have on the environment. It is obviously impossible to list the effects generated by every type of project, however, as a guide Table 5.1, shows some examples of aspects that must be considered from the environmental point of view when analyzing a new project.

5.3 Impact Identification

This is not an easy task and one of the reasons is that usually impacts are not isolated; that is, it is usual to find one direct impact influencing another, which in turn affects another like a domino effect. For instance, consider that treated wastewater (but that has not been subject to a quaternary process), is discharged from a sewage treatment plant, into a lake. This water still contains potassium and nitrogen, which

² Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs. (Brundtland report). See World Commission on Environment and Development (1987).

³ Carrying capacity can be broadly defined as the environment's potential and ability to indefinitely sustain the use of a renewable resource, such as water from aquifers, aquatic life, forests, clean air, etc.

Table 5.1 Factors to considered in a project environmental-wise

Sector	Sub sector	Generates, demands, produces, affects, amongst others:
Civil construction	Airports	<ul style="list-style-type: none"> – Noise – Large tracts of land – Clear and fluid car access
	High-rises	<ul style="list-style-type: none"> – Heat concentration – Shadows on other buildings – High energy consumption
	Residential housing complexes	<ul style="list-style-type: none"> – Loss of soil permeability – Land use
	Large constructions	<ul style="list-style-type: none"> – Land use – Loss of soil permeability
Energy generation	Coal-fired	<ul style="list-style-type: none"> – CO₂ (global warming) → Melting of the poles → Flooding of low countries and islands – SO_x (acid rain) → Decrease of PH in bodies of water → Affects aquatic life – Soot (global warming) – Cooling towers
	Combined solar and photovoltaic	<ul style="list-style-type: none"> – Land use (these installations require large tracts of land)
	Combined cycle	<ul style="list-style-type: none"> – Offers in general low level of environmental pollution
	Diesel-engines	<ul style="list-style-type: none"> – CO₂ – Particulates
	Fuel cells	<ul style="list-style-type: none"> – No pollution, but hydrogen manufacture, which is used to feed the cells produces pollution unless renewable energy sources are used
	Gas-fired	<ul style="list-style-type: none"> – Gas is the least damaging fossil fuel; it has no mercury, produces no particulate and almost no SO₂. It is low in NO_x and CO, however it still has a high CO₂ content albeit lower than coal and oil
	Gas-turbines	<ul style="list-style-type: none"> – Gas is the least damaging fossil fuel; it has no mercury, produces no particulate and almost no SO₂. It is low in NO_x and CO, however it still has a high CO₂ content albeit lower than coal and oil
	Geothermal	<ul style="list-style-type: none"> – No pollution
	Hydro- generation (Large power stations including dams and lakes)	<ul style="list-style-type: none"> – Creation of a lake behind a dam that can have effects on the soil structure (some say that it can provoke tremors) – If there are urban centres in the area they can be flooded by the lake (the most notorious modern example is the Three Gorges in China, where more than 1.2 million people had to be resettled) – It can have effects on the geology of the area (the dam of Vajont in Italy provoked in 1963 a massive landslide responsible for destroying five villages and more than 2,000 deaths) – Large amounts of rocks and earth must be removed and dumped elsewhere. For instance to build the Itaipú dam in Brazil, it was necessary to excavate a channel to reroute the mighty Paraná River. – The Itaipú project destroyed the largest (by volume) waterfall in the world, The Guairá Falls
	Mini-hydro	<ul style="list-style-type: none"> – No pollution
	Nuclear	<ul style="list-style-type: none"> – There is no solution yet for disposal of the highly radioactive spent nuclear fuel rods
	Oil-fired	<ul style="list-style-type: none"> – CO₂, SO_x, , water vapour, NO_x, and other gases
Photo voltaic	<ul style="list-style-type: none"> – Land use (these installations require large tracts of land) 	
Sea waves	<ul style="list-style-type: none"> – No known impacts 	
Tidal energy	<ul style="list-style-type: none"> – Forms a lake behind a dam 	

(continued)

Table 5.1 (continued)

Sector	Sub sector	Generates, demands, produces, affects, amongst others:
	Wind	<ul style="list-style-type: none"> – Alters the landscape – Noise – May cause death of birds
Harbours		<ul style="list-style-type: none"> – Vacant land (for no longer used wharves)
Highways	Roads	<ul style="list-style-type: none"> – Rivers – Lakes – Noise – Swamps – Wild life migration – Forests
Incinerators	Domestic waste	<ul style="list-style-type: none"> – Can generate furans and dioxins – Problems with their location and population – Road traffic – Particulate from fumes may be deposited on far away places
Industry	Car making	<ul style="list-style-type: none"> – Fumes from painting – Toxics, sludge – Wastes from manufacturing – Waste water
	Chemicals	<ul style="list-style-type: none"> – Fumes – Toxic discharges – Safety
	Electronic	<ul style="list-style-type: none"> – This is the largest industry in the world. Environmental concerns about this industry refer not only to its manufacturing stage but to the disposal of old equipment too. There exist tough regulations for manufacturing in the USA, Japan and Europe. There is a ban preventing the use of halogens as well as lead, and producers were expected to establish a system to recover electronic waste since 2003 (Lau et al. 2003)
	Food and beverages	<ul style="list-style-type: none"> – Odours – Contaminated wastewater – Water needs
	Manufacturing	<ul style="list-style-type: none"> – High energy consumption – Chemical residues – Noise – Dangerous by-products
	Meat packing plants	<ul style="list-style-type: none"> – Odour – Wastewater with high organic content (BOD₅)^a – Energy consumption – Cooling towers
	Oil refineries	<ul style="list-style-type: none"> – Salt water – Trade waste – Chemicals released into the atmosphere – Odour – Noise – Health risks – Spent catalysts
	Plastics	<ul style="list-style-type: none"> – Uses hydrocarbon resources – Danger for people working in plastic manufacture due to harmful vinyl chloride fumes – Some process residues can go to the sewers which in turn endanger aquatic lives in the water bodies where sewage is discharged
	Transportation	Railways
Road and railway bridges		<ul style="list-style-type: none"> – Rivers – Lakes – Noise – Swamps – Wild life migration – Forests
Road transportation		<ul style="list-style-type: none"> – Elevated fuel consumption – CO₂, NO_x, smog

(continued)

Table 5.1 (continued)

Sector	Sub sector	Generates, demands, produces, affects, amongst others:
	Shipbuilding	<ul style="list-style-type: none"> – Land use – Noise – Elevated energy consumption
Steel mills		<ul style="list-style-type: none"> – Compliance with environmental requirements was estimated to make up 20–30% of the capital costs in new steel plants (Chatterjee 1995) – Main contamination is produced during the blast furnace stage because generation of flue gas, however this is treated. There is also a heavy use of water as well as production of mill scale – Slag, the limestone and iron ore impurities collected at the top of the molten iron, make up the largest portion of iron making by-products. Sulfur dioxide and hydrogen sulfide are volatilized and captured in air emissions control equipment and the residual slag is sold to the construction industry (Peden et al. 1998)
Tourism		<ul style="list-style-type: none"> – Degradation of some places such as caves, forests, lakes

^aOne of the most common standards used for water is the Biological Oxygen Demand (BOD₅), which measures the amount of oxygen needed to oxidize, burn or break down organic matter in 5 days

promote the growth of algae (first effect). This growth is made at the expense of dissolved oxygen in the water (second effect). Water without too much oxygen is not adequate for aquatic life which emigrates or dies (third effect). When algae die the debris go to the bottom of the lake and continue to extract oxygen to decay (fourth effect), producing gases such as hydrogen sulphide that makes water smell like rotten eggs (fifth effect). In addition, the growth of algae can reduce the capacity of the lake.

For impact identification, and as mentioned in Sect. 5.2 a recommended procedure is to break a project down into its main components.

5.4 CASE STUDY: Construction of a Dam for a Hydro Electric Project

The breakdown is proposed and depicted in Fig. 5.1.

The project is decomposed into its main elements that are:

- (a) Concrete arch-gravity dam structure which also will contain the hydro-turbines (power house).
- (b) The lake impounded by the dam,
- (c) The transmission line, and
- (d) The connection to hwy. 73. At present, hwy. 73 crosses the river by way of a ferry service 10 km down the location of the future dam. The idea is to use the top of the dam for railway service as well as for hwy. 73 and thus connecting the two shores.

Now that the main blocks are defined it is possible to detect and analyze the impacts or actions to take to protect the environment. In this case the actions are:

Rock dumping: Construction of the dam involves blasting parts of the ground to reach the bedrock for the dam footing. This action creates the problem of deciding what to do with the removed material and where to dump it, i.e. an environmental quandary. A solution could be, if it is suitable, to use the rock by producing concrete for the dam, but if this is not a solution it is necessary to find a place where to dump the rock and find another place or quarry from where to get rock for concrete.

Concrete cooling: There is another issue related with concrete since the project will be located in a tropical region, and it means the necessity to cool the concrete before it is poured. This involves the construction of a cooling plant, which in turn presents some environmental actions, which include:

- Removal of a sizable number of existing trees which are part of a tropical forest, and
- Using the river water to refrigerate its compressors and discharging it into the river at higher temperature.

Construction camp: The environmental actions depend in large part on the location of the jobsite. If it is near a large city, probably its effects will be negligible, however, if the job site is in the middle of a wilderness, its effect can be considerable, taking into account soil clearance (perhaps with tree logging), for dorms, kitchen and offices trailers, water treatment and wastewater treatment plant, pavement, etc.

Fish migration: There is no doubt that there will be fish migration during construction and, most important, interruption of their spawning up waters when the dam is built.

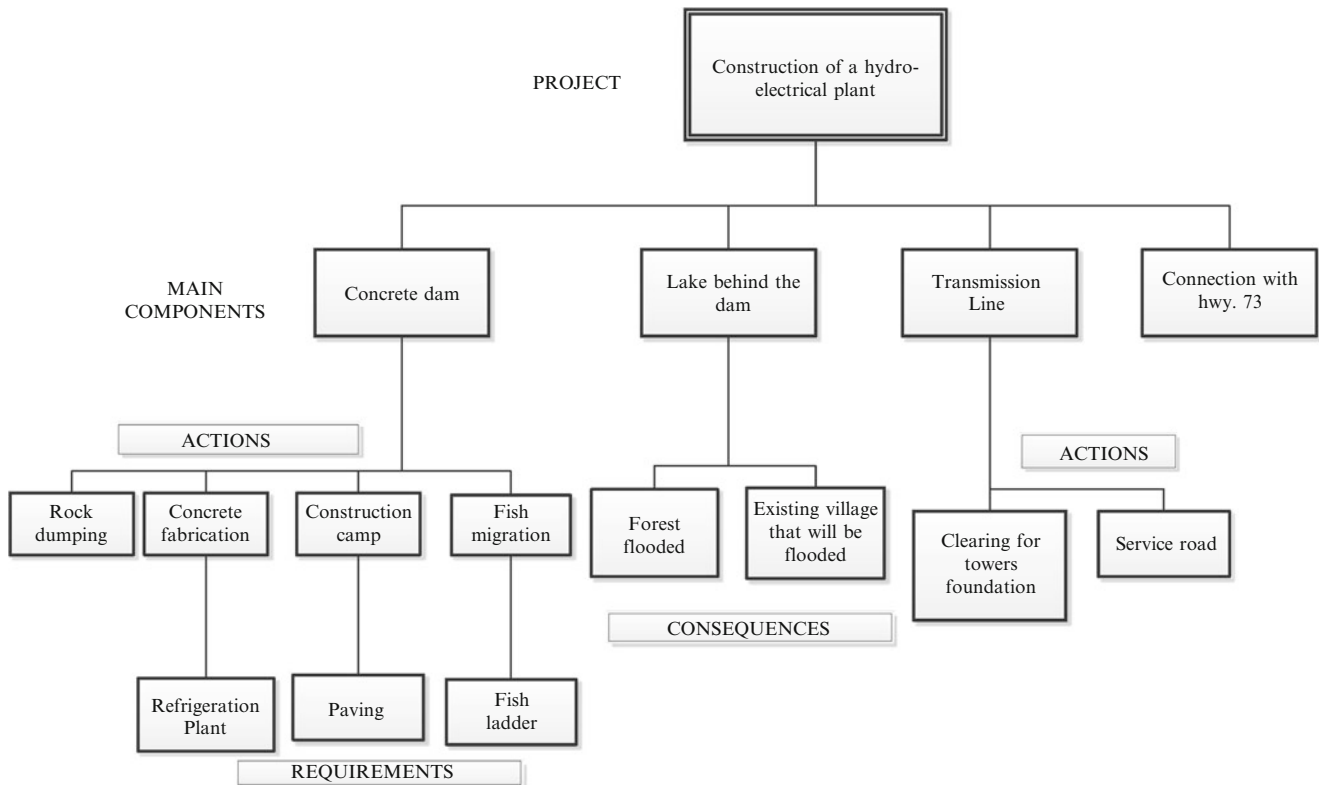


Fig. 5.1 Work breakdown structure for a hydroelectric project – Construction of a dam for a hydro electric project

Forest: Part of the forest will be flooded by the lake behind the dam; therefore, measures must be taken to compensate for this loss by preparing a reforestation program elsewhere.

Population: A village in one of the slopes will also be flooded; then a relocation plan must be prepared and dwellings built to relocate its inhabitants, and also compensate them. Remember that the plan must consider consultation with affected people.

Foundations for transmission line towers

A 96 km transmission line has to be built, which necessitates the erection of 240 steel towers; therefore, there is considerable damage to the environment because of excavations for them.

Service road: Needed for transmission line construction and for servicing.

A decision needs to be made about how to ‘compensate’ the environment for this damage.

The four main elements commented on above are shown in the ‘Main components’ level. Each one (except Hwy. 73) is in turn broken down in its most important constituent’s parts *from the environmental point of view*, as analyzed above, and that involve taking diverse actions to affect the environment the least possible.

Notice that ‘Concrete fabrication’ is closely related with ‘Refrigeration plant’. Consequently, it is necessary to

analyze and evaluate carefully this action in such a way as to minimize its effect. The same happens with ‘Paving’ the camp roads, because it will impede rain water percolation into the soil and even can produce some flooding. Maybe an underground drain will be necessary to convey the rain water into a zone where it can percolate. Needless to say, at the conclusion of the project and since most probably the camp will be dismantled, it will be necessary to break the pavement to leave the ground in its original conditions.

Regarding ‘Fish migration’, and if this aspect was not considered in the design stage, then it is necessary to be aware of the obligation of building a ‘Fish ladder’ for the fishes to overcome the hurdle imposed by the dam, in their annual swim up the river for spawning. The same analysis must be executed on other actions.

5.5 Projects Designed to Protect the Environment

Some projects are devoted to protecting the environment such as replanting trees to compensate for trees logged by a project, or a project to clean a river such as the famous project to clean the Rhine River by the Rhine Action Program in 1987, or the Weldon Springs Site Remediation Project, in Missouri, USA, at a cost of about 650 million

dollars to clean up a site heavily contaminated with chemicals and radioactive debris.

In this kind of undertaking different actions in comparison with conventional projects must be taken mainly because the existing danger that the decontamination of a site can accidentally contaminate another. For instance in heavily contaminated courses of water such as the Riachuelo River in Argentina, the bottom is mud that is seriously contaminated with heavy metals such as chromium, lead, copper, nickel, etc, produced by industrial discharges, and the nature of the contamination makes decisions difficult to take, because there is the suspicion that removing the mud and disposing it in another place will be more dangerous than leaving the river as it is.

Projects to remove and rehabilitate old structures are often confronted with the existence of asbestos, used in the past as a construction material, and a proven cancer-causing agent. Contamination also exists on the ground in many places around the world.

5.6 CASE STUDY: The Hidden Contamination in Manufacturing

5.6.1 Background Information

This case involves working with contamination produced along the project life cycle.

SMC is a semiconductors company that wants to build another plant. The mandatory Environmental Impact Assessment (EIA)⁴ submitted to authorities has been approved.

Background information

1. Identification of processes and components.

Main inputs are: sand as well as a sort of different metals, bought to suppliers and with the highest degree of purity.

2. Impacts determination.

To obtain silicon with a degree of purity of 99.9999% complex techniques are used, which also are very contaminant, while production demands high energy consumption. This contamination can be measured for silica as well as for the other components; however, normally there are secondary, tertiary and quaternary effects, since for acquiring an element, such as sulfuric acid it is necessary to start with purified sulfur, then hydrogen, etc. In turn, each of these elements demands other elements and machinery whose fabrication also

produces contamination. That is, each element used in the fabrication of the semiconductor is the result of a process that generates contamination due to the production of every one of its components, generation that replicates with each subcomponent, and proceeding backwards to the first element, in a sort of chain.

5.6.2 Life Cycle Computation

Computation of the total contamination produced in the chain, or '*life cycle*' is obviously complicated; however, there is a mathematical tool that facilitates this analysis. It is based in the input-output (I-O) matrix developed by Vassily Leontief⁵ in 1936, in order to analyze industrial interrelationships. For instance, the railway industry needs input from the same industry (such as railcars to transport materials), but also necessitates inputs from the steel industry (rails, steel sheets, etc.), and from the engine manufacturing industry (Diesel engines), and also from the food, transportation, chemical, metallurgical industries, etc. The final result of this matrix contains coefficients that indicate how much each industry is getting from the others. This same procedure is applied in this example to determine the total contamination generated in the fabrication of semiconductors. The method was developed by Carnegie Mellon University's Green Design Institute, USA, and has been placed on the Internet for everybody's use.

The computation starts by assigning an economic value to the project, and in this case it is assumed that the project is worth 100 million dollars. The I-O matrix defines a system of linear equations, and therefore the amount of contaminants produced when fabricating say 100,000 semiconductors per year is approximately proportional to other production 2, 4 or 10 times greater or smaller. In this case the results related to conventional air pollutants are shown in Table 5.2.

5.6.3 Analysis

Notice the high CO content (211 metric tons), followed by that of the SO₂ (89.6 metric tons). Now, is it true that fabrication of semiconductors generates a high content of SO₂? The answer is negative.

⁴ EIA is a systematic analysis of the potential impacts that a project can produce on the environment, and it tries to find a balance between gains and losses.

⁵ Prestigious Russian/American economist

Table 5.2 Contamination of conventional air pollutants produced by the project – The hidden contamination in manufacturing (Using EIOLCA methodology and table lay out – Green Design Institute)

Sector # 334413: **Semiconductors and related device manufacturing**
Economic activity: 100 Million Dollars
Displaying: **Conventional air pollutants**
Number of sectors: Top 10

Sectors	SO ₂ Mt	CO Mt	NO _x Mt	VOC Mt	Lead Mt	PM10 Mt
Total for sectors	89.6	211	64.1	52.7	0.164	19.1
221100 Power generation and supply	70.2	3.47	31.7	0.308		1.48
325180. Other basic inorganic chemical manufacturing	4.04	0.426	0.275	0.220		0.253
331411 Primary smelting and refining of copper	3.39	0.096		0.158	0.001	0.362
331311 Alumina refining	1.49		0.0367	0.337		0.140
325998 Other miscellaneous chemical products manufacturing	1.14	0.001	1.28	0.257		0.107
331111 Iron and steel mill	0.871	7.37	0.679	0.411	0.005	0.610
331312 Primary aluminum production	0.829	4.61		0.045		0.208
541300 Architectural and engineering services	0.724	1.05	0.569	0.292		0.168
211000 Oil and gas extraction	0.609	1.03	0.453	0.697		0.021
325110 Petrochemical manufacturing	0.562	0.180	0.422	1.33		0.032

Table 5.2 details how much is the participation of each one of the ten activities (shown in rows) for SO₂ gas production, and it can be seen that more than 70% of the total generation belongs to only one activity, which is ‘*Power generation and supply*’. It has low percentages when compared with other participating activities, albeit the contributions of the chemical industry are also important with 4% and the copper refining with 3.4%.

What is it suggesting? It says that in the project for the construction of semiconductors, the main environmental impact is due to electricity generation, being irrelevant if this energy is created or purchased. Consequently, efforts must be oriented in reducing this large production of contaminants.

How can it be done?

Possibly, by purchasing energy generated by renewable sources such as hydro, wind or photovoltaic. Also it could be thought that SMC could generate its own energy using the same elements that it produces; in this case SO₂ generation will decrease from 89.6% to 19.4%. Also perhaps a way to reduce SO₂ could be consumption in the plant of certain chemicals, through a reengineering in the fabrication of the semiconductors, or perhaps recycling.

Table 5.3 show the results, when it is required to know the amount of greenhouse gases and the following contaminants are considered: Carbon Dioxide (CO₂), methane (CH₄), Nitrogen dioxide (NO₂) and fluoride compounds(CFCs). All of them are expressed in equivalent metric tons of CO₂ (MTCO₂E). The GWP (MTCO₂E) is the total generated contamination expressed in the common unit.

5.7 Closing a Project

When closing a project (Chap. 17) care should be taken to restore everything to its original condition. Thus, temporary pavement must be removed, as well any other temporary construction including the sewage plant.

The site must be cleaned and all existing signs such as road signals, fences and gates, and of course garbage and debris eliminated. If trees were logged for a camp construction the site must be replanted with original species.

5.8 Conclusion of This Chapter

The importance of impacts affecting the environment has been the core of this chapter; this issue has been commented on and suggestions made for detection of impacts as well as for impact identification. An actual case study is proposed which shows the different steps that must be taken from the environmental protection point of view. Its only intention is to serve as an example for similar projects and as a guide to the nature of work to be done, environmental-wise, for other types of projects. The special case of (unfortunately) infrequent projects dedicated to preservation of the environment is also briefly analyzed.

The chapter also presents a case study where the enormous damage done to the environment can be appreciated when all intervening factors in the project life-cycle are considered.

Table 5.3 Contamination of greenhouse gases produced by the project – The hidden contamination in manufacturing (Using EIOLCA methodology and table lay out – Green Design Institute)Sector # 334413: **Semiconductors and related device manufacturing**

Economic activity: 100 Million Dollars

Displaying: **Greenhouse gases**

Number of sectors: Top 10

Sectors	GWP MTCO ₂ E	CO ₂ MTCO ₂ E	CH ₄ MTCO ₂ E	N ₂ O MTCO ₂ E	CFCs MTCO ₂ E
Total for sectors	44,600	26,700	2,500	422	14,978
221100 Power generation and supply	12,900	12,800			156
334413 Semiconductors and related device manufacturing	9,910	1,070			8,840
325120 Industrial gas manufacturing	6,520	1,870			4,650
325180 Other basic inorganic chemical manufacturing	1,990	1,990			
562000 Waste management and remediation services	1,430	227	1,200	174	
331419 Primary nonferrous metal, except copper and aluminum	1,120	70.5			1,050
484000 Truck transportation	1,100	1,080	1.68	15.1	
331111 Iron and steel mills	758	758			
481000 Air transportation	693	685	0.867	7.37	
211000 Oil and gas extraction	583	97.9	485		

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Marta Fernández-Diego

Abstract

Project risk can be defined as a deviation from the project objectives, in terms of time, cost and functionality. In order to increase the probability of project success, managing this deviation, i.e. considering risk in projects, should be the project manager's major concern. Risk indicates the probability that something can happen endangering the project outcome. Since the probability and the impact of the different threats may vary over the project lifecycle, project risk management should be a never-ending effort which implies a continuous process.

Keywords

Project • Risk Management • Probability • Impact • Safeguard

6.1 The Importance of Considering Risk in Projects

Failing to reach objectives is a major concern in project management. Risks can generate problems whose consequences are not often considered, and indeed, in many cases risk management is not even taken into account (Fernández-Diego and Munier 2010).

The benefits of risk management are considerable allowing at the beginning of the project to detect problems that could be otherwise ignored, and so effectively to help the Project Manager (PM) in delivering the project on time, under budget and with the required quality. However if risk management is not carried out along the whole project, the PM probably will not be able to take advantage of its full benefits.

6.2 The Purpose of This Chapter

The purpose of this chapter is to make the reader aware of the importance of risk management in projects. A proper risk management implies adequate risk identification, and the necessary risk measures to be taken in order to reduce it, since it is normally impossible to completely eliminate it. For example, in many technological projects, there is resistance to changes, and this is a normal risk, which if it exists but has not been correctly identified will provoke the project to fail.

The objective of the chapter is to identify and further mitigate project risks along its lifecycle. The risk management process also implies focusing on monitoring project risks and the procedures of the organization involved. The chapter is organized as follows: First, a definition of project risk is given as well as the basis for a general classification. Second, and before introducing the concept and different stages of project risk management, the different risk components are analysed, as well as the international risk standard, a matter of great concern. Finally, a case study is proposed and solved with dedicated software.

M. Fernández-Diego
Universitat Politècnica de València, Valencia, Spain
e-mail: marferdi@omp.upv.es

Fig. 6.1 What is the risk of a project?

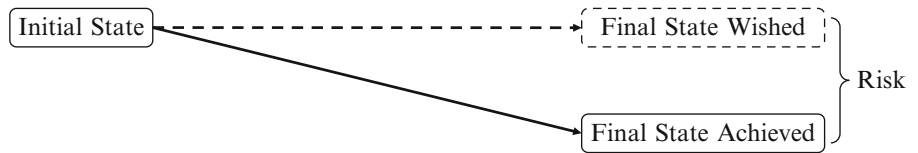
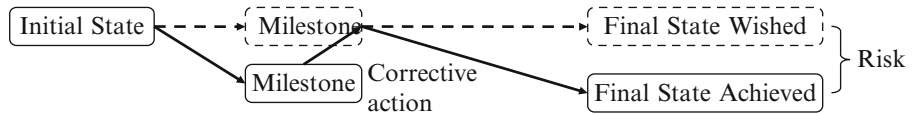


Fig. 6.2 How to reduce the risk in a project



6.3 Definition of Project Risk

Risk is the possibility of loss or damage. In general, risk can be defined as an event of uncertain nature that, if materialized, may have adverse consequences for achieving a given objective. Nonetheless, other definitions postulate that some risks can produce positive impacts. The former is identified with threats while the latter with opportunities. Indeed, risk can be threats, opportunities or both.

When planning a project, a plan is developed, and this plan entails risk, since the consequence of risk is precisely the deviation from the scheduled plan, in terms of scope, time, cost, and quality. Thus, risks are caused by those threats that may affect the project causing delays, occupational accidents, material losses, and detrimental effects to assets or any other type of damage.

In other words, the non-success of a project can be interpreted as the difference between the final state wished and the final state actually achieved, i.e. a deviation in excess from objectives, as shown in Fig. 6.1. Risk indicates then the probability that something can happen endangering the project outcome, and that may be different from the final wished state; this potential difference is the effect of risk.

A project may create a new product or improve a previous one, and its development could involve a change of state of the final product regarding the initial state. However, the *projected development* is never *what was planned*, since the actual development leads to a final state which differs from the final state wished. In short, the undertaking of any project entails risk.

Traditionally, this deviation is reduced by establishing milestones or intermediate targets in order to attain the ultimate goals, and then taking corrective actions. This idea is reflected in Fig. 6.2.

6.3.1 Risk Classification

At this stage, notice that a project is something that does not exist independently since it is related with the environment, products or services, business, etc., as shown in Fig. 6.3; thus, it is absolutely necessary to place the project into

context within the organization. In a project-oriented organization, a project is developed sharing resources with other existing undertakings, which means that it must be inserted into an organizational milieu or framework. In this sense, risks in a project can be classified as follows:

- *Organizational risks* can threaten the outcome viability. They affect the organization developing the project, often jeopardizing it and therefore the product, and may endanger its very existence.
- Regarding the project considered as a *process of change*, its risks (for instance a wrong selection of staff or an unrealistic schedule) might be differentiated from the risks of the specific goal or outcome to be achieved, i.e. the final product or service as an outcome of the project. Then, the former risks are associated with the project itself and threaten the project plan. In short, if project risks materialize, it is likely that the project will be delayed and costs will increase. Thus, these risks identify potential problems regarding budget, timing, staff organization, resources, suppliers, customers and requirements, and their impacts on a project.
- *Associated with the product* and threatening functionality, quality or performance of the result, i.e. the product. The materialization of these technical risks may imply difficulties in developing the product, and can even turn it impossible. In this sense, risk factors may arise from ambiguity in specifications or technical uncertainty such as obsolete techniques or advanced technologies. Technical risks occur when the problem is more difficult to solve than previously thought, or when the project is executed based on incomplete technical developments or knowledge.

This classification provides a hierarchical structure in which risks may propagate through the pyramid depicted in Fig. 6.3 as follows: A problem at the bottom of the pyramid, i.e. the environment or context, may adversely affect some aspect of project development, which in turn might have a negative consequence on the product or service itself. Following the propagation of risks to the top of the pyramid, these deficiencies in the product or service will adversely affect the business, since each of the products or services developed should in turn be part of the business goals. Finally the right or wrong business development will affect intangible factors, such as customer loyalty, company

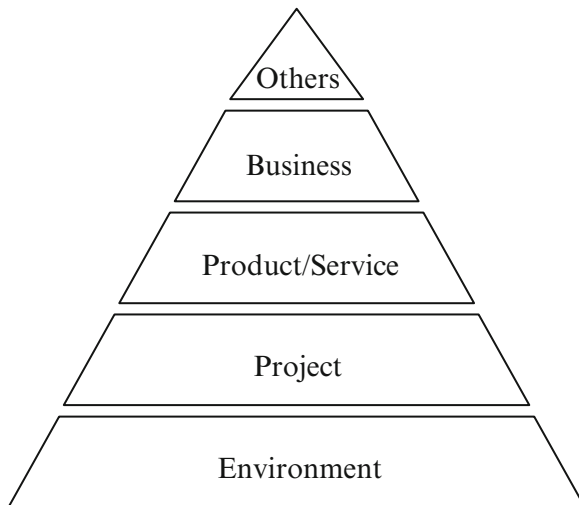


Fig. 6.3 A project within the organization

image, etc., which also represent an enterprise value and therefore should not be neglected.

6.4 Risk Components

This section analyzes the different risk components in order to be able to introduce later the concept of project risk management. There are six risk components: (1) Threats or risk factors, (2) Assets, (3) Probability of occurrence, (4) Impact, (5) Risk and (6) Safeguards.

6.4.1 Different Threats in Projects or Risk Factors

Threats are events that involve risks. For example, a snow storm can be considered a threat because it may stop railway traffic or cause havoc in a highway. Other examples are strikes, sabotage and natural disasters. There are financial threats like the non-materialization of a bank loan, economical threats, for instance the threat of imposing import taxes to protect local production, or political threats that may provoke a project suspension, or delays, etc.

Threats are usually classified by groups, such as logistic threats (failure of suppliers, difficulties in transporting equipment, power breakdown, etc.), labor accidents (falls, burns, poisoning, etc.), threats from unknown or uncertain factors (for instance, considering weather conditions or nature of terrain, etc.), inaccuracy (calculation errors, wrong evaluation regarding personal performance, etc.), uncertainty threats (inflation evolution, politics, etc.), intentional threats (sabotage, strikes, unwillingness to work, etc.).

Many threats depend strongly on the type of project. However there are several categories of threats that are more

or less common to all projects and should be considered. Table 6.1 lists various types of threats which must be taken into account during the project initiation stage. For each type of threat, the table provides actual examples.

It is interesting to see the quantitative influence of risks in projects based on a study of 24 completed high-rise construction projects (see Sect. 12.1.1).

6.4.2 Assets Under Threat

An asset is any item of economic value owned by an individual or corporation. Examples are cash, buildings, inventory, office equipment, vehicles, patents, copyrights, trademarks, and other property. Simply stated, assets represent ownership of value that could be converted into cash. In a project, assets are important elements for achieving the goals outlined and these assets may be subject to threats. Personnel skills, machinery, computer programs, commercial products, which are required to execute the project, are other examples of assets. In identifying risks, it is convenient to make an inventory of assets and proceed to analyse each in order to determine what threats exist or may arise.

Once assets and threats are established regarding a project, they constitute asset/threat pairs that can be characterized by two properties, (a) the *probability of occurrence* and (b) the *outcome*; both are features of the pair, and define the relation between them. As a matter of fact, if there is no threat affecting an asset, there is no risk at all. In a project, a threat can affect specific tasks or resources, but it can also influence the project as a whole. For example, economic crisis is not limited to specific tasks or resources but has a probability of affecting the entire project.

The prospect of a threat affecting an asset is expressed as a *percentage* measuring the *probability* of such an event taking place; the outcome is the *severity of the damage* produced by the event. For example, a road along a river has a certain flood probability, which outcome is the water flooding the road, the damage or impact being the consequence of the severity of the flooding.

6.4.3 Probability of Occurrence

The probability of occurrence may be estimated by observing how often similar events have occurred in the past. Estimates of probabilities are based on the law of large numbers.¹

¹The law of large numbers describes the result of performing the same experiment many times. According to this law, the average of the results obtained from a large number of trials should be close to the expected value, and will tend to become closer as more trials are performed (Wikipedia).

Table 6.1 Types of threats and actual examples

Threat	Examples
Commercialization	Section 4.4, details a case where the import of a product into the American market was not properly evaluated, and a <i>threat about potential enacting of a controversial regulation</i> aimed at restricting imports and affecting this product, was not even considered. The risk materialized 2 years later when import of the product was banned.
Environmental	In an amusement park at a sea shore, the <i>risk associated with alteration of the ecological aspect was not considered</i> . After years of operation the venture incurred heavy losses in trying to ameliorate the impact, and reduce the negative image fueled by environmental organizations.
Financial and economic	Half-finished buildings stand everywhere and many abandoned because the <i>risk inherent to non compliance to building regulations</i> or due to cash flow problems.
Geological	In the construction of line number 1 of the Seville (Spain) subway it was necessary to cross by a tunnel the mighty Guadalquivir River. The analysis of the soil in the bed of the river warned about the <i>risk of potential leaking of water into the tunnel during its construction</i> . Fortunately, the warning found an adequate response, and a safeguard, consisting in the construction of a concrete slab spanning the width of the river and following the outline of the tunnel, eliminated that threat.
Health	An American company was granted the construction of a large paper mill in Gabon, which had a history of endemic illness. There existed a <i>threat of workers infected</i> which was indeed important, and the company preferred to delay for a couple of weeks the departure of its personnel and instead sent them to an exhaustive medical examination and vaccination with time to see how well they reacted. As a matter of fact two workers were taken out of the initial crew because they showed a propensity to acquire some of those diseases.
Heritage	In a European city the City Hall already started the demolition of an old neighborhood to make room from the continuation of an avenue connecting downtown with the beach. However, work was interrupted by court decision promoted by owners. <i>There was a real threat that this could happen</i> , but the City Hall evaluation found no substantial risk.
Information	A company decided to build in a very old medium size city a pneumatic system for garbage collection and transportation. It was known that there would be the probability of finding old tunnels, some ruins, and forgotten underground services buried in the path of the pneumatic system. As such, a <i>threat of perhaps halting the work</i> because archaeological findings was a real possibility as well as damage in service utilities. The threat was discarded, and the result of that evaluation error meant huge expenditures in additional work, as well as considerable delays.
Information Technology	There is <i>risk when selecting a company or 'partner' when planning to install an ERP system</i> , regarding lack of experience or choosing systems that are not adequate for the firm, or that use a technology and provides features that the company does not need.
Legal	An actual example was the definite cancellation, already in advanced construction, of a huge hydroelectric project in Canada, with an economic loss of more than 1,000 million dollars already invested in construction. The halt came from an order issued by the Supreme Court which favored the demands of native people that argued that extracting water from a lake that would feed the turbines, <i>will threaten their own existence</i> , because of their reliance on trout fishing, their staple. The company knew about this threat, however, apparently its risk assessment was not properly done.
Logistics	The construction of a large hydroelectric plant in Guyana was delayed, with the corresponding costs. The delay was because of non-availability on site of the turbines fabricated in Japan. When the contract with the manufacturer was signed it did not include a clause charging him with the responsibility to have the equipment on the job site at a certain date, and nobody realized that <i>there could be a threat because of the lack of available direct transportation between Japan and South America</i>
Natural causes	Examples are the projects in the Ao Nang Beach in Thailand subject to <i>tsunami threats</i> , or construction projects in the slopes in the Santa Monica Mountains in Los Angeles, which is an earthquake prone area.
Political	In the construction of the Baku-Ceyhas oil pipe line <i>there were threatening factors associated with the diverse routes that the pipeline could follow</i> , due to internal fights between opposite factions. These threats were considered, risks evaluated, and from there the definite route was selected.
Quality	<i>The automotive industry knows very well this type of threat, leading to a resulting risk</i> . This usually happens when, as a consequence of a certain failure of a vehicle component, a manufacturer needs to recall thousands of vehicles for repairs or replacement, which is enormously expensive and also damaging to the company's prestige.
Safety	The Challenger disaster that was the loss of the USA space shuttle in 1986 and with it the death of seven people was due, according to some researchers, to a threat that was not correctly evaluated. <i>The risk of the disaster happening</i> was documented and attributed to a failure of an O-ring: the possibility of a disaster was clearly enunciated because a severe flaw had been detected and warned about.
Social	Relocation projects in many parts of the world, when families living in shantytowns are relocated to other sites and without consultation provokes a threat of a series of lawsuits by the people being moved. Normally, these people, assessed by lawyers, make it known that they do not want to be relocated, and threaten disturbance if moving takes place. Therefore, for the City Hall <i>there is a risk in this undertaking</i> whose consequences must be evaluated.
Structural	Consider the Vajont Dam and its lake in Italy, which, once finished, suffered a disaster provoked by a large rock slide. There were, even during construction, symptoms that led to a threat about consequences because of the lack of stability in one of the mountains forming the lake, <i>which strongly suggested the existence of a structural risk</i> , but that was considered, or perhaps dismissed as unimportant.

(continued)

Table 6.1 (continued)

Threat	Examples
Sustainable	Large agricultural projects have almost depleted the Ogallala aquifer in the USA. There was a <i>threat that improper water consumption will deplete the source in some decades</i> , without any possibility of refilling. However, this threat was not considered and as of today it has almost materialized.
Technical	There is a risk when companies installing large advertising boards in cities and highways do not consider the <i>real threat that they pose as a consequence of strong winds</i> , that may cause serious traffic accidents and kill people if adequate safeguards are not taken.
Updating	<i>This is the risk when a company applies a system that it did not need or using inexperienced people</i> , which brings havoc because of the confusion it produced. It is common in the updating of company internal procedures.
Working aspects	A company bought the assets of a glass manufacturing plant for the automotive industry; the company was bankrupt, and without workers, who were dismissed and duly compensated by the previous owner. However, the new owner did not pay attention to an <i>existing risk derived from workers threatening to occupy the plant if their demands for reincorporation under the new administration were not met</i> .

Adapted translation from Fernández-Diego and Munier (2010), with kind permission from Editorial Universitat Politècnica de València, España

However, care should be taken in considering historical data from similar projects, since no two projects are the same and most probably different circumstances apply. The value of this probability considers the closeness between something potential (the threat) and its real manifestation as an aggression on the asset.

In other words, a threat experienced very often, e.g. occurring several times along the project (probability of occurrence less than once a week), is not the same as a threat experienced very seldom or not expected to occur (probability of occurrence once in more than 6 years). There is another factor, and it is the length of exposure to the threat. Depending on the project duration, the same asset may be exposed a few or many times to a specific threat. Thus, it is clear that the longer the time of exposure the greater the probability of a threat materializing. Threat probability of occurrence can be broken into four different categories: frequent, likely, occasional and unlikely.

6.4.4 Outcomes and Impacts

An outcome is the immediate consequence of a threat on an asset, therefore it centers on what happens to it. In projects there are different possible outcomes from threats, such as scheduled, cost related, associated with safety, as well as others. For example, a change order can cause a delay of 6 days, or a notice of change from a supplier regarding delivery dates could mean either a negative outcome, if there is a delay, or a positive outcome, if the delivery speeds up. Regarding costs, a change of a supplier may cause either a cost increase, if the new supplier is more expensive, or a cost decrease, if switching to a *cheaper supplier*. In short, in these examples, the

outcomes define how much the duration of a task or the cost of a resource will be increased or reduced if the risk affects respectively the duration or the cost. A non-scheduled or non-cost related threat, as for example a legal outcome, does not usually directly influence the project schedule. The same applies to outcomes affecting safety or quality, even though they *can be translated into time or monetary units*.

The impact, on the other hand, is a broader concept than outcome, and describes the effect of a threat on the overall project. The impact is the consequence of a threat on the project degrading or changing its characteristics in terms of delays, cost overruns, etc. For instance, there is a probability of a *3 days delay* from a supplier, which causes an outcome that is the *delay in a non-critical activity with a 2-day float*. The impact is that the *whole project has a 1 day delay* because the float of the non-critical activity cannot absorb the impact and becomes critical. As another example, you can have the probability of an earthquake, say very often. You can appraise the outcome, that is destruction of buildings, and establish the impact, i.e. the severity of destruction. If it takes place in the desert, there is an outcome since the earth shakes, but the impact is null because does not affect any valuable asset. Moreover, the duration of the aggression may cause different impacts. A 1-min earthquake does not have the same impact as another that last for 3 min.

In other words, the impact is the difference in the estimates of the state of a project obtained before and after the aggression or the threat realization. Each impact must be evaluated through an impact measure. The potential impact on the project includes the following categories: catastrophic, critical, moderate and negligible. In the case of a road beside a river, if the threat of flooding materializes, its effects on the road can be ranged from a negligible damage to its total destruction.

Fig. 6.4 Risk assessment matrix

RISK Matrix		PROBABILITY OF OCCURRENCE			
		Unlikely	Occasional	Likely	Frequent
IMPACT	Catastrophic	High	Extreme	Extreme	Extreme
	Critical	Medium	High	High	Extreme
	Moderate	Low	Low	Medium	Medium
	Negligible	Low	Low	Low	Low

6.4.5 Measuring the Risk

Risk can be measured in terms of severity of impact and the probability that an incident occurs. A mathematical way of expressing risk leads to:

$$\text{Risk} = \text{Probability of occurrence} \times \text{Impact.} \quad (6.1)$$

With the certainty of the materialization of the threat, the risk would be equal to the impact; if the probability of the threat materialization is zero, there is no risk at all. However, risk is a combination of both impact and probability. In statistics, risk is often modeled as the expected value of some impact. This combines into a single value the probabilities of various possible threats and some assessment of the corresponding outcomes. Consequently, when many assets are considered each pair asset/threat contributes partially to this expected value or risk.

Project risk has been defined as a deviation from the project objectives. These objectives are to deliver the project on **time**, under **budget** and with the required **functionality**. Let us examine each one of the three boldface issues:

- Regarding its delivery date, imagine a project composed of three tasks which must run sequentially. The tasks are threatened to be delayed 2 days each with a probability of 50%; that is the appearance of the threat is equal to its non-appearance. Since these three activities are in the critical path, any delay will be translated to the whole project. In this case, the expected delay can be expressed as:

$$\text{Expected delay} = 0.5 \times 2 + 0.5 \times 2 + 0.5 \times 2 = 3 \text{ days.} \quad (6.2)$$

- Regarding the agreed budget, suppose that two different resources will not be available in time due to delivery problems. If the probability of this event occurring is 0.25, and the consequence is the change of supplier which implies a cost increase of 30,000€ for the software equipment and 15,000€ for the hardware equipment, the expected cost overrun can be expressed as follows:

$$\begin{aligned} \text{Expected cost overrun} &= 0.25 \times 30,000 + 0.25 \\ &\times 15,000 = 11,250\text{€}. \quad (6.3) \end{aligned}$$

- Regarding the required functionality, imagine the case of a software project with an estimated functional size² of 40 function points. Function points (FP) are a unit of measure used to express the amount of business functionality that a software provides to its users. If the threat produces a certain degree of damage, such as 50% (i.e. a loss of half its functionality), and if it might occur with a 75% probability, then the expected functionality can be expressed as:

$$\text{Expected functionality} = 0.75 \times 0.5 \times 40 = 15 \text{ FP.} \quad (6.4)$$

In this case, the initial value or reference is not zero, as in the expected delay and cost overrun. The reference for functionality is the estimated functional size of 40 FP; thus, the expected functionality is a measure of the amount of risk assumed in terms of functionality. If the expected functionality equals '0', there is no risk at all, while if the expected functionality equals the estimated functional size, all of the function points are compromised.

In addition, risk can be estimated in a qualitative manner using a risk assessment matrix, as illustrated in Fig. 6.4.

Some Information and Communications Technology risk analysis and management methods, such as the British CRAMM (2003) or the Spanish MAGERIT (2005), recognized by NATO and the European Network and Information Security Agency (ENISA 2005), use the consequence/

² A Functional Size Unit (FSU) is a standard unit of software size for measuring the functionality of software. Numerous software sizing methods have been proposed in the past, such as the number of source lines of program code and various measures derived from the technical characteristics of the software. However, these methods have limitations being superseded by the concept of Functional Size, which focuses the measure of size in terms of the functions required by the user. In short, an FSU is to software acquisition and development what a square foot is to the building construction industry.

Table 6.2 Risk effects on the project

Risk	Description
Extremely high	Complete failure on accomplishing the project
High	Not all parts of the project will be accomplished or will be accomplished as planned
Medium	Reduced impact on project accomplishment
Low	Little or no impact on project accomplishment

probability matrix technique to rank risks, sources of risk or risk treatments on the basis of the level of risk. The risk assessment – ranging from extremely high to low – can be found where the values for probability of occurrence and impact intersect. Risk effects on the project are described in Table 6.2.

The matrix covers all possible situations. For instance, in a project for the construction of a dam, there is an unlikely probability of occurrence of a tremor – according to statistics in 100 years – when it is considered that the dam will be located in a non-seismic area, or conversely, a very high probability of occurrence, assuming the opposite. However, if indeed there is a tremor, the dam can suffer different kinds of damage. These damages or degradations may be catastrophic if the tremor breaks the dam and then kills thousands of persons living in villages as well as destroying cities located downstream the dam; it can be also catastrophic by wiping out hundreds of hectares of crops and fruit trees. But it could also be the case that the impact is not so serious if the dam is located in an area scarcely populated.

As shown in Fig. 6.4, the Risk Assessment Matrix is an asymmetric matrix in which the impact prevails over the probability of occurrence. Therefore, if there is a *frequent* probability but producing a *negligible* impact, the risk is *low*, and possibly acceptable, while, if the occurrence is *unlikely*, but with a *critical* impact, the risk is *medium*. For instance, the probability that your computer stops responding or hangs is fairly frequent, say once a week, however, after a major system problem, when the computer fails to respond you have to restart the computer, which is a quite easy and a fast solution. In this case, even if the probability of the threat occurring is frequent, since the impact is negligible, the resultant risk is low, which means no need to waste money in safeguards. However, if something threatens the life of a person, a worker for example, even if the probability of the threat occurring is unlikely, since the impact is catastrophic, the ensuing risk is high. Therefore, all possible measures need to be applied in order to avoid this unacceptable consequence.

6.4.6 Safeguards

Safeguards are actions taken against threats; the goal is to reduce the probability of a threat turning into an aggression,

and to limit the consequences of the aggression if it eventually occurs. This can be achieved by using controls to reduce either the probability of the event occurring or the severity of the impact. In this sense, safeguards are classified according to their mode of action: those acting on the probability of occurrence (i.e. before the attack) reducing its probability, and those acting when the impact has already occurred (i.e. after the aggression), and ameliorating the damage by reducing the severity.

The first kind of safeguards are *preventive safeguards*. The second kind comprises *healing safeguards*. Examples of preventive safeguards are, amongst others, awareness, information and staff training, deterrence, the use of personnel protective equipment or preventative detection. They are effective tools since threats occur with a lower frequency. Examples of healing safeguards are correction, recovery, the use of a different piece of equipment or healing detection. When some of these measures are taken, threats usually do not cause important problems.

To calculate the actual risk of a project, it is necessary to analyse the safeguards considered and implemented. A *threat* and its corresponding *safeguard* constitute a pair, in such a way that the threat is not as threatening as potentially expected because of the safeguard. The pair threat/safeguard can be characterized by a decrease of the occurrence, impact or both factors, depending on the type of safeguard. Then, the actual risk can be expressed as:

$$\text{Risk} = \text{Probability}(1 - \Delta \text{Probability}) \times \text{Impact}(1 - \Delta \text{Impact}) \quad (6.5)$$

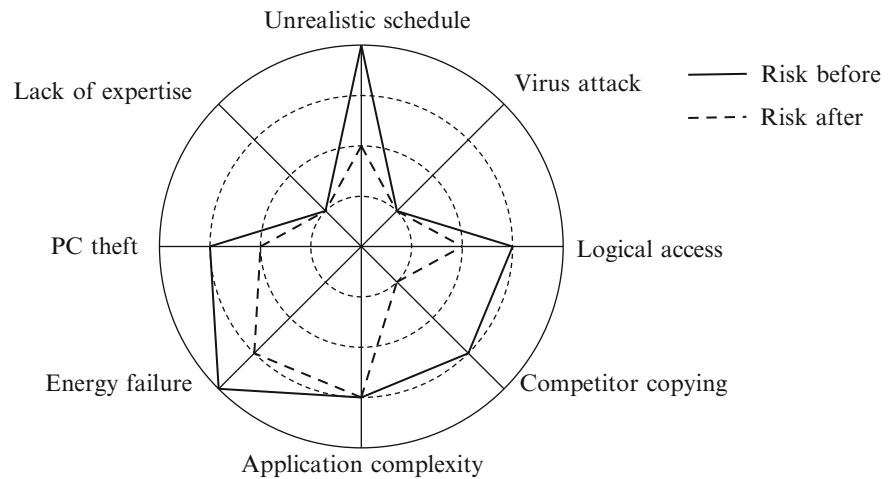
Where ' Δ Probability' corresponds to a decrease of the occurrence as a consequence of the actual preventive safeguard measures, while ' Δ Impact' relates to a decrease in the impact because of the actual healing safeguard measures.

Returning to the previous example in which two different resources could not be available in time due to delivery problems (Sect. 6.4.5), if the probability of this event occurring is 25%, and if the consequence translates into the necessity of changing a supplier which implies a cost increase of 30,000€ for the software equipment and 15,000€ for the hardware equipment, then the expected cost overrun already expressed in Eq. 6.3 is replicated here:

$$\text{Expected cost overrun} = 0.25 \times 30,000 + 0.25 \times 15,000 = 11,250\text{€}. \quad (6.6)$$

However, suppose that the PM has been looking for an alternative and finally a new supplier has been retained for the software equipment only. In this case, since Δ Probability = 100% for the software equipment, the actual expected cost

Fig. 6.5 Risk before and after a battery of safeguards



overrun considering this preventive safeguard can be expressed as:

$$\text{Expected cost overrun} = 0 \times 30,000 + 0.25 \times 15,000 = 3,750\text{€}. \quad (6.7)$$

Moreover, in this case assume that the former supplier fails to deliver on time and the PM plans to reuse old hardware, which does not imply a cost increase of 15,000€ but 5,000 €. In that case, the impact decrease equals:

$$\Delta\text{Impact} = \left(1 - \frac{5,000}{15,000}\right) \times 100 = 66\%. \quad (6.8)$$

Considering this healing safeguard, the actual expected cost overrun can be expressed as:

$$\text{Expected cost overrun} = 0.25 \times 15,000 = 1,250\text{€}. \quad (6.9)$$

If the *level of risk* is not accepted a usual policy in risk management is to apply measures to reduce it, and, if the most important component is *probability of occurrence*, these measures aim at decreasing risk by using preventive safeguards. If instead the most important component of risk is *impact*, these measures seek to reduce it by healing safeguards. In the worst case of high risk levels due to both, high probability and impact, implementation of joint actions is the only way to address the issue.

The effect of adding safeguards can be simulated in order to compare the risk before and after said addition, and its effectiveness is better appraised graphically, by comparing the performance of a battery of measures on the whole project and observing the changes in risk (see Fig. 6.5).

6.5 Project Risk Management

“Nobody likes to think about what may go wrong on a project, but to overlook risk management means that you chance an unnecessary project failure” (Project Smart 2011). Ideally, risk management should be considered well in advance of the project, when it still is in the initiation stage. The purpose of project risk management is to reduce risk, that is to increase the probability of project success.

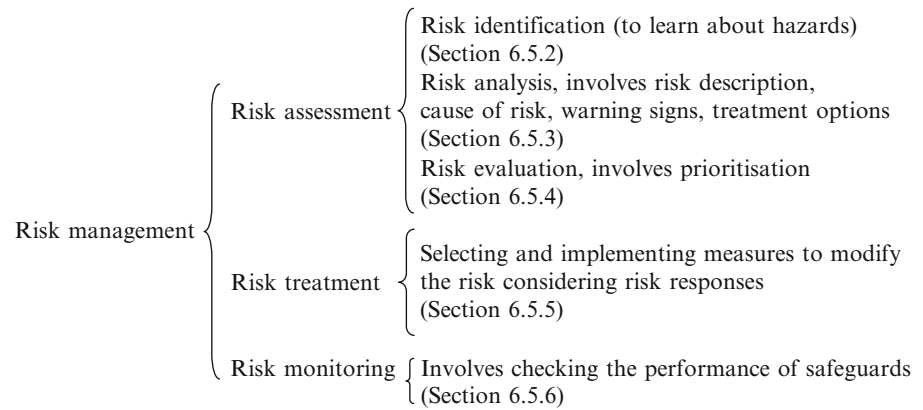
In this sense, risk management is a process that manages the resources available in the project to limit the difference between the wished for and achieved final states. If the difference exceeds the prescribed threshold, the risk of non-fulfilling the project objectives is present, and in order to ensure the adequacy of the result, decisions to undertake further actions to reduce that difference are often required. If achieving the final state, noticeably deviates from the final state wished, the project will miss the goal, and even its achievement may be impossible or in doubt.

Ultimately, the success of a project depends largely on the risk management process, and this should be the project manager’s main concern. If not performed adequately it can lead to serious consequences. Moreover, as the probability and the impact of the different threats on the assets may vary over the project lifecycle, a good risk management practice requires a continuous adjustment, since:

- New risk factors may appear,
- Some previously identified may disappear,
- The importance or the severity may change,
- The probability of occurrence may change,
- The tolerable risk level may also change.

In addition, the PM has to consider and study what threats the enterprise is likely to encounter during the project lifecycle, since they may affect the project itself. Disregarding enterprise risk management is a very common mistake in

Fig. 6.6 Risk management overview



project management. Furthermore the PM has to be congruent with enterprise environmental factors such as probability and impact scales, predisposition or particular attitude to risk-taking, and risk management software to be used.

Finally, risk management is an ongoing process which involves three significant phases: risk assessment, risk treatment and risk monitoring and review (see Fig. 6.6).

6.5.1 Risk Assessment

Risk assessment is fundamental and prior to risk treatment. Most of the time risk assessment leads to the necessity of performing tasks that were not foreseen and consider costs that were not budgeted. If the risk is very high it could even influence the decision whether to carry the project out. The risk assessment process consists of three main phases: risk identification, risk analysis and risk evaluation.

6.5.2 Risk Identification

It is very important to identify risks before they become problems; in reality, the identification of risks existing in the project is the first step in project risk management, since only the identified risks can be managed later, and this is performed by going through the risk identification process. However, consider the fact that if a large number of threats materialize in the last steps of a project it may cause its failure, since near completion the response capacity is fairly reduced; in this sense the risk control process needs to be implemented all along the project.

It is necessary to identify risks associated with all tasks and resources. For this reason, one must examine from the beginning what can go wrong and why, and how this situation could be reached. However, the risk identification process requires an open mind to foresee all possible scenarios since not all the risks in a project are obvious. Unlike other

activities that are well documented, the PM must detect causes of risk that might never have occurred, i.e. by looking for unknown risks that could happen.

In short, it is very important at the beginning of any project to go through the risk identification process, but not only once; risk management is not a one-time process, but a continuous effort and as seen before, risks evolve over time and thus need to be updated. There are several identification techniques that are suitable to treat the issue according to (a) the complexity of the project, (b) the previous experience in similar projects, and (c) the organizational maturity in terms of risk management. These techniques comprise brainstorming, surveys, panels, SWOT (see Sect. 4.4.2) or Delphi³ techniques. Notice that by combining different identification techniques, the probability of missing one risk is strongly reduced.

To facilitate risk identification, the PM can work with a template or a Breakdown Risk Structure (BRS) (similar to Work Breakdown Structure (WBS), see Sect. 9.4.5), which should contain all potential risks. An example of BRS for photovoltaic solar power projects can be found in Aragonés-Beltrán et al. (2010). Checklists of threats specific to tasks being performed are helpful for quickly identifying the bulk of the project threats. However, the BRS is highly dependent on the project type and characteristics; in this sense, it should be customized based on previous projects and specific risks, since each project has its own associated risks.

³ “The Delphi method was developed after WWII by Olaf Helmer and Norman Dalkey of the RAND Corporation. It is essentially an iterative communication system that works with groups of experts, spatially located, in order to get their independent input about certain issues and responding to a coordinator. A questionnaire is prepared about some specific subject and then sent by mail or email to this panel of experts whose members are not known to each other. The experts are allotted some time to answer the questions posed, make their evaluations and comments and send them back to the coordinator. Once the responses of one round are received they are analyzed, aggregated, and then returned to the experts. The experts work with this information and refine their estimates” (Munier 2004).

6.5.3 Risk Analysis

The identification process should already have allowed collecting all this information at a very rudimentary level, which is developed in detail during the risk analysis process, as follows:

- Risk description: A short description of the threat permits a better identification of a potential problem,
- Principal cause of the risk: Knowledge of the threat implies to be aware of its causes or principal cause,
- Warning signs of the risk: These are the symptoms. It is important to be able to recognize the warning signs in order to treat the imminent problem as quickly as possible. By recognizing them in time and taking action, the PM may be able to prevent the event or reduce its impact. For example, stress at work is a risk factor, and seeing only negative aspects or isolating oneself from others are warning signs or symptoms,
- Risk treatment options: Also called safeguards (see Sect. 6.4.6). These are perhaps the obvious options to treat the risk. Later these options will be refined and extended,
- Risk responsible: The team as a whole is responsible for the project risks; however, not all risk management must be assigned to the PM; he/she is not always the most able person to manage it. Thus, assigning a responsibility for each risk is a part of the risk management process,
- Probability of the risk occurring (see Sect. 6.4.3),
- Range of outcomes of the risk (see Sect. 6.4.4),
- Estimated risk timing: Sometimes warning signs may indicate that the risk is imminent. This parameter is highly important to decrease or mitigate the damage immediately,
- Number of times the risk will occur: Remember that a long term exposure implies increasing the probability of the risk occurring.

An example of the information gathered during risk analysis concerning computer virus is shown in Table 6.3.

The perception of risk varies from person-to-person; it is the judgment that people make about the characteristics and severity of a risk, and where subjectivity must be avoided as much as possible. The Delphi technique could reduce the subjectivity of expert evaluation by trying to reach a consensus regarding a certain matter. In short, risk analysis allows the Project Manager (PM) to work on the most critical risks; then risks must be prioritized in order to focus efforts.

6.5.4 Risk Evaluation

Identified risks are listed according to their importance, and there are many criteria that can be used to prioritize risks. However, a criterion which is often used considers the

Table 6.3 Risk analysis for computer virus

Risk	Example
Description	Computer virus
Principal cause	Indiscriminate use of Internet, for example users need to be wary of opening unexpected email
Warning signs	Windows spontaneously restarts unexpectedly, the computer runs very slowly, a partition disappears, antivirus software indicates that a computer virus is present
Treatment options	Antivirus and anti-spyware software, operating system reinstallation
Responsible	Chief Information Officer
Probability of occurrence ^a	Low
Outcomes ^a	Display of text messages, images, audio or video, files corrupted, programs unavailable
Estimated timing ^a	During periods of intensive use of Internet
Number of occurrences ^a	Once during the project lifecycle

^aDepending on the type of computer virus

probability of the risk occurrence and the impact it would cause, therefore the PM can concentrate on the most important ones. Once again the criteria, whatever, should be used consistently. When the risk analysis process has been completed, it is necessary to compare the estimated risks against the risk threshold established by the organization. This comparison determines whether each specific risk should be accepted or treated.

6.5.5 Risk Treatment

The PM must plan how to mitigate each identified risk as well as to establish priorities, and how to respond if they take place; risk decisions should be made at the appropriate level, and for those risks that are above the risk threshold, a risk response plan should be developed. There are four risk response options:

- *Avoid the risk*: The strategy to avoid the risk consists in seeking an alternative path in the project so that this risk is no longer present. For instance, by changing the product design or the development process;
- *Transfer the risk*: Risk transfer is about shifting the responsibility or burden for disaster loss to another party. This can be done through different means such as legislation, contract, insurance;
- *Mitigate the risk*: The mitigation option can prevent the threat occurring by influencing the causes before (preventive) or by reducing (healing) the negative effects, once occurred. As an example of a preventive safeguard, an effective measure to prevent the team from deserting is an adequate compensation for the skills, knowledge and

experience each employee brings to the project. An example of a healing safeguard is developing a contingency plan for specific situations in such a way that the PM might be prepared to address the issue;

- *Accept the risk:* Accepting risks is the fourth option, i.e. accepting the consequences if the risk takes place. Sometimes, risks just need to be accepted, simply because the other three response strategies are non-feasible or non-favorable in terms of cost-benefit analysis or because the risk severity is low enough.

In order to avoid contradictions in the implementation of risk responses, a cost-benefit analysis should compare the costs of the safeguards related to the threat and their benefit in reducing the cost of risk. In other words, if implementing control is more expensive than the loss of value, there is no gain in doing it, and then it should be reasonable to accept the risk; pay more to save less makes no sense. Neglecting cost-benefit analysis is a costly error in risk management. Finally, risk treatment involves developing actions to address individual risks, but also prioritizing risk response actions, and creating an integrated risk management plan.

6.5.6 Risk Monitoring and Controlling

Just by planning how to deal with risk is not enough. Naturally, doing a real effort during the risk planning stage will increase the probability of project success, but since risks evolve during the project lifecycle, it is necessary to exert monitoring and control including forecasting risks when the project is underway. However, if these actions are not performed seriously, the project might still fail.

Monitoring is related with risk safeguards performance and analysis, while control is in charge of adopting new measures taking into account information from monitoring. These new measures may consist in creating new safeguards, deleting existing ones or modifying others. In addition, all team members should assist in the identification process, as well as treating and monitoring the risks. Thus, as said, communication is key to effective risk management; without constructive communication, no risk management approach can be viable.

6.6 International Risk Standard

Project risk management is a particular component of project management in such a way that a successful project risk management implies a successful project completion. As Charette (1996) says “*Large-scale project management is risk management*”. Thus, there are different standards of project risk management, mostly framed in the broader

field of project management (Rodríguez-Suárez 2010). Since 2009 the Project Management Institute (PMI) has a new standard specifically developed for project risk management (Project Management Institute 2009).

Although the PMBOK Guide (Project Management Institute 2008) is a de facto standard, i.e. published by a prestigious international organization but not a normalized official one, an international standard on risk management has been published recently by ISO (International Organization for Standardization). The convergence of the concept of risk as well as risk analysis and management in sectors such as finance, health, technical or labor, leads to a general model of risk management. Indeed, ISO 31000 (International Organization for Standardization 2009a) international standard provides principles and generic guidelines on risk management and is supported by ISO/IEC 31010 (International Organization for Standardization 2009b) which provides guidance on selection and application of systematic techniques for risk assessment.

6.7 CASE STUDY: Software Development Project

The following case is based on the schedule for a software development project; it aims at showing the importance of considering risk in projects. For this purpose, a leading tool for quantitative project risk analysis is used: *Risky Project* (Risky Project 2011).

The project consists of developing a Web application for a small service business to manage all its communications. The case focuses only on the first stage, that is requirements analysis,⁴ which is common to all software development processes. Therefore, those tasks involved in determining the needs of users for a new or modified product are depicted in Fig. 6.7. The current requirements analysis stage is composed of four tasks.

When no risks are taken into account, the PM should traditionally focus on the critical path, since the critical path involves activities that are critical to complete the project on time. Notice that three of them belong to the critical path, while task 3 named ‘*Conduct interviews*’ with a duration of 5 days, possesses a float of $40 - 5 = 35$ days. This data comes from considering that it starts at the same time of task ‘*Study similar system*’ which has a duration of 40 days, and must be finished at the latest at the same time.

⁴ Requirements analysis is the process of determining user expectations or needs for a new or altered (modified) product, and translating them into quantifiable and detailed features, also called requirements or functional specifications. The aim is to ensure that the final product conforms to client needs.

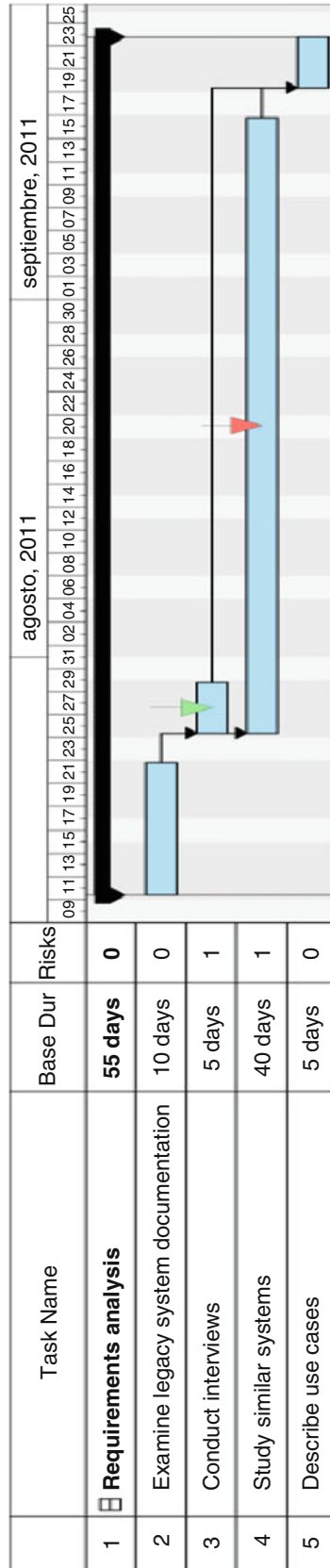


Fig. 6.7 Gantt chart illustrating requirements analysis stage – Software development project (Risky Project screen shots reproduced with kind permission of Intaver Institute Inc.)

	Risk Name	Threat/Opp	Risk Assigned To	Probability	Impact	Score	Score
1	Couldn't find appropriate documentation	Threat	Task 4: Study similar systems	50,0%	63,6%	31,8%	
2	Client will be busy and will not be able to participate	Threat	Task 3: Conduct interviews	50,0%	0,0%	0,0%	

Fig. 6.8 Risks in risk register sorted by score – Software development project (Risky Project screen shots reproduced with kind permission of Intaver Institute Inc.)

	Name	Type	Risk Assigned To	Sensitivity Chart	Ranking
1	Risk: Couldn't find appropriate documentation	Risk	Task 4: Study similar systems		0,949
2	Risk: Client will be busy and will not be able to participate	Risk	Task 3: Conduct interviews		0,256

Fig. 6.9 Sensitivity chart or how risks affect project duration – Software development project (Risky Project screen shots reproduced with kind permission of Intaver Institute Inc.)

This fact means that task 3 could be delayed as many days as its float, without affecting the duration of the entire project. It is then a non-critical task which should not be so closely followed compared to those on the critical path.

Requirements analysis involves frequent communication with the client and managing documentation to determine specific feature expectations. Suppose now that two threats are identified for this project, one associated with a critical task (task 4) and one to a non-critical task (task 3), as indicated in Fig. 6.7 by '1s' in the last column, and on the Gantt chart by arrows. There is a threat '1' associated with non-critical task 'Conduct interviews' because it requires the presence of the client in meetings – who is normally busy to participate in scheduled meetings – and because his inputs are badly needed to know what he wishes. A critical task such as 'Study similar systems' is associated with the threat '2' of not finding appropriate related documentation because, amongst others, planning of the project depends on experience gathered from other similar projects. The analyst assumes a probability of occurrence of 50% in both cases and considers a delay of 30 days for the outcome.

After introducing a project schedule and once the identified threats are associated to their respective tasks, *Risky Project* is able to compute the score of the different risks by multiplying probability and impact.

Since the float of task 3 is greater than the possible delay caused by the threat, Fig. 6.8 shows no impact for the whole project (impact 0%). In other words, when the duration of task 3 is increased to 30 days, the float drops by a corresponding amount, resulting in a 5 days float. However, any delay of an activity on the critical path directly impacts the planned project completion date, as shown in Fig. 6.8. *Risky Project* calculates the impact taking into account the correlation between the increase in task duration and the increase in project duration, and referred to the original

duration of the project. The risk of delay for the whole project due to the same 30 days delay on a critical task, and considering a 50% probability, amounts to $0.50 \times 0.636 \times 100 = 31.8\%$. This score depends on the original length of the project since the larger the undertaking the lesser the influence of a delay.

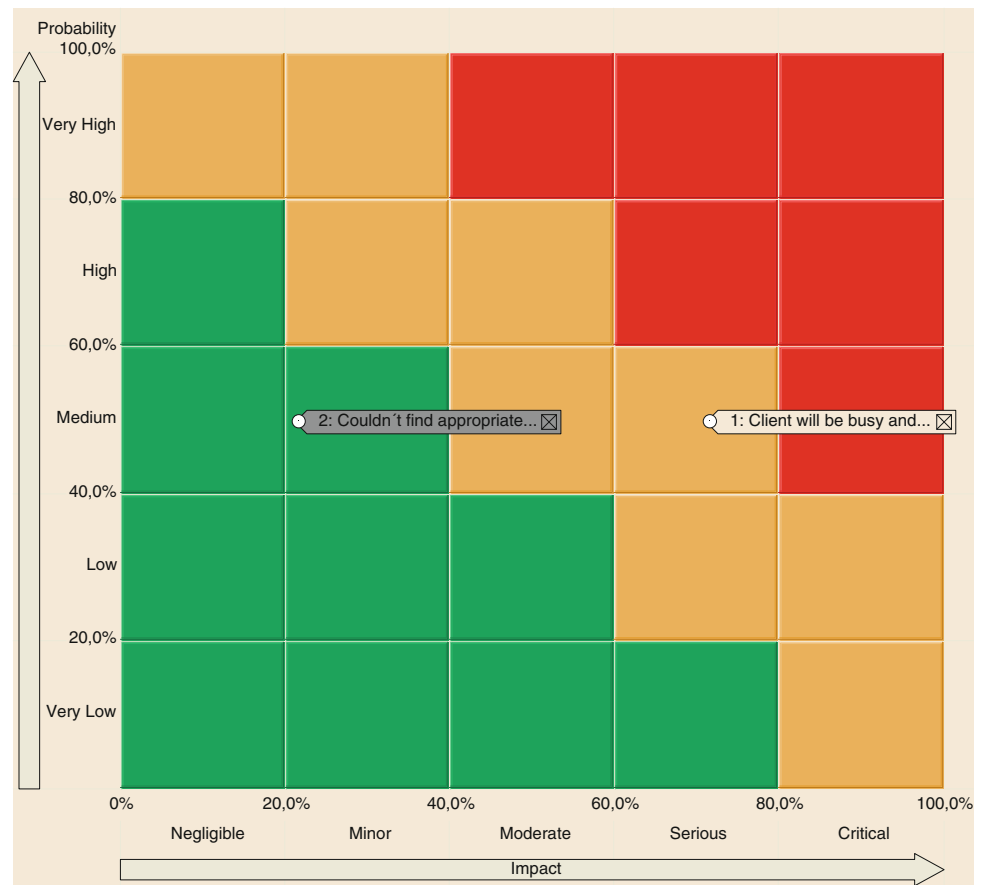
Now, coming back to non-critical task 3, if the delay associated with the threat exceeds the float of the task, it becomes critical, and consequently affecting the project duration. Figure 6.9 shows a sensitivity chart, i.e. how the two considered risks affect project duration, when the delay associated with the threat assigned to task 3 is set now to 40 days.

The sensitivity chart shows, by using the Spearman's rank correlation coefficient, which risks have the most damaging potential to affect the project duration. Since the threat assigned to task 4 is shown at the top of the sensitivity chart, this indicates that the project duration is very sensitive to the uncertainties caused by this threat.

Assume now that the non-critical task 3 has an 80 days delay, with the same probability of occurrence of 50%, and that the critical task 4 keeps the same probability of occurrence and the same delay. A similar analysis to Fig. 6.8 yields an impact of 71.7% for task 3 and of 21.9% for task 4. Then, another format of the risk matrix is shown in Fig. 6.10, where it is possible to visualize the two dimensions, *probabilities* in ordinates and *impacts* in abscises, in order to display the score of both risks. In there, the number 1 label represents the risk associated with the non-critical task 3, while number 2 label indicates the risk linked to the critical task 4. Evidently, the impact of the threat associated to task 3 is now more significant than the corresponding threat associated to task 4.

Notice that, when the delay of the non-critical task 3 exceeds the float of the task plus the delay assigned to the critical task, i.e. $35 + 30 = 65$ days, the impact associated

Fig. 6.10 Risk matrix – Software development project (Risky Project screen shots reproduced with kind permission of Intaver Institute Inc.)



with each task is reversed as shown in the risk matrix; in fact the non-critical task has become more crucial than the one so judged since the beginning. In short, when considering risk, other activities, not on the critical path, may also be very important and require extra diligence and focus.

Finally, to address that situation we use for example a safeguard consisting in an effort in order to raise awareness and support from client, which implies to add and execute a new task. This additional task can help in decreasing the probability of the threat associated with task 3, say from 50% to 25%, and the delay from 80 to 60 days. It is necessary to mention that in order to perform this analysis a baseline of the existing project schedule needs to be saved.

The matrix of Fig. 6.11 shows the risk associated to task 3 before the mitigation effort (2) and once the additional task has been added (1); and then the risk of non-critical task 3 drops from 35.9% to 7.4%.

This case study emphasizes the importance of considering risk in projects derived from possible delays. For this reason the discussion turns around the critical path; however *Risky Project* allows a more complete understanding of managing risk in projects. Risks affecting not only project duration but also technology, cost, environment, etc. may be taken into account, and for non-scheduled risks such as

quality or safety, a project schedule is not necessarily needed to perform any analysis.

6.8 Conclusion of This Chapter

In these turbulent times of major changes, project objectives can not always be well defined and, more and more, must begin to be developed with interim targets in a horizon of uncertainty, just with a referential and provisional planning, which is less worthy than in the previous case. This effort moves then to a more careful monitoring and controlling stage (Frame 2002), hoping and confirmed in general, to be able to react in time to problems and as well as to outline clearer and more accessible goals with the help of reasonable tweaks in the current planning.

Regarding a risk approach, it can be stated that managing a project consists essentially of:

- Planning the work; notice that the planning of a complex project is achieved by dividing it in simpler sub-projects;
- Working the plan or tracking it properly in order to reduce the deviations.

In short, risk management equates with project management. However, risk management is still one of the most

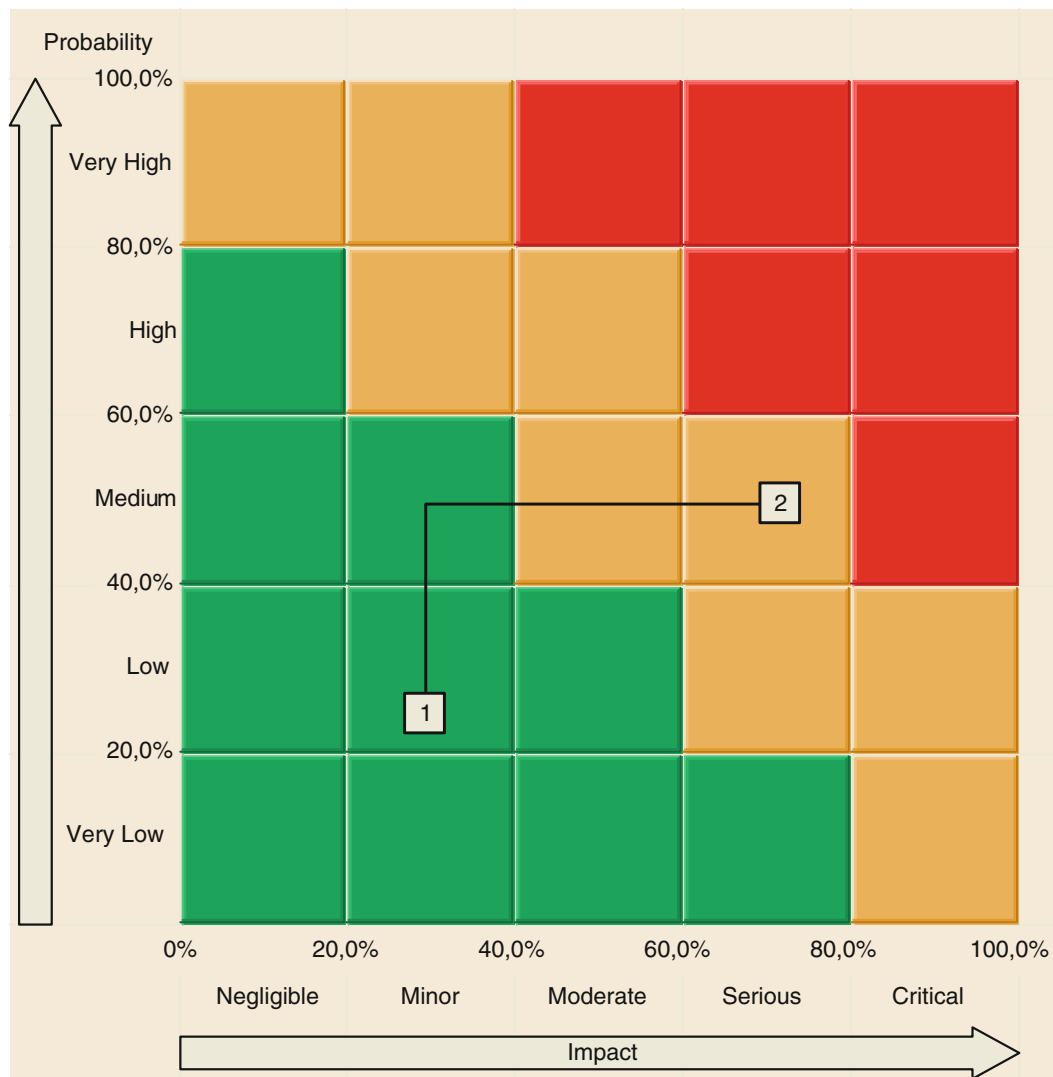


Fig. 6.11 Waterfall diagram or analysis of mitigation efforts – Software development project (Risky Project screen shots reproduced with kind permission of Intaver Institute Inc.)

immature project management knowledge areas. In fact, beyond project risk management, a higher level of organizational maturity in terms of risk management would be the integrated risk management of the portfolio, and even beyond, driving projects by their risks (Fernández-Diego and Marcelo-Cocho 2008).

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Abstract

This chapter starts with the capital investment cycle and its elements, analyzes the effect of financing a project by means of loans from banks as well as from other sources, reinvestments, interest income during construction, amortization, own capital, inflation, etc. It examines the different financial statements for the project, and as a final product gives the projected result of the operation during an operation horizon. It also comments about the necessity and possibility of performing sensitivity analyses to estimate how certain parameters, such as sales, operating costs, working capital, etc., may affect in the future the expected goals established by promoters. Special key indicators such as Internal Rate of Return, Payback period, Debt cover, Cash flow per action etc., are considered in this analysis.

Keywords

Own capital • Amount of loans • Balance sheet • Project cash flow • Loans schedules • Indicators • Sensitivity analysis

7.1 The Investment Cycle

Determining the economic and financial feasibility of a project is a fundamental step since from its results a decision can be made about pursuing the project or abandoning it. However, this chapter is not intended to be a condensed financial manual – it would be impossible – and certainly not included in this book scope. It aims to provide just a necessary review because usually engineers are consulted about some aspects of a project that are significant to the economic and financial feasibility analysis, and then it is important for them to have an idea of how the feasibility of a project is estimated.

In addition, many times engineers are requested to analyze the projected financial statements, which is a set of related documents prepared by the accounting and finance departments which predict the economical and financial performance of the project during construction and for a certain time horizon in the production or operation stage.

A ‘*Project analysis statement*’ is usually included in these documents, which condenses the results of the full operation regarding profitability (for instance computing for each year the Net Present Value and the Internal Rate of Return), and different financial ratios such as debt coverage, interest coverage, earnings per share, etc.

Additionally, the project manager is often asked by the accounting and finance people to provide information about costs, expenses, conditions of agreements reached with vendors and contractors, payment clauses, reinvestments, etc., that feed the financial process, and therefore it is important for him/her to have an understanding of the reasons for these requests. Funds assigned to the execution of a project follow a path that conforms to a cycle, since money is allocated and used, facilities built, operations started, and income, from the product or service generated by the built project, returning to the firm, presumably with a profit, although in social investments there is not a monetary gain but a social benefit rendered. This is called ‘*The investment cycle*’.

It commences with the origin or sources of the funds that will be applied to the project. This capital usually comes from different sources, such as:

- Company's own capital or equity capital,
- Bank loans, which can be short or long term, according to duration,
- Tax deferral, that is, the payment of taxes such as import taxes for certain equipment is sometimes deferred or postponed by taxation authorities until the plant enters in operation and generates revenues,
- Loans from suppliers, usually for heavy equipment.

7.1.1 Financing the Project Through Bank Loans

There are different types of loans and lines of credits, however this chapter refers to two common kinds of loans: Long and short term.

Long term loans: Their duration is usually measured in years, and have the following characteristics and definitions:

Loan application: It refers to the purpose of the loan, such as construction of buildings and structures, acquiring real estate, purchasing equipment, etc.

Interest: It is the amount, expressed as a percentage, charged by a credit institution for the use of the funds loaned. It may be constant or tied to periodic revision in agreement with some widely recognized parameters, such as the London Inter Bank Offered Rate (LIBOR).

Grace period: The loan recipient should start paying it back normally at the end of the first year from the date it has been granted, however, sometimes in projects it is agreed with the credit institution to start payments after a certain time called 'Grace period', which may include for instance the whole construction period and the first year of operation. Its purpose is clearly to lessen the financial burden on the owner or sponsor of the project and for the bank to start collecting its money when the project is generating some income.

However, this concession is not free, since during this period interests on the loan are effective, and usually paid by the year end, or else they can accumulate, adding up to the principal, and then paying interest over the interests due. These are called 'Interests during construction', and if not paid yearly they can reach a considerable amount, and whatever the criterion adopted and agreed with the banks, this aspect has to be considered.

Payback period: The number of years in which the loan will be completely amortized or cancelled.

Financial charges: They refer to commissions charged by banks, and also the commission charged to hold funds in reserve for a client.

Penalty, if the loan is repaid before the agreed number of years.

Short term loans: Usually have 1 year duration. They often come from banks, and their application could be for financing:

- Inventories,
- Letters of Credit,
- Accounts receivable,
- Working capital.

Supplier credits or loans: These are credits or loans from suppliers, which are reimbursed in a couple of years as agreed with the vendor.

For detail information about project finance see Hendrickson (2008).

7.1.2 Applications of Funds

The capital from banks and equity is applied to:

- Investment in capital goods, that is in buildings, structures, machinery, equipment, tools, etc., designed for manufacturing consumer goods such as aluminium, cars, dishwashers, electric energy, etc., or for providing services such as the construction of a Court House, a school or a hospital. Capital goods that can be depreciated¹ are also called 'fixed assets' or 'non-current assets', except land, which does not depreciate,
- Working capital. It is a financial tool, and in general terms can be expressed as the amount of capital necessary to pay liabilities. From the accounting point of view it is also defined as the difference between current assets and current liabilities.

7.1.3 Preparation of the Investment Schedule During the Construction Period

We need to know **what must be** done and **when**, that is, it is necessary to break down the construction work and installation of fixed assets along the construction period, to determine the amount of funds that must be spent each year, and considering the different main parts or areas in which the project has been divided. Therefore, we need a schedule of investments.

The first step is to classify the different costs as *direct* or *indirect*. Why is this classification needed? Because usually

¹ Depreciation. It is the continuous reduction from the original value of a good because wear and tear and obsolescence. It refers to an accounting procedure to spread its initial costs along the useful life of the good. Buildings and equipment are normally depreciated but not the land.

Table 7.1 Computation of direct and indirect costs

Areas	First year – Costs (×000)		Second year – Costs (×000)			Third year – Costs (×000)			
	Direct	Indirect	Direct	Indirect	Totals	Totals	Indirect	Totals	Totals
A – Site preparation	54	1,372	1,426	–	–	–	–	–	–
B – Process equipment	8,876	13,950	22,826	14,229	13,780	58,009	5,377	2,565	7,942
C – Buildings construction, electrical, plumbing, etc	11,262	3,479	14,741	11,962	6,257	18,329	4,983	1,209	6,192
D – Ancillary equipment	3,793	4,766	8,559	7,423	5,378	12,801	7,866	3,371	11,237
Total	23,985	23,567	47,552	33,634	25,415	59,049	18,226	7,145	25,371

the credit institutions want to know what will be the application of the funds that they are willing to lend, since it is uncommon for them to finance some expenses, such as custom fees or taxes. It is also convenient to discriminate between *local* and *non-local* costs; the reason is related with different interest rates. There is however another motive and it is linked with the sensitivity analysis that is explained further when analyzing for instance the influence of inflation. Probably there is inflation in both the country providing equipment and the recipient country; by discriminating among costs it is easier to determine the influence of each one. With these concepts exposed we can now proceed with an example, as shown in Table 7.1 which considers an undertaking where four areas A, B, C and D exist.

Data for each part comes from contractors and suppliers. For instance, in a project that involves site preparation as well as building construction, electrical and plumbing, information about costs per each part or area will come from the main civil contractor. Probably this contractor will subcontract the electrical installation and plumbing; these costs can be incorporated into the contractor's estimate or considered separately. Similarly, there will be vendors or manufacturers for process and ancillary equipment and the corresponding cost data will come from their approved tenders. If the manufacturer is in charge of the installation and testing of his equipment, this price could be incorporated to this data or perhaps shown as a separate item, such as '*Process equipment installation*'. Contractors and vendors also must submit their programs or schedules indicating when these different activities will be performed, by presenting their CPM (see Sect. 9.1.3) and Gantt chart (see Sect. 9.2).

These partial values and schedules from different contractors are sent to the Planning Department, where all of them are merged and integrated in a master schedule (see Sect. 9.3.1 about merging networks).

From here, it is possible to proceed with the computation about how much money will be invested in each year during the construction period, preparing tables as shown in Table 7.1, where for each area, and for each year the different costs are broken down into direct and indirect costs. Then, in our example the first year of the construction period will consume 47,552,000 Euros, the second year 59,049,000

Table 7.2 Schedule of investment in fixed assets during the construction period

Year	2012	2013	2014
Fixed assets (×000)	47,552	59,049	25,371

and the third and final year 25,371,000 Euros, as shown in Table 7.2.

As would be expected, in this report all costs, no matter category and contractor, are added up for each year, and this is the data that constitutes the invested capital for that first year, and following the same criterion for the following periods. This document is essential for the finance department to define with the credit institutions the amount of funds needed for each year of the construction period, since, of course, there is no advantage in paying interest for funds that are idling because they cannot be used, or the reverse, being short of funds, even momentarily, which can produce havoc in the development of the project. It is also a valuable tool to use in discussions with the taxation agency about the payment of import taxes and for negotiating, if so wished, a deferred tax allowance, as well as interest that will be charged.

7.1.4 Depreciation and Taxes

These two aspects are always present. Depreciation, as already commented, is an accounting process for the gradual conversion of fixed assets in expenses. Any asset, except land, has a useful life – determined for each type of assets by tax agencies – as a consequence of wear and tear, obsolescence, enhanced technology, etc. which produces a decrease in the service it renders. For instance, in the commercial airlines business where the useful life of an aircraft is broken down in several components, it is about 25 years for the airframe, 10 years for the engines and about 7 years for the undercarriage. The same happens for buildings, machinery and equipment, although each type of asset has a different depreciation rate according to taxation regulations.

At the end of its life, the asset usually has a remaining value called '*residual value*', or else '*salvage value*', which

is the net amount that can be obtained from the asset after its removal and sale (albeit sometimes the removal cost overcomes monetarily the benefit that can be obtained by selling the asset). At the same time the asset has to be amortized, that is to make a reserve to purchase a new one, as in the case of a machine for instance. Consequently, a fixed asset decreases in value due to its depreciation but increases because of amortization, however, depreciation is a cost, not cash, and because of that taxes to pay are reduced according to depreciation.

Fixed assets depreciation usually follows two different procedures for its calculation, with a final identical result but with different advantages and disadvantages. The two procedures are (a) *Straight line depreciation method* and (b) *Decreasing balance depreciation method*.

In the first method the total cost of the asset is divided by its corresponding life time expressed in years, therefore, the depreciation amount is constant.

In the second method a decrease in value is assumed which is a constant percentage of the residual value of the asset at the beginning of each year, and it is computed using the following formula; the depreciation amount is not constant but decreasing.

$$D = S(1 - r)^{n-1} \cdot r \quad (7.1)$$

Where:

D = Depreciation for a certain year

S = Initial book value

r = Percentage to be used

n = Year considered

Which method to use?

Naturally, taxes to be paid are the same irrelevant of the method used; the difference lies in the partial amounts to depreciate. In the decreasing balance method the depreciation amount during the first years of the project life is larger than in the straight-line method, and further on, this amount is smaller. This is an advantage of the decreasing balance method since it allows for fewer taxes to be paid at the beginning of the project. That is, it permits the generation of more earnings at the beginning of the operation phase of the project when possibly cash is more needed, and as a consequence the Net Present Value increases.

7.1.5 Reinvestment

Sometimes it is foreseen, as early as in the project planning phase, that at a certain time during the operation phase some equipment will have to be replaced because it will have reached its useful life² and it is not worth revamping. This happens for instance in a metallurgical project with a rotary furnace working at high temperature and subject to abrasion.

Even when its inside is covered by a protective layer, experience says that in 10 years time this protective coating will have been replaced three times, and the steel structure affected and weak due to abrasion produced by breaks in the coating, and stressed because of heat, and then it should be replaced. This is called a '*reinvestment*' which must be scheduled and the corresponding amount of money saved or assigned for a new purchase, transportation, installation and tests. This is also important because there is usually investment assignment money which is deducted from earnings before taxes, and consequently decreasing them, although normally it is not possible to deduct the total amount of the reinvestment. This is another situation where the project manager has an important role to play in assessing accounting and finance people in their management of this reinvestment.

7.1.6 Operating Costs

Those costs relate to manpower, energy, supplies, maintenance, depreciation and amortization; they appear when the plant is finished and has started producing the good it was designed for. To manufacture a good or render a service it is necessary to consider the assets that we have analyzed, however, there is also need of inputs in the form of labor, infrastructure, services, supplies, etc., which constitute the '*Operating costs*'.

To compute operating costs a similar process used for determining fixed assets is followed. Table 7.3 shows its calculation corresponding to the fourth and fifth years of operation. Information comes from the Engineering Department.

The computation of operating costs is very important; they enter in the income statement and are deducted from revenue produced by sales.

7.1.7 Working Capital (WC)

It has already been defined, and it is devoted to:

- Holding a raw materials inventory,
- Goods in process of manufacture,
- Finished goods,

²This term does not necessarily imply that an asset is no longer able to perform its function, given that it may be considered for replacement due to economic reasons, perhaps because it does not have the speed that it is needed now, or may be due to the fact that there exists in the market equipment with a larger production capacity and less maintenance costs, or for whatever rationale. In many cases, equipment discarded from one firm is acquired by another, with fewer expectations or production volume.

Table 7.3 Computation of operating costs

	Fourth year – Costs (×000)			Fifth year – Costs (×000)		
	Fixed	Variables	Total	Fixed	Variables	Total
Mine operation	1,325	5,277	6,602	1,614	5,454	7,068
Process plant	584	2,011	2,594	332	2,436	2,768
Infrastructure	1,344	4,502	5,846	1,382	4,901	6,283
Administrative services	155	626	781	184	606	790
Total	3,408	12,415	15,823	3,512	13,397	16,909

- Cash requirements,
- Spare parts,
- Receivables.

Since the WC is the difference between current assets³ and current liabilities⁴ it can be computed from the Balance Sheet. As an example, if values for current assets and liabilities are known, the WC is:

Current assets at : 31/12/2011 = 170,236,000 Euros

Current liabilities at : 31/12/2011 = 74,436,000 Euros

Therefore, the WC is : 170,236,000 – 74,436,000
= 95,800,000 Euros.

7.1.7.1 Analysing the Working Capital

Significance of its amount

Suppose now that the WC is zero. What does it mean?

It means that the company is theoretically able to pay its debts, however, it would be a very dangerous situation because accounts receivable and accounts payable are neither due at the same time nor for the same quantities, which means that there is no guarantee that money will be available in quantity and in time when needed.

The current ratio

Let us see now another important concept. Assume that for a firm, the WC is:

$$\begin{aligned} \text{WC} &= \text{Current assets} - \text{Current liabilities} \\ &= 600,000 - 250,000 = 350,000 \text{ Euros.} \end{aligned}$$

The ratio between current assets and current liabilities is called '*current ratio*', and thus equal to: $600,000/250,000 = 2.4:1$, meaning that current assets overcome by 2.4 times the current debts. This current ratio is a measure of financial solvency, which is the capacity of the borrower to repay a short-term obligation (normally

³ Current assets are goods, cash, inventory, work in progress, etc., subject to an inflow/outflow process to/and from the firm, and which can reasonably be assumed to be convertible into cash in a certain period, for instance 1 year.

⁴ Current liabilities are debts or obligations that a firm must cancel in a certain period, for instance 1 year.

within a year); in this case it shows that even if its current assets decrease by 58% the company is still able to cancel its liabilities.

The acid ratio

There is another more stringent ratio called the '*Acid ratio*' which has the same meaning as the current ratio, however, the acid ratio does not consider inventories as part of the current assets, but only '*liquid assets*', which are defined as cash or assets that can be quickly and easily converted to cash.

Current ratio value

One question arises: Is it convenient to have always a constant WC in order to have a healthy current ratio? Not really; in some projects and during some periods, the WC can remain constant or near constant because both current assets and liability increase in a similar amount, however, in this case, it is likely that a deeper analysis reveals that the current ratio is decreasing, and with it the solvency of the firm. How can this be explained?

If the firm is expanding, the current ratio decreases because for the same or near the same capital increment for both, current assets and liabilities, the percentage of expansion increases more in the latter than in the former, and consequently the firm's solvency is decreasing.

To clarify this important issue, see Table 7.4 where it is shown that the WC remains constant at 350,000 Euros during 4 years, because both current assets and liabilities are increasing in the same amount, however the current ratio is decreasing, due to a faster increase in the ratio denominator.

Assume now that the company finds that said current ratio is adequate and wants to keep it constant. Let us see what will happen with the WC. See Table 7.5 for this new condition.

It can be verified that, in order to keep constant the current ratio to 2.4:1, either the obligations have to reduce the increases or the current assets have to raise the increases, and in both cases the WC increases, as shown in the last column.

Selecting a current ratio value

What reasons does the company apply to select a current ratio?

The answer comes from comparing the obtained value with those published for similar industries, since it varies from

Table 7.4 Changes in the current ratio

Year	Current assets (€)	Increase (%)	Current liabilities (€)	Increase (%)	Current ratio	Working capital (€)
1	600,000		250,000		2.4:1	350,000
2	625,000	4.2	275,000	10	2.27:1	350,000
3	640,000	2.4	290,000	5.5	2.21:1	350,000
4	670,000	4.7	320,000	10.3	2.09:1	350,000

Table 7.5 Changes in working capital

Year	Current assets (€)	Increase (%)	Current liabilities (€)	Increase (%)	Current ratio	Working capital (€)
1	600,000		250,000		2.4:1	350,000
2	625,000	4.2	260,000	4	2.4:1	365,000
3	640,000	2.4	267,000	2.7	2.4:1	373,000
4	670,000	4.7	279,000	4.5	2.4:1	391,000

one industry to another; this is called ‘*Cross-sectional analyses*’. Many government’s statistics departments as well as banks in several countries, publish annually the average figures for each type of industry; therefore, there is a source with which to compare.

Where the funds for assets increase come from?

They come from the ‘*Retained Earnings*’, or from a bank short term loan.

What are ‘retained earnings’?

Profits from the result of an operation are distributed as dividends; however, many companies keep or ‘retain’ part of these profits and hold them as a reserve. This amount is called ‘*Retained earnings*’, and they are also a source for future investments or reinvestments.

7.1.8 Difference Between Fixed Assets and Working Capital

So far we have analyzed the two types of destinations where capital is applied, that is in fixed assets and in the formation of the WC, but what is the difference between both of them? The difference lies in the fact that fixed assets are subject to depreciation, and at the end of the project or at the end of their useful life, they are worth only a fraction of their original cost, which is known as ‘*residual value*’, which can bear a scrap value or may be sold to other users. Regarding the WC it is recovered at the end of the project.

7.1.9 Project Manager Involvement

Even when the computation of some costs is usually not a function of the project manager but for the accounting and financial department, nevertheless his/her input is necessary,

as shown for instance in Table 7.3 used for the calculation of operating costs; consequently, information about facts or works affecting production – such as when the plant is scheduled for maintenance work – has to come from this department. Also consider that a potential improvement or a new method to accelerate concentration will affect the WC calculation, and it might be that the accounting and financial departments are not aware of it. The same could apply to spare parts and operations requirements.

7.2 The Investment Cycle in Statements

We have briefly analyzed in a very general way the different components of the investment cycle, and now it is time to put them all together which is done through the ‘*Financial statements*’. Therefore, we can examine in more detail the investment cycle, starting with the formation of capital from different sources.

Investments produce benefits, and in their formulation intervene different concepts such as sales, unit price, depreciation, interest for the loan, interest during construction, and then it is necessary to deduct taxes, which produces ‘*Benefits after taxes*’.

Benefits are also influenced by assets depreciation and generate the project cash flow, that is, the comparison between the source and the destination of funds for each year, making sure that there is money when it is needed. The cash flow is integrated by the net benefit, working capital, operating costs, interests during construction, loan amortization, and deferred taxes. From here dividends, that is payment to shareholders is withdrawn, as well as money for loan repayments. The final result is the ‘*Retained earnings*’, which then closes the investment cycle.

All this information is linked and not stored in a sole document but in a series of closely interrelated documents

called '*Financial statements*', which can be thought of as the analytic version of the investment cycle and used to assess the performance of investments. Any modification in any of the financial statements, if relevant, will have immediate repercussion on the others. Finally the information of the individual financial statements is condensed in the Project Analysis statement. There are financial software packages to produce the financial statements and also allowing for a fast and very effective way of performing sensitivity analysis (see Sect. 7.3).

Each of these statements will be now briefly commented on to understand their meaning and the information they contain.

7.2.1 The Balance Sheet

It gives information about the financial position of a company. It is like a snapshot at a certain time, normally once a year, and in it the nature of assets and liabilities are exposed.

Assets are listed as:

$$\text{TOTAL ASSETS} = a + b - c + d + e + f$$

Where:

- (a) + Working capital
- (b) + Increase in cash
- (c) – Depreciated fixed assets
- (d) + Depreciated plant
- (e) + Interests during construction
- (f) + Deferred charges

Liabilities and equity are listed as:

$$\begin{aligned} \text{TOTAL LIABILITIES \& EQUITY} \\ = g + h - i + j + k + l \end{aligned}$$

Where:

- (g) + Short term loans
- (h) + Long term loans
- (i) – Principal withdrawn
- (j) + Deferred taxes
- (k) + Shares
- (l) + Retained earnings

$$\text{TOTAL ASSETS} = \text{TOTAL LIABILITIES AND EQUITY}$$

It is clear that for a certain year TOTAL ASSETS must coincide with TOTAL LIABILITIES AND OWN EQUITY

7.2.2 Cash Flow Statement

Briefly, it depicts where the funds from different sources come (inflow), and where the funds to diverse uses or

applications go (outflow). Even if a firm has the necessary funds to pay for its liabilities, i.e. it is economically sound, it does not necessarily mean that those funds are available at the time when they are actually needed, and keeping track of an adequate and timely equilibrium is the purpose of the cash flow statement. The composition of the cash flow statement is as follows:

SOURCE OF FUNDS	FUNDS APPLICATION
Net earning	Fixed assets
Depreciation	Construction interests
Amortization	Long term loan repayments
Deferred taxes	Deferred charges
Own capital	Short terms loans
Long term loan	Dividends
Short term loan	Increase in working capital
Decrease in working capital	Increase in cash
Decrease in cash	

It is clear that for any year of the project TOTAL FROM SOURCES must coincide with TOTAL TO APPLICATIONS

7.2.3 Income Statement

Composed of:

Income from sales

- Operating costs
- Depreciation
- Interests on loans
- Amortization of deferred charges
- Amortization of interests during construction
- Taxes

$$= \text{TOTAL EARNINGS}$$

7.2.4 Project Analysis

This is the condensation of the information from the above schedules and others such as '*Assets depreciation and amortization*', '*Long term loan schedule*', etc.

Depends on a particular construction but it can depict for each year the following information:

- Project cash flow,
- Project return,
- Debt coverage,
- Earnings per share,
- Interest cover,
- Current ratio,
- Acid ratio,
- Benefit margin. (Ratio between net benefit and sales)

This information allows for a clear and complete picture of the project performance from construction to the end of its operation life, and consequently allows for accepting or rejecting the project.

7.3 Sensitivity Analysis

Whatever the project, there is no assurance about its future development and further operation, because normally there are many uncertainties. For instance, in an industrial project to produce a consumable product, uncertainties refer to demand, price, competition, acceptance, etc. In a social project such as establishing courses to train out of work people in different trades, it might be difficult to ascertain the number of people that will be attending; in a construction project there could be uncertainties about geological conditions, advance, weather, etc. For this reason, and even when certain parameters might be known with relative confidence, nobody can guarantee that they will not change, or how a change in one of them can alter other parameters, it is necessary to perform a sensitivity analysis which consists in assuming variations of one parameter at a time, or more than one together, and then find out how the main indicators of the project feasibility react.

For instance a project for developing and operating a commercial mall can badly fail if the expected average number of visitors falls beneath a certain assumed threshold or volume. Then, it is important to learn how it will affect the profit of the undertaking, which can be measured using the Internal Rate of Return (IRR) in a year, and computed considering this decrease in visitors, when compared with the minimum IRR percentage established by the sponsor at the beginning of the project, which forecasted a higher number of visitors. It also applies to the construction stage since a delay in completion can very seriously jeopardize the success of the opening, considering commitments to be tied up with perhaps hundreds of merchants to occupy the mall's premises, who in turn, have other commitments to supply their stores. This aspect of uncertainty is closely related with risk, which is examined in Chap. 6.

7.4 Sequence to Prepare an Economic and Financial Analysis for a Project

To wrap-up the above information this section shows the departments involved and their responsibilities in an approximate sequential order. Naturally, there is not a lineal path between them but a continuous forth and back process with feed back.

Intervening departments and functions:

Marketing: Estimates:

- Potential demand,
- Price,
- Product characteristics.

Engineering: With the information of volume or annual production, produces:

- Plant layout,
- Preliminary drawings for civil works, including foundations, buildings, services, internal transport, etc.,
- Operating costs.

Planning (see Chap. 9): Establishes sequence of activities (planning), arranges those as a function time (scheduling), and assigns resources (levelling).

Purchasing (see Chap. 10): Based on specs from Engineering, calls for:

- Bids to select contractors,
- Bids for equipment.

Human Resources (see Chap. 13): Based on specs from Engineering:

- Recruits personnel.

Project Cost (see Sect. 12.1): With information from: Purchasing (Fixed assets quotations), Engineering (operating costs), Planning (Resources), prepares the costs for the project during the construction and the operation period.

Accounting: With information from Project Costs about fixed assets computes import taxes, direct and indirect costs and an estimate of inflation.

Budgeting (see Sect. 12.3): With information from Project Costs about fixed assets costs and from Planning about planning, schedule and resources, prepares the baseline S-curve.

Financing: Based on data provided by Budgeting, gets loans from banks, computes working capital, prepare projected financial statements and execute sensitivity analysis.

7.5 CASE STUDY: Construction of a Copper Concentration Plant

This case deals with a metallurgical project involving the construction of a copper concentration plant using copper sulphide ore extracted from an open-pit mine in Africa. The project encompasses the civil works for buildings and the supply and erection of the necessary equipment, as well as ancillary installations such as cone crushers and rotary mills, a furnace to roast the material to eliminate sulphur, floatation cells, belt conveyors, construction of a tailings pond, power house, etc.

The basic engineering is already done and now it is necessary to determine the economic and financial feasibility of the project, considering that there exists a huge market for this concentrate and the unit price in €/pound has been almost constant during a considerable period, however a study made by an independent consultant foresees an increase in the price of the metal in the international markets.

7.5.1 Background Information

According to the company's planning department the construction period is estimated in 3 years with 15 years of operation as a planning horizon. Production is based on a Marketing Department sales forecast, which also wrapped up an agreement with an Asian company to refine the concentrate subject to minimum deliveries per year. The unit price is estimated at 1,400 €/ton according to an estimate made by experts.

7.5.2 Investment During Construction

The Planning Department developed the merged logic network and the Gantt chart (see Sect. 9.3.1) and from them computed the partial and accumulated investment as seen in Table 7.6 with the monthly estimated funds to be expended during construction. Therefore, the total investment amount to 131,972,000 Euros.

These values allow drawing Fig. 7.1 that depicts the budget baseline (see Sect. 9.2.1).

Figure 7.2 graphically shows the intervening departments as well as the existent interrelationships for this project.

7.5.3 Taxes During the Construction Period

These are taxes levied for importing machinery and equipment and computed as a percentage of CIF (Cost, Insurance, and Freight) and are as shown in Table 7.7.

7.5.4 Financing

Financing comes from equity and bank loans, as follows:

70% of the project will be financed by a long term bank loan that is:

$$131,972,000 \times 0.70 = 92,380,000\text{€},$$

30% of the project will be financed by equity, i.e.:

Table 7.6 Partial and accumulated investment – Copper concentration plant

Month	Partial amount (in 000 of €)	Accumulated amount (in 000 of €)
1	1,276	1,276
2	3,744	5,020
3	2,800	7,820
4	3,253	11,073
5	3,761	14,834
6	3,187	18,021
7	5,525	23,546
8	3,649	27,195
9	3,822	31,017
24	6,761	106,601
30	2,417	123,230
31	1,973	125,203
32	1,616	126,819
33	1,318	128,137
34	1,367	129,504
35	1,256	130,760
36	1,212	131,972

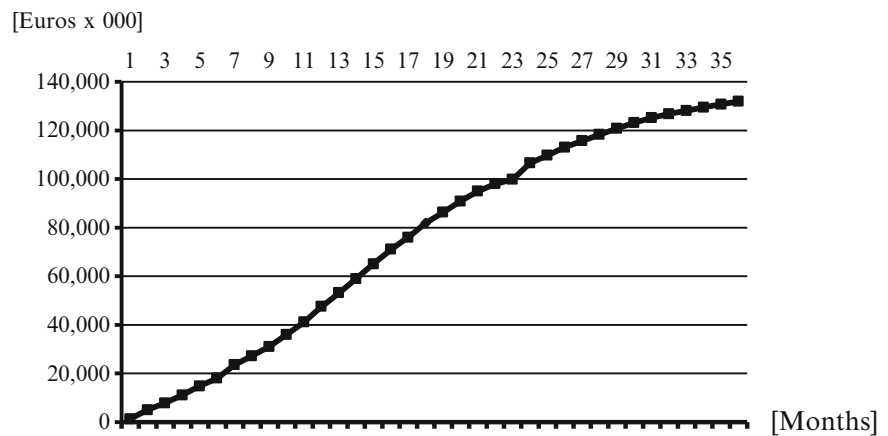


Fig. 7.1 The budget baseline – Copper concentration plant

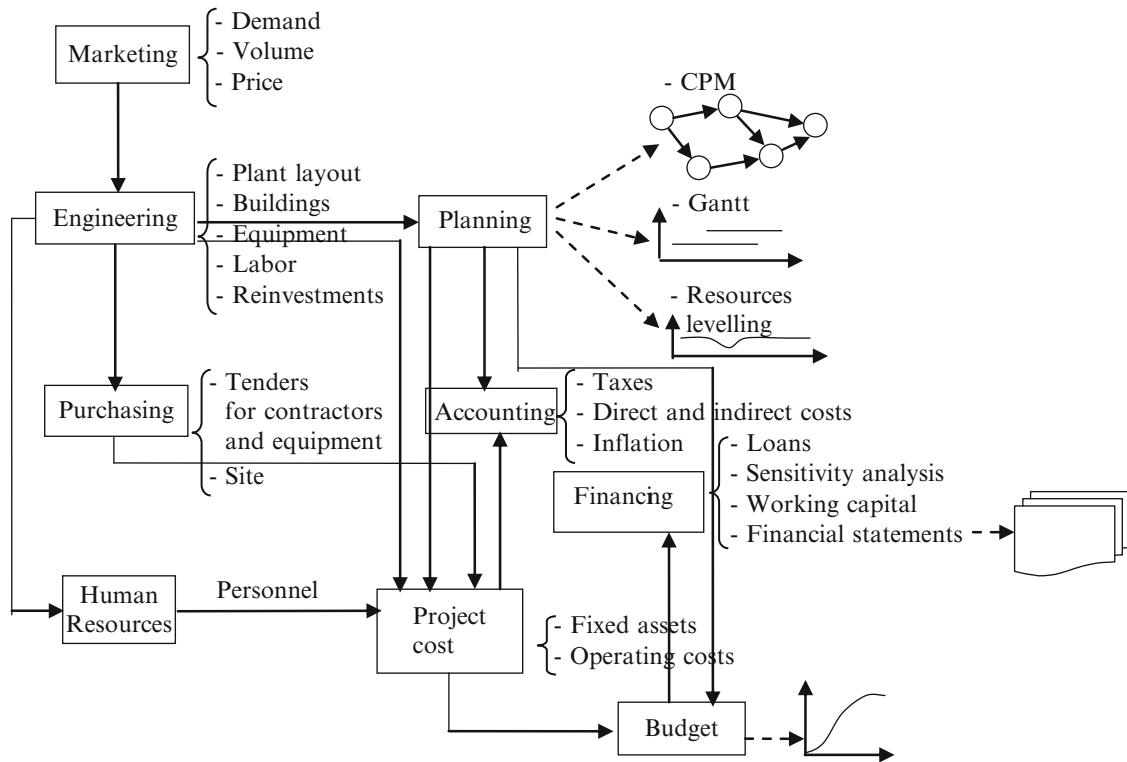


Fig. 7.2 Information flow for a project financial analysis

Table 7.7 Schedule of taxes

Year	Taxes (×000 €)
1	3,930
2	4,023
3	1,246
Total	9,199

$$131,972,000 \times 0.30 = 39,592,000\text{€}.$$

Conditions of the long term loan are:

- Fixed interest rate: 10%/year,
- Payback period: 10 years,
- Grace period: 4 years including construction period.

Conditions for the short term loan are:

- Total amount: 5,990 €,
- Fixed interest: 10.25%/year,
- Payback period: 1 year.

Deferred taxes credit: Tax authorities have agreed to defer import taxes for equipment until the plants commences production, under these conditions:

- Amount: 9,199 €,
- Interest: 9%/year,
- Payback period: 10 years,

- Grace period: 5 years including construction period.

Considering the cost of capital as well as the opportunity cost of equity capital, the Board of Directors has put a threshold of 8.5% of project return as a average target during the operating years. That is, the available equity capital could be placed in other undertakings; however, it is believed that this project offers better growth opportunities since its product has an ever increasing rate of demand and with forecasted increasing unit prices. That threshold is considerably better than the returns offered by actual opportunities.

7.5.5 General Specifications

- *Depreciation:* By the decreasing balance method (as agreed with taxation authorities),
- *Equipment useful life:* (as agreed with taxation authorities)
Processing equipment: 10 years,
Ancillary equipment: 10 years,
Reinvestment in equipment: 12 years,
Buildings: 20 years.
- *Reinvestment:* 14,694,000 Euros will be reinvested 10 years after starting of operations.

7.5.6 Operating Costs

Operating costs were computed as exemplified in Table 7.3, but for the whole life of the project, and are further used to prepare the financial statements.

7.5.7 Working Capital

It has been calculated for each one of 15 operating years. Table 7.8 records the account receivables, starting with the first year of operation. It is considered a 90 days operating cycle.

Table 7.9 shows the calculation of working capital for the first 7 years of operation.

	€ (×000)
Amounts receivable (from Table 7.8)	65,484
Amounts receivable in 90 days: (65,484/4)	16,371
Total current assets (from Table 7.9)	23,298
Total current liabilities (from Table 7.9)	-4,827
Working capital	18,471

7.5.8 Statement of Project Analysis

As mentioned this is the document that condenses the information from other financial statements and that shows the

Table 7.8 Calculation of receivables – Copper concentration plant

Operation year	First € ×000	Second € ×000	Third € ×000	Fourth € ×000
Income at 1,400 €/ton	55,160	65,484	65,688	66,220
In 90 days	13,790	16,371	16,422	16,555

Table 7.9 Calculation of working capital – Copper concentration plant

Project year	First € ×000	Second € ×000	Third € ×000	Fourth € ×000	Fifth € ×000	Sixth € ×000	Seventh € ×000
	Construction phase		Operation phase				
Current assets							
Spare parts and operation requirements				2,500	2,500	2,500	2,500
Cash (3 months)				200	200	200	200
Concentrate (25% of operating costs)				3,956	4,227	3,606	4,730
Accounts receivable				13,790	16,371	16,422	16,555
Total				20,446	23,298	22,728	23,985
Current liabilities							
Accounts payable (3 months of operating costs)				3,956	4,227	3,606	4,730
Expenses (salaries and wages)				600	600	600	600
Total				4,356	4,827	4,206	5,330
Working capital				5,990	15,890	18,471*	18,655

(*)The calculation of the WC proceeds as follows. Consider as an example the fifth year of the project (or second year of operation)

financial viability of the project. Table 7.10 shows the last 4 years of this projection, using different financial indexes.

7.5.8.1 Comments on This Projection

Refer to Table 7.10.

Project NPV:

1. It is negative (albeit not shown here) during the construction period because there are only investments or outflows of money, no benefits or inflows. The latter start on the 4th year of the project or the 1st of the operation due to the selling of the concentrate produced those years in the new plant.
2. At that time the NPV (not shown here) amount to 20,365 million Euros, it further increases up to the 3rd operation year and then starts diminishing. Why? Because the NPV reports the cash flow at present value, that is at the very beginning of the project. When the operation years move away from this early date the capital discounted factor used in the update formula gets smaller and since it multiplies the cash flow for any year, the actual value decreases. As already mentioned, this is one of the reasons that the decreasing balance for depreciation is sometimes preferred because then there is an increase in profit in the early years of operation of a project, which reflect in the NPV.
3. Albeit not shown here, on year 2026 the NPV reached a 26,365 million Euros value. Observe the NPV for next year, that is 2027, which shows a sharp decrease; it is provoked because in that year an outflow of money takes place due to reinvestment. By 2030 it shows a sharp increase. Why? Because at the last planned year the working capital is added in the amount of 18,655 million Euros as shown in Table 7.9.

Table 7.10 Statement of Project analysis (values in € ×000) – Copper concentration plant

Financial indexes	2017	2018	2019	2020	2027	2028	2029	2030
Project NPV					11,406	27,294	26,834	67,155
Equity NPV					681	26,331	26,834	67,155
Project IRR					12.45	13.21	13.79	14.90
Equity IRR					22.82	23.68	24.30	25.40
Earnings per share					4.83	4.78	4.79	4.79
Debt coverage					2.37	27.26	0	0
Gross profits/sales ratio					0.71	0.71	0.71	0.71

Table 7.11 Results from sensitivity analysis – Copper concentration plant

Indicator ↓	A	Variable 1 [Unit price]		Variable 2 [Sales volume]		Variable 3 [Operating costs]		Variable 4 [Process equipment]	
		Original value (*)	Decrease of 10%	Diff. between A & Var. 1 [%]	Decrease of 10%	Diff. between A & Var. 2 [%]	Increase of 10%	Diff. between A & Var. 3 [%]	Increase of 10%
Project NPV	67,155 €	63,712 €	–5	52,399 €	22	52,399 €	22	59,409 €	–12
Equity NPV	67,155 €	67,155 €		67,155 €		67,155 €		67,155 €	
Project IRR	14.9%	13%	–13	6%	–60	6%	–60	15%	
Equity IRR	25.4%	25.4%		25.4%		25.4%		25.4%	
Earnings per share	4.79 €	4.07 €	–15	3.76 €	–22	4.23 €	–12	4.79 €	
Debt coverage	27.26	23.83	–13	22.43	–18	24.69	–9	23.64	–13
Gross profit/sales ratio	0.71	0.68	–4	0.58	18.04	0.29	–59	0.71	

(*) From last column of the project analysis statement

Project IRR:

4. The IRR, as expected (although not shown here), is negative during the construction years because the money outflow and continues being negative up to the 4th operation year included, for the reason that the project still does not generate enough benefits to compensate the investments, although the situation reverts in the 5th with a small positive IRR of 0.87. From then on it is incrementing and reaching a figure of 14.90% in 2030. Not considering the construction years nor the following three operation years, the average IRR is about 9.92% which is higher than the target fixed by the Board of Directors of 8.5%.

7.5.9 Sensitivity Financial Analysis

A sensitivity analysis is performed considering variations in four variables, as follows:

Variable 1. *Unit price*, a decrease of 10% in the unit price, although it is not likely to occur.

Variable 2. *Sales volume*, with a decrease of 10%. Also very unlikely, because consumption has been increasing during the last 20 years; however, new mines are constantly put in operation and also old mines are now recovering raw material (ore) that were discarded in the past because of low copper content. However, with new technology,

and with the new prices for the metal, it is now possible to process those poorer ores with a profit.

Variable 3. *Operating costs*. This is the main concern because manpower costs are constantly rising as well as direct and indirect costs. A 10% increase is also considered here.

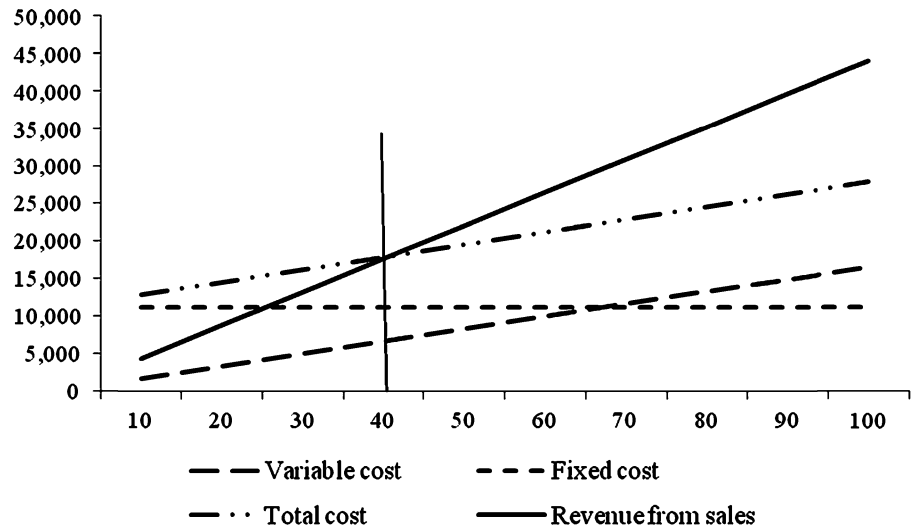
Variable 4. *Process equipment*. Although computerized equipment is used requiring fewer personnel to operate, they are quite expensive. This heading also includes the cost and maintenance of large trucks employed in ore transportation from the open pit mine to the crushers.

Table 7.11 portrays, for each of these variables, the differences with the baseline values in column A. It can be seen that:

1. The largest reduction (60%) in the Project IRR corresponds to *sales volume*, which is understandable considering that this volume is directly linked with the economy of scale of the undertaking. That is, if for whatever reasons, for instance a drop in demand, the plant must produce less concentrate than its design capacity, it is obvious that the production cost per ton increases, since fixed costs probably would not change.

Because of this, and based on this information, measures possibly might be taken now to reduce this impact if it actually happens, and perhaps a part of the solution could be the construction of silos to store the concentrate when the demand is low. There is no question that said

Fig. 7.3 Determination of the breakeven point – Paper mill construction



additional construction and investment should be considered at the time of the analysis, before beginning construction, so that the new facilities can be included in the plant lay out, and in order to minimize transportation costs perhaps by making room for the future construction of a conveyor belt to feed the silos. Another solution that can be weighed up is the construction of an electrolytic refining facility to process all concentrate and to manufacture copper of high purity in bars, which has thousands of uses, and as a vertical industrial integration, which will increment the project's profitability.

2. There is also a large drop (60%) in the Project IRR corresponding to *operating costs*, and confirming the presumption that this is a critical aspect in production. Again, considering the importance of this factor it would be wise to reconsider the type of equipment to be purchased, possibly changing to more expensive but at the same time more efficient, machines such as crushers, or a rotary furnace. Another alternative could be to take advantage of the sulphurous flue from the rotary furnace, by recovering the sulphur and using it for the production of sulphuric acid on the site, thus developing a horizontal expansion.
3. Earnings per share, a fundamental aspect for shareholders, are also affected badly by a drop of sales volume, with a loss of 22%.

7.5.10 Final Remarks on This Example

The proposed actual case, which description is far from complete, was developed with the objective of showing how all the computed elements enter in different financial statements, which pave the road for the construction of the project analysis statement, which in turn allows for assessing

the profitability of the project and for analyzing revenues and determining the trend of financial indicators, data that is sometimes requested by the credit institutions. The other very important mission of this project analysis statement is that it permits performing a sensitivity analysis, absolutely necessary given the uncertainty of future developments external to a project and that can be only estimated or guessed.

In this example the sensitivity analysis pinpointed critical factors such as sales volume and operating costs, and more important, allowed for adopting adequate measures before the start of the project, to at least ameliorate the impacts of negative variations of those factors. Needless to say, this was only an example of a financial and economic feasibility of a project, and although it is probably true that this evaluation will be executed by the accounting and finance departments, it is useful and necessary for the PM to know and understand its different intervening concepts, elements and calculations, considering that most information will probably come from other departments and also requiring his/her intervention.

7.6 Breakeven Point Diagram

It is often of capital importance to determine the minimum amount of a product that needs to be manufactured in order to generate profits. That amount receives the name of '*Breakeven point*' and it is the quantity that equates revenues with costs. Any magnitude below it will generate a loss and conversely any magnitude above it will make a profit. This quantity '*n*' can be determined graphically as shown in Fig. 7.3 or algebraically through a simple formula.

Table 7.12 Values of costs, total costs and revenues – Paper mill construction

Monetary values in US\$ ×000	Tons ×000									
	10	20	30	40	50	60	70	80	90	100
Variable cost	1,658	3,316	4,974	6,632	8,290	9,948	116,063	13,264	14,922	16,580
Fixed cost	11,220	11,220	11,220	11,220	11,220	11,220	11,220	11,220	11,220	11,220
Total cost	12,878	14,536	16,194	17,852	19,510	21,168	22,826	24,484	26,148	27,800
Revenue from sales	4,410	8,820	13,230	17,640	22,050	26,400	30,870	35,280	39,690	44,100

This example corresponds to a project for a paper mill. In abscissas are thousands of tons, while in ordinates, dollar values. The components are as follows:

- Fixed costs: The horizontal dashed line. Includes: Labor + supervision + real estate taxes + services + administration expenses, etc.
- Variable costs: The inclined dashed line. Includes: Variable production costs + write offs + sale taxes + electric energy, etc.
- Revenues: Gross sales – short term liabilities
- Total costs: The inclined dash and dots line that is the sum of the two above mentioned,
- Revenue: represented by the solid line.

The breakeven point corresponds to the intersection of the total cost and revenue, and its value is indicated by a vertical reference line of 40,700 tons. That is, over this amount there is a net profit and a loss in case this amount is less than 40,700 tons

Graphical representation of Table 7.12 produces Fig. 7.3 and the determination of the breakeven point at 40,700 tons.

Analytically this value can be found using formula 7.2

$$n = \frac{\text{Fixedcost}}{\text{Unitsaleprice} - \text{unitnvariablecost}} \quad (7.2)$$

$$n = \frac{11,200,000}{(441 - 165.8)} = 40,700 \text{ tons} \quad (7.3)$$

7.7 Conclusion of This Chapter

This chapter deals with a fundamental task which allows for the decision of going ahead with a project or to cancel it. Even if this is a matter for the financial department it is impossible to even start considering the subject without information provided by other departments, most especially engineering and planning. These departments have to provide technical information about the undertaking, especially related with costs, schedules, and fundamentally by providing a schedule of investments in fixed assets during the construction period. This is the reason that this subject is considered in this book devoted to project management, considering that the PM needs to understand the intricacies of project evaluation in order to be able to provide reliable, consistent data and information and at the same time participate in the evaluation process.

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Abstract

This chapter considers the situation where there are several projects, alternatives, plans or programmes pertaining to the achievement of a certain objective. As usual, only one project must be chosen, or perhaps a blend of projects or alternatives selected as the more convenient solution, and this determination is the aim of this chapter. It is a vital part of the making-decision process and there are a series of tools available to help the decision-maker. These tools are briefly analyzed and exemplified, and the corresponding software commented. The idea is to give enough information for the decision-maker to be able to select the software or program that he/she believes is the best, or which yields the more convenient solution, and at the same time act as transparent and objective as possible.

Keywords

Decision-maker (DM) • Decision software • Compromise solutions • Sensitivity analysis

8.1 What Is the Decision-Making Activity in Project Management?

Most projects have a goal, which can be defined as the aspiration to get something done, be a factory, the launching of a new product or the opening of an international event, such as for instance the World Cup. The goal is usually well determined, albeit there can be more than one.

Once the goal or goals are established there are a series of activities or targets that must be met. For instance the construction of several buildings for the factory, the marketing and feasibility studies for a new product, or the construction of facilities and organization of events for the World Cup. Needless to say, these targets amount to a few for a simple goal or to hundreds for complex projects with several goals. The planning and scheduling of these targets is done using the conventional tools described in Chap. 9; however, there is a facet that must be considered, and which is probably one of the first, even before the planning; that is, making a decision about what is the ‘best’ alternative to apply when several alternatives of a project have been studied, or the ‘best’ project to pursue in case of a portfolio of projects, or

the ‘best’ technique to use to attain a goal, or the ‘best’ route among several for construction a high voltage line, etc.

Normally, there are different ways to achieve a goal, even assuming the same quality and efficiency, and the problem consists in selecting which is the most appropriate when simultaneously different and even contradictory aspects are taken into account. What are these different aspects?

They refer to the diverse conditions and constraints that every project is normally subject to. These can be internal, that is pertaining to the project itself or to the company pursuing it, or external, due to market, political, economic and environmental circumstances. Therefore, projects are subject to a usually large series of constraints of different kinds.

Assume for instance a company with some capital available to be invested in some venture and that is considering different types of investment projects such as building a furniture factory, a large printing facility or a plant to assemble laptops. In the past, practically the only important concept was the economic one; consequently, an economic and financial analysis was normally done – as described in Chap. 7 – the Net Present Value (NPV) or the Internal Rate

of Return (IRR) computed, and selected the venture which best satisfied these two criteria or one of them.

At present, this choice is by far more complicated because additional criteria or restrictions must be considered involving social and environmental issues. Therefore, if there is a portfolio of potential projects, from which one or more must be selected, and customarily subject to a large series of restrictions obeying different aspects, all of these restrictions need to be considered. The project chosen is the one which best complies with all of these criteria and wishes of the DM and stakeholders. The process consists in finding equilibrium by considering trade-offs between *advantages* and *disadvantages* offered by the different candidate projects.

What has been said considering several projects also applies to one single project because normally there are several alternatives or options, and all of them subject to the same and different constraints. For instance, assume that the project aims at building a factory to manufacture heavy trucks, and that there are three potential locations in sight such as Le Havre in France, Barcelona, in Spain, and Bremen, in Germany. Which of these locations or alternatives is the most convenient to establish the factory? This is a decision-making problem, and its solving is the object of this chapter.

There are several aspects to be considered in this project, such as (naturally these options depend on the type of project).

- Merchandise distribution. This is why the three locations are harbours, to facilitate the exporting part of the factory production (which is one of the goals). However, each location is probably different from the others because of different loading services (for instance facilities for containers loading and unloading), speed of operations (the larger the time to load a ship the greater the cost), tariffs, road connections with the rest of Europe, distances in km. to the main consumer centres, weather (because some harbours can be ice-blocked part of the year), etc.
- Local competition from another truck manufacturer located nearby or in the region,
- Agreements signed with other factories, maybe in other countries, producing vital components that can be used in this truck, for instance engines and tires,
- Suppliers. Existence of nearby suppliers of essential inputs such as steel in different shapes, glass, cables set, subsets, etc.
- Availability of workers,
- Workers expertise, since it is obvious that a region with a large history of industrial production in similar activities, will have a roster of people highly qualified for the job in this new factory,
- Benefits, which are normally granted by local authorities in the region where the harbour is located, and that can translate into subsidies for each worker during a certain time, or by real estate tax reductions during an established period, or other benefits. Normally local authorities are interested in the venture for the reason that it will create

new job opportunities for their citizens, and because it will produce a multiplier effect in the economy and will generate more revenues due to taxes paid.

- There could be environmental differences amongst the three locations related with available land, potential damage to wild life (because of noise and heavy traffic if near protected areas), necessity to use agricultural land, landscape alteration, etc.,
- Social benefits. These could be a consequence of jobs created,
- History of potential union problems which in the past produced strikes and stoppages,
- Amount of salaries and wages paid to staff and workers according to each country's labor laws,
- Price of land,
- Etc.

As seen, there are numerous and varied aspects to take into account in deciding on the most convenient location, which makes selection a tough problem. Observe that it is said '*the most convenient*' and not '*the best*', because either an ideal location probably does not exist (it would mean that said location has everything in favor and nothing against it), or because this ideal is unknown. However, there is another aspect to consider. Notice that all the criteria mentioned above are *quantitative*, i.e. it is possible to have quantities in connection with them, either number of jobs to be generated, quantity of hectares needed, or average distances to the markets.

However, there are many criteria that are *qualitative* in the sense that there are no values to measure them – for instance the *opinion* of the society about the project; nevertheless, they must be incorporated into the analysis. This opinion can be expressed as '*bad*', '*very good*', '*disturbing*', '*indifferent*', or whatever other qualification, and the problem lies in the fact that these opinions are subjective, that is, they depend on the person or group polled and may vary with another person or group consulted. This research for public opinion is usually done in steps, where the first consists in performing surveys or polls involving the people that will be affected by the project, using a sampling procedure. Next is the conversion of these linguistic variables into numbers. This can be done using a scale in a certain interval, for instance between 1 and 10, or 20–30, or whatever other interval, and assigning values. For example, say that we choose the 1–10 scale and establish the following comparison:

- * Bad = 1
- * Not very good = 2
- * Good = 4
- * Better than good = 6
- * Very good = 8
- * Excellent = 10

Table 8.1 Structure of the decision matrix for a power project

Criteria (i)	Alternatives (j)		
	Option A (Coal fired) represented by (x_1)	Option B (Photovoltaic) represented by (x_2)	Option C (Hydro) represented by (x_3)
Criterion 1 Output	a_{ij}	a_{ij}	$a_{13} = 240$
Criterion 2 Personnel availability			a_{ij}
Criterion 3 Water availability	a_{ij}	a_{ij}	a_{ij}
Criterion 4 Land	a_{ij}		
Criterion 5 Atmospheric contamination	a_{ij}		
Criterion 6 Distance to 750 kV high tension transmission line		a_{ij}	a_{ij}
Criterion 7 Interconnection	a_{ij}	a_{ij}	a_{ij}

Therefore, if a poll indicates that for a criterion such as ‘*Impact of the project on people*’, people think that it will be very good for them, it gets an 8, while another criterion such as ‘*Traffic generation in the area*’, which many people do not like, may get a 2.

Naturally, this is an arbitrary scale and with subjective estimates, and it is also possible that another poll shows different results, but there is no method that can accurately reflect in numbers, the feelings, opinions and views of people. There is still another problem because we are assuming here that all criteria have the same weight or importance. Is that true, or at least believable? For instance, does merchandise distribution have the same importance as compared with workers availability, or compared to whatsoever other criteria? Probably not, and then a weight should be assigned to each criteria reflecting this relative importance and adding another source of subjectivity or uncertainty, since we do not have an evident measure of importance, i.e. what is very important for some people may be of no significant for others.

As seen, this is a complex problem, and for which it is necessary to have methods that organize and process the information. These are grouped and known as ‘*Multicriteria Decision Methods*’ of MCDM for short.

All of them start with a matrix or table called ‘*Decision matrix*’, consisting of a series of columns (j) corresponding to the different alternatives, projects or options, and rows (i), pertaining to a series of criteria. See Table 8.1 for the basic structure of the decision matrix for a power plant project with three options.

The criteria are the conditions, constraints or restrictions to which the alternatives are subject to, and are designed to

reach the objective or goal. Each criterion must comply with a maximization or a minimization action, or an equality.

At the intersection of a column and a row are expressions ‘ a_{ij} ’ that indicate for each criterion ‘ i ’ the contribution from each alternative ‘ j ’. As an example, assume that the alternatives correspond to different options of power plants, and that alternative C belongs to a hydro installation. In that case $a_{13} = 240$ indicates that for the first criterion ‘*Output*’, ($i = 1$) this alternative ($j = 3$), contributes with 240 MW.

For another criterion such as ‘*Atmospheric contamination*’, the only option that has an impact is the coal fired plant and it is expressed as ‘ a_{ij} ’ or ‘ a_{51} ’, measured perhaps in mg/m^3 .

Another criterion such as ‘*Distance to 750 kV high voltage line*’ shows that there is no distance for option A but that said condition applies to alternatives B (a_{62}) and C (a_{63}).

Notice that there are empty spaces, for instance for a_{53} . This indicates that for criterion ($i = 5$), there is no contribution from alternative C ($j = 3$) for whatever reasons. This criterion could refer for instance to the production of sulphur in the gases released from the stack, which of course must be minimized. Alternative C, because it is hydro does not produce sulphur as options A does, and for that reason its contribution is null, and the same applies to option B. It can then be seen that this matrix when properly built can represent very approximately a real scenario. We say ‘*very approximately*’, because it is normally near impossible to faithfully represent an actual scenario.

8.2 The Decision-Making Process in Projects

In order for the reader to have an evaluation of the importance of the decision-making process in project management, Table 8.2 lists a series of actual projects which have been solved by different methods by researchers around the world. There are a large variety of methods to treat this kind of problem and based on different procedures. In this book we use a method called Simus (*Sequential Interactive Model for Urban Systems*).

Notice the variety of areas of application as well as the diversity of projects. All of these projects have been also solved with the Simus method which is explained in this chapter, and results contrasted with those from other methods. It is necessary to mention that theoretically at least, results from the different methods from a given problem should coincide; however, that is not the case in general.

The reasons for this lack of concordance are the different assumptions made by the different methods and the level of subjectivity involved, and because of these subjectivities different results can be obtained even using the same method but from different decision-makers.

Table 8.2 The use of decision-making methods in different projects

Project area	Description	Number of alternatives	Number of criteria	Method used
Infrastructure	River navigation and harbors – USA	6	7	SAMI
	Airport – USA	6	7	Simulation VISA
	Airport – USA	4	6	AHP Goal Programming
	Airport – The Netherlands	4	20	REGIME
	Harbor – Taiwan	6	17	ELECTRE
	Road and railways – Thailand	4	37	ANP
	Road materials – Poland	4	3	ELECTRE
	Drinking water – Brazil	8	4	ELECTRE
	Sewage – Norway	2	11	Cost/Benefit
	Urban reconstruction – Palestine	8	7	AHP
Solid waste management	Oil pipeline – Azerbaijan and Turkey	4	10	Unknown
	Solid wastes – Canada	11	11	SWA ELECTRE TOPSIS CGT WP
Government projects	Solid wastes – Italy	4	11	Cost/Benefit
	Personnel in commercial missions – UK	7	6	ELECTRE
Industrial location and distribution	Environmental Canadian policy – Canada	5	11	Unknown
	Industrial location – Thailand	4	3	AHP
	Determining location for a university – Brazil	10	5	Unknown
Electric generation and distribution	Distribution for an electric company – Poland	7	29	ELECTRE AHP
	Ranking electric projects – New Zealand	4	5	ELECTRE
	Hydraulic projects – Nepal	16	10	Unknown
	Selection of routes for overhead power lines – South Africa	4	17	GIS
	Selection for electrical generation – Europe	6	7	PROMETHEE
	Selection of renewable energy sources – Canada	5	6	AHP/SIMUS
	Importing electric energy – Norway	4	7	MAUT AHP
Agriculture	No traditional sources for electric generation – Italy	4	10	PROMETHEE
	Crops protection – USA	3	4	AHP
	Agricultural research – Ukraine	17	3	AHP
Economic development	Sustainable use of agriculture land – Greece	4	20	REGIME
	Business location – Europe	7	4	Unknown
Residential housing development	Investments selection – Romania	5	4	ELECTRE
	Selection of housing styles – Switzerland	4	11	ELECTRE
Miscellaneous	Decision-making with uncertainty	6	3	Compromise programming
	Selection of medical treatment – USA	3	3	MAUT
	Investment manager selection – USA	4	9	PROMETHEE
	Selection of broadband technology – Colombia	4	8	AHP
	Selection of a bomber aircraft	4	4	ELECTRE
	Decision-making about effectiveness of mathematical models – USA	3	3	AHP
	Car selection	3	4	AHP

(continued)

Table 8.2 (continued)

Project area	Description	Number of alternatives	Number of criteria	Method used
Environmental projects	Selection of strategies to promote recycling – Malaysia	5	4	PROMETHEE
	Measuring sustainability – Europe	4	9	MAUT
	Economic instruments for environmental management	4	11	NAIADE
	Recycling methods-Malaysia	5	4	PROMETHEE
Industrial activities	Selecting a transportation system for an underground mine -Turkey	5	6	PROMETHEE
	Selecting and advertisement media to promote a product – USA	6	5	PROMETHEE
	Selection of different paint primer for cars – Austria	6	7	PROMETHEE

The sources of subjectivity are:

- The setting of values by means of personal preferences in the AHP and ANP methods,
- The assumption that in most cases actual situations comply with the mathematical transitivity. That is, it is assumed that if $A > B$ and $B > C$, then A must be $> C$, and this is a feature of the AHP and ANP methods. Unfortunately this is not true in many cases,
- The necessity to establish weights for criteria in the Promethee method, as well as to select thresholds of acceptance and rejection in both the Promethee and Electre methods,
- The necessity to choose for a metric in the Topsis method,
- The need to specify quantity and characteristics of criteria in all methods, Simus included.

The Simus method does not need any weight, preferences or assuming levels, and for that reason it is considered – at least by this author – as a more reliable methodology, although more difficult to understand, but not to use. In addition, Simus, based in a mathematical technique called ‘*Linear Programming*’ (LP) allows for a more down-to-earth representation of the reality than other methods, albeit without being capable of faithfully represent it.

In addition, it is believed that for large and complex problems such as those related with the analysis of river basins or some complex environmental problems, the sole methodology able to handle them is LP/Simus.

As an example of the nature of these complex issues, consider the following actual projects:

8.2.1 Rio Colorado Basin Study, Argentina

Essentially the problem consisted in the *selection of 20 alternatives* that included: Fair share of water from this small river between five provinces situated in an arid area, the irrigation of different types of crops with different water requirements, erosion protection, drinking water treatment

and distribution, protected swamps, industrial uses, etc., and subject to 32 criteria concerning with:

- Economics,
- Financing,
- Society,
- Environment.
- Sustainability,
- Technical,
- Territorial,

These criteria were usually tough restrictions, including for instance:

- *Quality of water*: The necessity of guaranteeing the quality of the water discharged (salt content wise), for the last province using the water,
- *Uses*: The potential utilization of the river water for electric generation, as well as for consumptive and non-consumptive uses,
- *Flooding*: The necessity to prevent annual flooding of agricultural land during the de-icing period in the river sources,
- *Erosion*: The prevention of erosion of river shores,
- *Energy*: The generation of energy in two places,
- *Economy*: Compensations to be paid to the less favored province because of higher salt levels in water, at the mouth of the river, and at the same time keeping a certain flow to prevent salt water intrusion from the sea into aquifers,
- *Evaporation*: In one of the reservoirs to be built,
- *Etc.*

This very difficult problem was solved using LP and Simulation¹ yielding as a result, the best possible projects to be undertaken. A complete description can be found in (Cohon et al. 1973).

¹Mathematical procedure that consists in building a mathematical model that tries to represent as faithfully as possible a real or a theoretical scenario. Giving values to this model and running it many times it is possible to examine its results and obtain useful conclusions.

8.2.2 Scheduling Bridge Repairs, Canada

This case pertains to developing a particular schedule for repairs, dismantling or construction of ten bridges in a region. The *selection consisted in determining which of the ten bridges should be scheduled for immediate, short term or long term repairs and/or replacement*. These works were financed from different sources from local, provincial and federal government, according to the ownership of each bridge, which posed an additional problem. There were other restrictions, for instance:

- The immediate repair or replacement issue included three different alternatives that is High, Medium and Low priority,
- State of repair of each bridge,
- Technical aspects to consider, related with each bridge age and permissible load,
- Neighbors opinions about the necessity of each one and frequency of use,
- Financial considerations, since funds came from three different sources,
- Replacement and geometric costs,
- Execution time for each bridge.

As can be seen, this is a complex problem, and it was solved using Simus. The result showed, for each bridge, the most appropriate period for repairs or replacement in accordance with the immediate, short term, or long term scenarios. For detailed information see Munier (2011a).

8.2.3 Selection of a Manageable Set of Urban or Regional Indicators to Measure the State of the Environment

The challenge is to *develop a set of a small set of indicators* (quantity to be established by the DM, and which may be no more than 25 indicators), out of an initial set of perhaps hundreds of indicators of every type, subject to many different criteria on diverse issues, and with the condition that each criteria must be expressed by a certain number of indicators (also at DM choice). In addition, the set of selected indicators must provide the maximum amount of information gathered for the initial set.

We have again a difficult problem that was solved by Simus. See Munier (2011b).

These few examples show the power of LP to solve actual and complex problems.

8.3 Different Methods

All models compare alternatives based on certain criteria, and follow three main procedures, as follows:

- (a) By establishing preferences from the DM (Methods AHP and ANP),
- (b) By using outranking of one alternative on others (Methods Electre and Promethee),
- (c) By computing distances to ideal and no-ideal points (Method Topsis),
- (d) By computing contribution to an objective function (Method of Linear Programming/Simus).

Each method has its advantages and disadvantages and some are more adequate for solving certain type of problems than others. For instance AHP is very often used when there are no values to build the decision matrix and for deciding the values of weights.

The explanation of the workings of each of the different method is beyond the scope of this book, and for that reason only the Simus process will be discussed. However, a comprehensive bibliography is provided for those readers interested in learning about other models and their use.

8.4 The Simus Method for Decision-Making

Simus is in reality an application of Linear Programming (LP) – a technique within Mathematical Programming – and especially the Simplex algorithm, developed by Dantzig (1948).

Since its inception LP has been applied and is currently used in thousand of applications around the world, and has deserved the title of the most important mathematical contribution of the twentieth Century. There is a vastly array of uses in many different fields, and a recent survey showed that most Fortune 500 companies regularly use linear programming in their decision making.

The Simplex method is an iterative procedure based in matrix algebra that optimizes a linear objective function subject to linear constraints. The process guarantees that it will find the best or optimum solution, provided that it exists. There are many computational programs to execute the Simplex; this book uses the ‘Solver’² which comes as an ad-in of the *Excel*³ spreadsheet. In reality the whole problem is formulated in Excel; the Solver takes the data from here, processes it following the Simplex algorithm, and returns the solution to Excel to a row previously chosen by the user.

The decision-making process starts with the building of the decision matrix as mentioned in Sect. 8.1. In LP this matrix has some extra features which are:

- An objective function that mathematically expresses what is the desired goal. It consists in a linear equation

² ‘Solver’ is developed by Frontline Systems Inc.

³ ‘Excel’ is developed by Microsoft Corp.

formed by the alternatives (as variables x_j) and coefficients attached to them. For instance, suppose that there are different alternatives for power generation, with the objective of minimizing costs, or maybe to maximize the economic benefit. If it is the first case the objective function can be expressed as:

$$Z = c_1x_1 + c_2x_2 + c_3x_3 \text{ (Minimum)}. \quad (8.1)$$

where:

Z = Objective function

c_j = Unitary production cost (€/MW) corresponding to each alternative

x_j = Variables that represent the different alternatives.

And in the second case:

$$Z = g_1x_1 + g_2x_2 + g_3x_3 \text{ (Maximum)}. \quad (8.2)$$

where:

' g_j ' = Unitary benefits (€/MW) corresponding to each alternative.

That is, in the first case, the sum of the products between the unit cost of each alternative times the amount of energy generated by that alternative, must be a minimum, and the opposite in the second case. However, the alternative coefficients are not always costs or benefits, they can have different meanings. For instance, if the objective aims at reducing contamination as much as possible, the coefficients could be amount of pollution per MW generated by each alternative, and then the objective will call for a minimization of the total contamination generated.

The formula of the corresponding objective function is placed in the Excel sheet in a cell chosen by the user. Again, the Solver will consider this formula to calculate Z , and then the result is being displayed in that cell.

- Another feature is that there must be a single value or a range to determine the scope of each criterion.

That is, if one criterion refers to economic benefits, then there must be a value (called '*independent term*', and identify as ' b_i ') that establishes a minimum value for that benefit. Normally, the owner or company promoting the project will want an Internal Rate of Return (IRR) as large as possible, and then the model needs a criterion that specifies what is the lowest IRR they are willing to accept. If not, the model can give a result with a very low IRR that the company will reject, since it would be more convenient to invest the money elsewhere.

As an example, the first criterion will be written as follows (assuming values for the coefficients a_{ij} , for A, B and C):

$$\text{Maximize } 125x_1 + 458x_2 + 240x_3 \geq 550 \text{ MW.}$$

The operator ' \geq ' (equal or greater than), is used to express that the sum of the outputs of all alternatives must be greater than or equal than 550 MW.

If the criterion refers to minimizing damage to the environment by controlling the emissions of a certain polluter gas, then this criterion will look like this (with assumed values for coefficients a_{ij} for A, B and C):

$$\text{Minimize } 0.67x_1 + 0.98x_2 + 0.79x_3 \leq 0.98 \mu\text{gr}/\text{m}^3.$$

Observe that the operator ' \leq ' (equal or lower than) has been now used.

If the criterion calls for equality, for instance establishing that all of the alternatives must be considered, then:

$$\text{Equal } x_1 + x_2 + x_3 = 1. \quad (8.3)$$

There are other aspects that can also be considered and incorporated into the model, for instance (this is another example):

- Project 7 must take precedence over project 18. This would be the case when to commence project 18, project 7 must be finished,
- If project 6 is chosen then, project 9 also must be chosen. For instance this is the case when planning hydro electric dams over a river, or when selecting contractors that form joint ventures for that project,
- The model must produce results in binary format, that is, the selection should be project 5 or 7, but not both,
- A project advance measured in percentage in a certain period, must tally the amount of money available in that period,
- In a portfolio of several projects to select, one of them, maybe for political reasons (for instance a promise made by a candidate in pre-election times), must be in the ultimate solution.

As appreciated, LP allows for many real situations to be modeled.

Once the decision matrix is prepared in an Excel spreadsheet, Solver is summoned, the Simplex applied, and a result obtained.

8.5 CASE STUDY: Construction of a Gas Pipeline

The case example shows the decision-making process using the Simus method.

8.5.1 Background Information

The South Pat Gas Company is considering developing a gas pipeline project to link gas wells with their polyester producing plant, about 157 km away, as the crow flies. The ground area is not uniform between the two places, because of the existence of medium and low altitude ranges

Table 8.3 Decision matrix – Construction of a gas pipeline

Selection criteria	A	B	C	Sum of values in rows
Estimated costs (×000) (€)	144,630	80,854	106,857	332,341
Percentage on surface	0.90	0.92	0.92	2.74
Percentage in periurban area	0.92	0.34	0.26	1.52
Rivers crossing	2.00	1.00	1.00	4.00
Forests crossing	2.00	1.00	1.00	0.57
Percentage in urban area	0.02	0.20	0.35	0.57
Percentage in hilly country	0.06	0.46	0.33	0.85
Percentage in tourist area	0.00	0.00	0.06	0.06

Table 8.4 Normalized decision matrix – Construction of a gas pipeline

Selection criteria	A	B	C	1	2	3	4
				Action	Result from calculation	Operator	Required threshold
Estimated costs (x000) (€)	0.04	0.24	0.32	MIN		≥	0.24
Percentage on surface	0.33	0.34	0.34	MIN		≥	0.33
Percentage in periurban area	0.61	0.22	0.17	MIN		≥	0.17
Rivers crossing	0.50	0.25	0.25	MIN		≥	0.25
Forests crossing	0.50	0.25	0.25	MIN		≥	0.025
Percentage in urban area	0.04	0.35	0.61	MIN		≥	0.04
Percentage in hilly country	0.07	0.54	0.39	MIN		≥	0.07
Percentage in tourist area	0.00	0.00	1.00	MIN		≥	0.00

Z= LP result

and a river valley. The engineering department says that there are three options or alternative routes (A – B – C), which vary in length, cost and difficulty according to the nature of the terrain. For instance one route is considerably longer than the other two, but also with the lowest construction costs since it follows the river valley, however it traverses a forest and an environmentally protected area. The other two alternatives are friendlier with the environment but involve higher altitude and a passage through the mountains by way of two expensive tunnels. Table 8.3 depicts the characteristics of each route, as well as the respective cost.

Therefore, it is of interest to decide about the most convenient route amongst the three, which are subject to eight criteria. That is, it is necessary to find a compromise solution between contradicting and even opposed features, such as distances and costs, and also involving economic, environmental and social issues, which are normally present in this kind of projects.

8.5.2 Establishing the Mathematical Model

The first step is to represent the problem into a mathematical model, which is a common procedure for all methods. The mathematical model takes the form of a table or matrix as

depicted in Table 8.3. Data is obtained from technical studies, surveys, expert's opinion and DM and stakeholders judgements.

The next step is the normalization or homogenization of this matrix, which is shown in Table 8.4. This is done by dividing each coefficient in a row by the sum of coefficients in that row.

Notice that four columns have been added to the original decision matrix and their purpose is:

Column 1: Expresses the sense of the action for a criterion. For 'Forest crossing', for instance, it is obvious that this crossing must be reduced to a minimum, hence the 'MIN'. In this example actions for all criteria call for a minimum, but they can be mixed in any order and quantity. For instance, if one criterion were 'Benefits to villages and towns', it is obvious that it should be maximized, because they could get access to natural gas for heating, cooking and small industries.

Column 2: It is blank because it is here where the Solver places 'Results from calculation' when the Simplex process is completed.

Column 3: Depicts the operators responding to the Actions, that is, '≥', '≤' or '='.

Column 4: Here are placed the values or thresholds wished, allowed, or mandatory for each criterion. For instance, for

Table 8.5 Solution values – Construction of a gas pipeline

Selection criteria	A	B	C	1	2	3	4	Marginal values
				Action	Result from calculation	Operator	Required threshold	
Estimated costs (x000) (€)	<u>0.44</u>	<u>0.24</u>	<u>0.32</u>	MIN	0.24	≥	0.24	
Percentage on surface	<u>0.33</u>	<u>0.34</u>	<u>0.34</u>	MIN	0.33	≥	0.33	0.15
Percentage in periurban area	<u>0.61</u>	<u>0.22</u>	<u>0.17</u>	MIN	0.23	≥	0.17	
Rivers crossing	<u>0.50</u>	<u>0.25</u>	<u>0.25</u>	MIN	0.25	≥	0.25	0.08
Forests crossing	<u>0.50</u>	<u>0.25</u>	<u>0.25</u>	MIN	0.25	≥	0.25	0.77
Percentage in urban area	<u>0.04</u>	<u>0.35</u>	<u>0.61</u>	MIN	0.34	≥	0.04	
Percentage in hilly country	<u>0.07</u>	<u>0.54</u>	<u>0.39</u>	MIN	0.52	≥	0.07	
Percentage in tourist area	<u>0.00</u>	<u>0.00</u>	<u>1.00</u>	MIN	0.00	≥	0.00	0.08
LP result	0.021	0.957	0.000					
Z = 0.2422								
Ranking to minimize costs	2	1						

criterion ‘Percentage on surface’, understandably, it is desirable to have as little pipe as possible above the ground, amongst other reasons, to prevent sabotage. Because of that we place in this column the minimum value that is 0.33. Why?

Because we could not get a percentage on a surface lower than the minimum offered by alternative A.

If we were maximizing a criterion such as ‘Benefits to villages and towns’, then we would put the maximum value. Why?

Because we could not get a benefit greater than the maximum offered.

There is also a new row, labelled ‘LP result’, which is now blank, because that is where the Solver will place the result of the problem, i.e. the figures whose values define the ‘best’ alternative.

Notice a cell (Z =), also blank, but where the formula for the objective function ‘Z’ will be placed to indicate the model which the objective is. This formula will be used by the Solver, and the final Z value will appear here when the computation is done. In this example, the objective function calls for a minimization of costs, through the following mathematical expression:

$$Z = 0.44 x_1 + 0.24 x_2 + 0.32 x_3 (\text{Minimum}).$$

Let’s analyze now the criteria; in each criterion the minimum coefficient value is underlined.

First criterion: The minimum value corresponds to B, which is then the best alternative according to this criterion.

Second criterion: Notice that values are very close, and for alternatives B and C are identical. This makes selection difficult because there is no clear winner, since there is not enough discrimination or differences between values.

Third criterion: The minimum corresponds to C, therefore there is no doubt here.

Fourth and fifth criteria: Both coincide in their values and minimums, favouring B and C.

Sixth criterion: The best value belongs to A.

Seventh and eighth criteria: They both coincide in the A alternative and alternative B is also preferred in the eighth criterion.

Observe that some alternatives have the best values for some criteria and the worse for others, for instance, alternative A is the best for the second criterion, but by far the worst for the fourth and fifth criteria. Something similar happens with alternative C; it is the best in the third criterion and the worst in the sixth, and the same applies to alternative B, which shares the best qualification with C in criteria fourth and fifth, but is by far worse in the seventh criterion.

With this table it is possible to understand the nature of the decision-making problem.

This is the scenario the DM is faced with, and then it is easy to realize that it could be very difficult to make an evaluation of the ‘best’ alternative. And this is the reason for using mathematical models. If the DM is happy with this matrix, that is, if he considers that it contains all possible available information and data, and those are reliable as possible, then he/she can run the Solver (after instructing the Solver about the location of data in Excel, which is done in a Solver window).

The process, even for complex scenarios takes only a few seconds, and then values appeared in column 2 ‘Result from calculation’ and row ‘LP result’, and the objective value shown in cell ‘Z=’. All are important, because values in column 2 must match the values of respective rows in column 4. Thus, for ‘Rivers crossing’ for instance, requiring a value of ‘0.25’, the corresponding value in column 2 must be equal to or greater than 0.25. If this does not happen, the Solver will indicate that a feasible solution has not been reached.

If there is indeed a solution, Solver will announce that it has reached a feasible solution of the problem, which is also optimum, that is cannot be bettered, and in row ‘LP result’ will appear the values for this solution. At the same time, a value will come into view for the objective function ‘Z’ in the box chosen by the DM. See Table 8.5.

Observe column 2 and check that all values are equal to or greater than (\geq) the corresponding values of the corresponding values in column 4. Consequently the values in the '*LP result*' row say that the largest value, by far, corresponds to route B, and hence this is the preferable alternative, followed by alternative A and with no value for C. Therefore the ranking is:

First choice : B = 0.957

Second choice : A = 0.021

Objective function Z = 0.2422.

Now, comparing alternatives A and B (since C has not been chosen), notice that alternative B is the best in three criteria (1-4-5), while A is the best in the other three criteria (2-6-7); why then did the model choose B by a large difference instead of A?

Because of the relative importance of criteria.

However, the DM did not use any weight to measure that importance, which, as was pointed out, is one of the advantages of LP. Therefore, where do these importance assessments of criteria come from?

From the Simplex, since it computed some sort of weights by itself.

The explanation lies in a curious and enormously useful feature of LP. That is, when a LP problem called '*primal*', is solved in the way explained (as in this example), its '*mirror*' image automatically appears where constraints become alternatives and alternatives constraints. This mirror image is called its '*dual*'. Both are like the head and tails of a coin and both give the same Z value, the same as a coin, which no matter how it is thrown into the air its value is always the same, irrelevant of the side it shows.

The difference between the primal and the dual is that the *primal gives the values of the alternatives that correspond to an optimal solution*, while the *dual produces the marginal values of the constraints*. These marginal values indicate how much the objective function changes when there is a unitary change in the marginal value. Therefore, even when this value is not a weight it acts as a weight, because the larger its value the more important the criterion, because the more the influence on Z.

In our example, getting the marginal values are not shown here, but are obtained in Excel (in a separate spreadsheet), at the same time when solving the primal. They are:

Percentage on surface : 0.15

River crossing : 0.08

Forest crossing : 0.77

Percentage in tourist area : 0.08

By definition, the unitary variation in any of the marginal values directly affects the objective function positively or negatively. Consequently, if we allow for instance for a higher cost as a threshold there will be an increase in the objective function, which of course is not desirable (remember that in this example it calls for minimum costs), while a lower cost will produce a decrease in the objective function. In both cases the variation can also produce a change in alternatives selected.

In this case, the marginal value for criterion '*Forest crossing*' is 0.77. It means that if we change the corresponding threshold from 0.25 (Table 8.5, column 4) to 0.26, (i.e. if we allow a larger percentage to be built in hilly country), there will be a corresponding increase in Z of a hundredth of 0.77. This can be easily checked just by doing that and running the Solver. The new objective function will be Z = 0.2499, that is 0.0077 larger. Remember that the marginal value considers the change of '*one unit*'; therefore if we change only from 0.25 to 0.26.

Is this a logical result?

Yes, because we have increased the cost, consequently the minimization before the change, that is the original problem, was better than after it. What happens if we decrease the coefficient?

Then, there will be a decrease in Z. However, not in this example, as a change from 0.25 to 0.24 does not produce any effect because the marginal values corresponding to criteria changed, and then '*Forest crossing*' is no longer critical and now '*River crossing*' is the most important criterion, however, the alternatives selection does not change.

As seen and by far the largest marginal value corresponds to '*Forest crossing*', and notice that for this criterion alternative A has the largest cost coefficient (Table 8.5), that is the least favored, and thus, not selected.

Something similar happens with the '*Percentage on surface*' criterion, which is the second most important. Notice that for this criterion, alternative A is now the most favored. However, since '*Forest crossing*' criterion has a much larger marginal value than '*Percentage on surface*' criterion, the model chooses alternative B.

8.5.3 Sensitivity Analysis

There are many tests that can be made by changing values, adding or deleting activities and criteria, as well as coefficients of the objective function, and new Z values obtained. This is called '*Sensitivity analysis*' and is a fundamental part of the process, since, as its name implies, it determines the sensitivity of a solution regarding changes in the data. In other words when an alternative or option is selected, the sensitivity

Table 8.6 Efficient results matrix – Construction of a gas pipeline

Objectives	A	B	C	Sum of values in rows
Estimated costs (x000) (€)	0.021	0.957		0.98
Percentage on surface	0.492		0.091	0.58
Percentage in periurban area			1.000	1.00
Rivers crossing	0.021	0.599	0.358	0.9
Forests crossing	0.021	0.599	0.358	0.98
Percentage in urban area	1.000			1.00
Percentage in hilly country	1.000			1.00
Percentage in tourist area	0.400	0.587		0.99

analysis permits determining how sensible is that solution to changes in some parameters such as construction costs, inflation, environmental issues, etc. In addition if the data is not very reliable and there are only approximate values, the sensitivity analysis can illustrate about how much the data can vary without changing the solution.

A sensitivity analysis can be performed by varying just one parameter or various simultaneously. The solution could be or not the same, that is, perhaps there is a new selection of alternatives and also there could be a change in the objective function, indicated by the Z value.

One important aspect to take into account, is that the result is the outcome of a rigorous mathematical process, and hence its optimality, but of course, its worth depends on the data inputted, and if said data is not correct or reliable, then the result will also be not trustworthy, since the mathematical model can do nothing to ameliorate it. But if the data is the best the DM can get, the result will show the best solution. However, it could very well be that the DM is not interested in getting this mathematically unchallenged solution, and instead prefers a solution that takes into account his/her opinions or his/her staff opinions and feelings.

This is normal and very frequent, and probably more valuable than the optimal result given by this method. Therefore, the model must have the capability to accept changes proposed by the DM. For instance, he may not like very much route C, because there is danger of flooding from a river. He then can create another criterion with this special circumstance and re-run the model. Perhaps the result does not change or may be it does, but the model will allow him to have the answer in seconds.

8.5.4 Projects with Several Objectives

The last section examined a case when only one objective was sought – that was the minimization of costs; however, in most projects there is more than one objective and usually qualitative and quantitative criteria, but unfortunately LP works with only one objective and with quantitative criteria. There are some LP variations that can work with several objectives such as ‘Goal Programming’ but that still need

quantitative criteria. Other methods exist, all based in LP, but their field of application is rather poor because they can only treat projects with a reduced number of alternatives and criteria, and again, these must be of a quantitative nature.

For that reason the method Simus was developed, for it allows working with *quantitative and qualitative criteria* in any proportion – and even with sole qualitative criteria – permitting also as *many objectives* as wished. However, Simus’ procedure, as opposite to LP, cannot guarantee that an optimal solution is reached.

To address the *qualitative* requirement Simus develops criteria whose thresholds are a function of the data, as was seen in Sect. 8.5.2. To address the second issue, i.e. the use of *several objectives*, Simus develops an algorithm, which is illustrated now using the same example for construction of a gas pipeline. In that case we worked with only one objective ‘Estimated costs’, but now, all criteria will be considered as objectives. The procedure is as follows, using the normalized matrix of Table 8.4.

1. Choosing one criterion or target (any), removing it from the decision matrix, and then using it as an objective function,
2. Using the Solver it gives – if it exists – a solution consisting in values for the different alternatives, in the same manner as was seen in the example,
3. These values are placed in a matrix called (Efficient Results Matrix, see Table 8.6). Then for the first criterion ‘Estimated costs’ the Simplex shows that the solution assigns 0.021 ‘points’ to A and 0.957 to B.
4. This objective function is then put back into the matrix (Table 8.4) and it becomes again a target,
5. Choose the second criterion ‘Percentage on surface’, remove it from Table 8.4 and use it as a new objective function. Run the Solver and new values for the alternatives are obtained, in this case $A = 0.492$ and $C = 0.091$. Place these values in the second row of Table 8.6 and put back into Table 8.4 the target extracted.
6. Choose the third criterion from Table 8.4 and repeat the whole operation, getting the value ‘1’ for C, and place it in the third row of Table 8.6. Put back this objective into Table 8.4.

Table 8.7 Normalized efficient results matrix – Construction of a gas pipeline

Objectives	A	B	C	
Estimated costs (×000)(€)	0.02	0.98		
Percentage on surface	0.84		0.16	
Percentage in periurban area			1.00	
Rivers crossing	0.02	0.61	0.37	
Forests crossing	0.02	0.61	0.37	
Percentage in urban area	1.00			
Percentage in hilly country	1.00			
Percentage in tourist area	0.41	0.59		Sum of values in row
Sum of columns (SC)	3.31	2.80	1.89	
Participation coefficient (PC)	0.88	0.50	0.50	1.88
Normalized participation coefficient (NPC)	0.47	0.27	0.27	
Simus result (SC) × (NPC)	2.90	1.40	0.94	
Multiobjective ranking	1	2	3	

7. Choose the next one and follow the same procedure until all targets are considered.
8. Once Table 8.6 is completed, normalize it using the same procedure as explained before, and build Table 8.7.
9. Add-up values for each column and get the ‘Sum of columns’ (SC) row,
10. Count the number of times an alternative has values regarding criteria. For instance, A has values in 7 criteria, B in 4 and C in 4. This is called ‘Participation’,
11. Find the ratio between the participation number just found and the total number of criteria, in this case 8. The result is the ‘Participation coefficient’ (PC) row,
12. Normalize these values and get the ‘Normalized participation coefficient’ (NPC) row,
13. Multiply SC times NPC and get the ‘Simus result’. The values obtained are the final result.

As seen, because we now consider multiple objectives, the alternatives ranking changed, and now is:

First choice : A = 2.90

Second choice : B = 1.40

Third choice : C = 0.94

Why did the result change?

Because in the first case we considered that the whole project should satisfy *only the minimum cost objective*. In the multiobjective case, the problem *must satisfy simultaneously eight objectives* – therefore the result could change – and it did, including now alternative C as a third option, and changed the ranking of alternatives, with alternative A as the best one. It is considered that a multiobjective scenario is closer to reality since some objectives other than costs are now incorporated, such as environment and social aspects which are nowadays mandatory issues to take into account in projects evaluation.

8.6 Vendor Selection

When there are several sellers, vendors, manufacturers and contractors competing for a work in a project, this technique can be very advantageously used. In this case the criteria may cover a large range such as experience, number of works completed, background information from other clients, prices, reliability, time compliance, etc. A detailed example of its use in vendor selection can be found in Munier (2011a).

8.7 Conclusion of This Chapter

This chapter examines an important issue, which is the selection of projects to be executed out of a list of potential candidates, a situation common in investments as well as financial firms. A methodology has been explained using an actual example for a project with only one objective, and the same project when several objectives are considered and exemplified. Sensitivity, a fundamental issue, has also been examined and commented.

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Abstract

This chapter focuses on the very core of project management that is the planning, scheduling and control of the job. It commences with project planning where all the activities pertaining to the project have to be detailed and sequenced. This is normally a complex and a delicate task and because of that, the *Critical Path Method (CPM)*, used for this endeavour, is exemplified in a simple but comprehensive enough case to understand and grasp the methodology, which is the base for the use of planning software such as MS Project® (Microsoft), and Primavera® (Oracle). It follows with the construction of the ‘S curve’, a very useful tool, which is paramount in monitoring work really done and money actually spent. The *Work Breakdown Structure (WBS)* is also explained to describe this tool for the right allocation of funds to work packages. Naturally, potential activities to safeguard against risks are also considered, and an example using *PERT (Program Evaluation and Review Technique)* is proposed when there is high uncertainty in the completion time of activities.

Scheduling takes into account resources and floats, and also aims at having the utilization of the available resources as steady as possible in order to maximize their deployment. Contractors’ schedules are also examined in order to verify matches between all contractors, that is, a smooth transition from the end of one subproject and the beginning of another. Control, a most fundamental activity, details a series of actions to perform and documents to prepare to make sure that everything goes as planned in time and costs.

Keywords

Cost estimate • Responsibility matrix • Critical path schedule • S-Curve • WBS • Master schedule

9.1 Planning the Work Related with a Project

To start the planning process the following sequence is suggested albeit it does not mean that it must be followed in a strict chronological order. It is supposed that prior activities such as market study, design of the product object of the project, and approval from Board of Directors are completed, as well as the Project Charter, and also that a rough estimate of costs and feasibility has been performed and found adequate. It is also assumed that the owner’s staff

is doing the project management or that a consultancy firm has been retained for that purpose.

9.1.1 Requesting Information About Tasks and Activities

Requests are sent to each department of the firm demanding a listing of all tasks or activities concerning each department and perceived necessary to execute the project. Thus, Human Resources, if staff recruitment becomes necessary

Table 9.1 Task information by departments – Planning a water supply system to create a water park

Task code	Task name	Task department	Task load (man hours)	Task responsibility and dedication (%)	Task load (man power)	Task duration (days)	Task precedence
0–1	Mobilization	Const.	100	R. Wright (80)	4	4	
1–2	Survey & Staking	Const.	120	R. Wright (20)	2	4	0–1
1–3	Clear & Grub	Const.	230	Tom Wark (5)	1	3	0–1
3–4	Trenching	Const.	570	Tom Wark (15)	3	18	1–2, 1–3
1–6	Stringing	Const.	700	Tom Wark (15)	6	10	0–1
6–7	Welding	Const.	800	Tom Wark (30)	4	10	1–6
4–5	Bedding	Elect.	280	Tom Wark (5)	6	12	3–4
7–8	Placing pipe	Const.	600	Tom Wark (15)	8	12	4–5, 6–7
8–9	Testing	Test.	160	Tom Wark (10)	2	2	7–8
9–10	Backfilling	Const.	220	Tom Wark (5)	1	3	8–9

and according to a human resources plan, must produce a list of activities such as: Preparing qualifications descriptions, placing advertisements in the media, contacting people who fulfill the requirement for a position, interviewing them, and finally producing a short list, which will be handed over to the project manager (PM), for him/her to decide on the person or persons who will be invited to join the project.

Another department, say, Civil Construction, must make a list of all activities for them to perform, for instance, ‘*Construction of building for stamping press*’, and then detailing aspects such as: Mobilization, excavation, foundations, forming columns, installing roof, cladding, etc. In turn the Mechanical Department, will prepare specs for tenders aiming at ‘*Equipment supply and installation*’.

In addition, these lists must provide the following information:

- Duration of each activity in days, weeks, or whatever unit of time the PM chooses. The same unit of time is to be used for all activities or tasks no matter their nature or department to which they belong, and must indicate only working days, that is without weekends or holidays,
- Equipment needed for executing each task,
- Number of people needed to perform each task and dedication in percentage or number of days for each person. Of course a person can participate in several different tasks,
- Name of the responsible person in each department for every activity,
- Natural sequence, that is indicating which task or activities precedes or precede another one or several; a task is usually preceded by another and in turn, may precede others.

9.1.2 Planning for Manufacturing Projects

What is needed for planning? The following list can help.

- Design of product, building, service, etc.,
- Bill of materials,

- Materials cost,
- Manpower needed,
- Manpower cost,
- Indirect cost,
- Tooling cost,
- Tasks to perform,
- Task sequence,
- Resources cost,
- Equipment cost,
- Other resources.
- Work calendar,
- Resources calendar,
- Scheduling,
- Demand,
- Duration of each task,
- Sale cost,
- Unit cost,
- Origin of funds,
- Hire personnel,
- Place purchase orders,
- Quality cost,
- Safety costs,

9.1.3 CASE STUDY: The Critical Path Method (CPM) – Planning a Water Supply System to Create a Water Park

Table 9.1 shows an example of necessary information for planning a job. In this case it is for a water supply system project, which is part of a larger undertaking, and data is provided by a company, or by the owner, or by the consultant’s Mechanical and Electrical Department and/or by a contractor. Probably the only column in need of explanation is the last one, where ‘*Precedence*’ means that a task can not start until another one – a precedent task – is finished. Different kinds of precedence are explained in

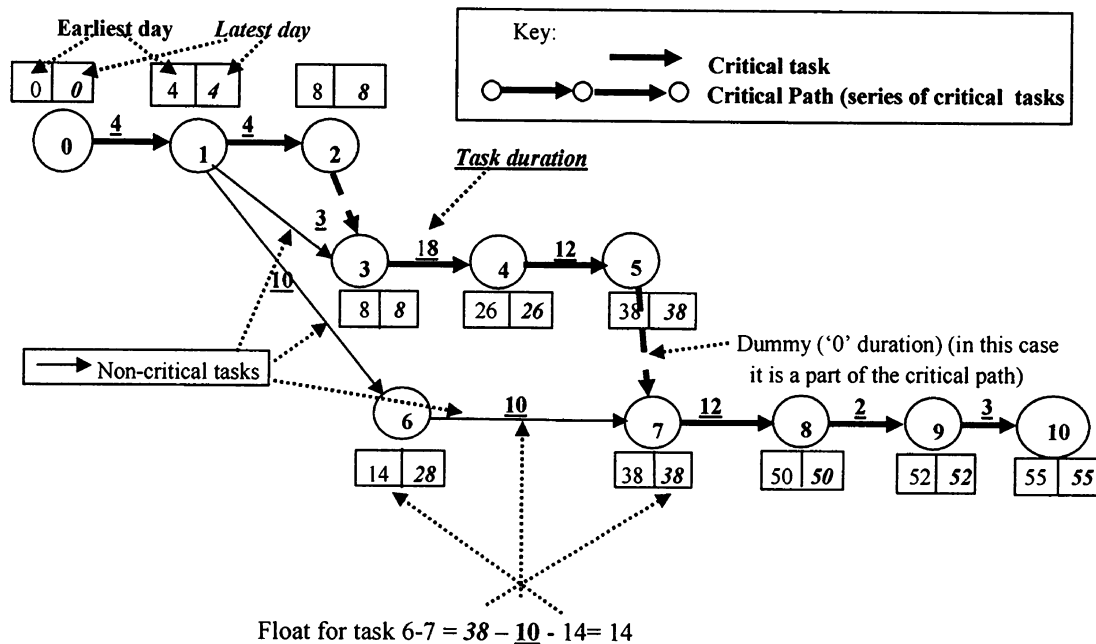


Fig. 9.1 Construction of logic or arrow diagram – Planning a water supply system to create a water park

Sect. 9.5, which are normally used when solving the problem by dedicated computer software.

Durations come from personal experience, dedicated tables for cost estimates, estimating software, comparison with similar tasks in other projects already completed, etc.

9.1.3.1 Establishing the Sequence of Work by Building the Logic Diagram

This step involves the construction of a diagram composed by nodes (which represent only instants), and arrows (which correspond either to tasks, or indicate precedence, according to the system used); this arrangement is also known as a ‘network’ or as an ‘arrow diagram’ or ‘logic diagram’.

Build the diagram as you wish, that is, it does not matter the length, inclination or shape of the arrows (they even can be curves), either representing tasks or precedence. Using arrows to indicate tasks is one method of building this diagram; using nodes to represent tasks is another one, but the procedure is the same, and naturally so is the result of the calculation. Using one or another method is just a matter of preferences. Refer to Fig. 9.1 where arrows represent tasks and with data from Table 9.1.

Start with the first task ‘Mobilization’, task code (0–1), from node ‘0’ to node ‘1’. Observe that no task precedes this one, therefore it is the first. Now check which is the task or tasks that are preceded by task (0–1) and draw them. In this case, they are ‘Survey & Staking’ (1–2), ‘Clear & Grub’ (1–3) and ‘Stringing’ (1–6). Observe that underlined numbers are placed above each arrow; they indicate the duration of each one.

To commence ‘Trenching’ (3–4) it is necessary that both ‘Survey & Staking’ (1–2) and ‘Clear & Grub’ (1–3) be finished. Precedence from task 1–2 is indicated with a dashed arrow, called ‘Dummy’. This is a non-real task; it has ‘0’ duration and its only purpose is to indicate that task (1–2) must precede the task starting in node ‘3’, that is task (3–4). We could have indicated this by placing an arrow from node 1 to node 3, but then there would be two tasks with the same coding; to avoid this, a dummy must be used. A dummy can also be employed when several tasks precede others. Incidentally, the dummy is not necessary when using the other method commented on above.

Continuing the analysis:

- ‘Welding’ (6–7) can commence only when predecessor 1–6 has finished,
- ‘Placing pipe’ (7–8) can star only after bedding (4–5) and welding (6–7) have finished; a dummy is used again to indicate this (4–5) precedence,
- ‘Testing’ (8–9) can only be done after that ‘Placing pipe’ has finished,
- ‘Backfilling’ (9–10), the last task, can start only after the test has finished, and of course can be executed only when ‘Testing’ is complete.

The logic diagram is finished, it has been useful to show precedence, and now we can start working with it.

9.1.3.2 Using the Logic Diagram

We proceed with a forward and a backward analysis. Forward analysis is used to compute the total duration of the project.

Forward Analysis

We begin with task (0–1) assigning a value of ‘0’ as its **earliest start day**, i.e., the day when the project starts, and place this value in the left square box (over node ‘0’). Since this task has duration of 4 days, it should be finished $0 + 4 = 4$ days later; this value is placed in the left square box (over node ‘1’) and therefore it indicates task (0–1) **earliest finish day**.

Notice now that three tasks originate in node ‘1’. The first one (1–2) will finish in $4 + 4 = 8$ days, from the project start date, the second task (1–3) will finish in $4 + 3 = 7$ days, and task (1–6) will finish in $4 + 10 = 14$ days. The two first tasks precede task (3–4); then, which will be the early start date for task (3–4)? Obviously the largest, that is 8, and as such an 8 is placed in the left square box corresponding to node (3). Notice that if we choose 7 days instead of 8 days, task (3–4) have to still wait 1 day to start because (1–2) has not finished yet. Following this procedure and since task (3–4) has an 18 days duration, it will finish in $8 + 18 = 26$ days from the project start date.

Task (4–5) will finish in $26 + 12 = 38$ days; therefore, the early start day for next task (7–8) will be $38 + 0 = 38$. This value is placed in the left square box above node (7).

Let now analyze task (1–6). It will finish in $4 + 10 = 14$ days from the start of the project, and then task (6–7) will finish in $14 + 10 = 24$ days after the initiation of the project. This last task precedes task (7–8), but notice that the latter is also preceded by task (4–5) from another branch and through a dummy, with 38 days, which is then the early start day for task (7–8) and preferred over the other value of 24 days, coming from the other branch of the diagram. Continuing with the calculation, task (7–8) will finish in $38 + 12 = 50$ days, task (8–9) in $50 + 2 = 52$ days and finally task (9–10) in $52 + 3 = 55$ days from the project start. **This is the minimum duration of the whole project, and also should be the maximum.**

Backward Analysis

Since the project lasts 55 days it is the project’s **earliest finish day** (placed in the left square box above node (10)). Since 55 days is the total duration of the project this figure also represents its **latest finish day**, and we indicate that by placing this figure in the right square box above node (10) and in *cursive*. Now we go backwards, that is computing the latest finish days for each task to start. Observe that for task 9–10 the **latest start day** will be $55 - 3 = 52$. This value is enclosed in the **right** square box above node (9).

Following the same procedure, we find that the latest day that task 8–9 can start is $52 - 2 = 50$, and task (7–8) will have a late start day of $50 - 12 = 38$.

Now, task (4–5) through the dummy, will have a latest start day of $38 - 0 = 38$ and for task (3–4) will be $38 - 12 = 26$. In turn task (1–2) through the dummy will have $8 - 0 = 8$ as latest day.

If we analyze the other branch, task (6–7) will have a latest start day of $38 - 10 = 28$, which is also placed in the right square box above node (6). Task (1–6) in turn will have a late start day of $28 - 10 = 18$.

Now, task (1–3) will have its latest start on $8 - 3 = 5$ days, while task (1–6) latest start day will be $28 - 10 = 18$ days, and remember that task (1–2) has $8 - 4 = 4$ days as latest start. Which of these three values do we choose? The smaller, i.e. 4.

Why? Because choosing one of the other two values will produce a late start day that will delay the project. For instance assume that we select as late start day the one corresponding to task (1–6), that is 18. Then, all tasks commencing in node ‘1’ should commence at this day as the latest and the project will be delayed.

Finally we reach task (0–1) whose late finish is $4 - 4 = 0$, that is equal to its early day.

9.1.3.3 Finding the Critical Path

Now notice that there are nodes where the early and late days coincide; they can be linked by a continuous line (bolded), from start to finish. This is the **critical path** of the project. Why is it critical? Because a delay in any of its tasks will affect the whole project. Because of that, the critical path is formed by a series of **critical tasks**. These are, as can be guessed, very important tasks and special attention should be taken for their time compliance, through monitoring and control. Regarding the critical path, usually there are more than one in a complex project.

9.1.3.4 Computing Floats in Non-critical Tasks

Floats, measured in days, is an important characteristic of non-critical tasks. It means how much a task can be delayed without influencing the total duration of the project. Look at the calculation done at the bottom of Fig. 9.1, which considers as an example task (6–7). If the difference between late starts in nodes ‘6’ and ‘7’ is calculated, and from this value the duration of the task deducted, the result in days, is called **float**. In this case it is: $38 - 10 - 14 = 14$ days.

What is its meaning?

It means that task (6–7) has 14 days margin to start without compromising the total duration of the project, i.e., it can start at any day between 14 and 28, and provided that it keeps the same duration of 10 days. Floats are very important because they are used for resources appropriation. However, note that this task starts at its late date, that is at day 28 and takes say 12 days to complete, then it will finish on day 40, and, in addition of delaying 2 days the whole project, it now becomes a critical task. Tasks that have floats are called **non-critical**.

9.1.3.5 Determining Completion Date

If a start date is defined, say for instance 20 June of 2011 (that corresponds to the ‘0’ early start day in node ‘0’), then

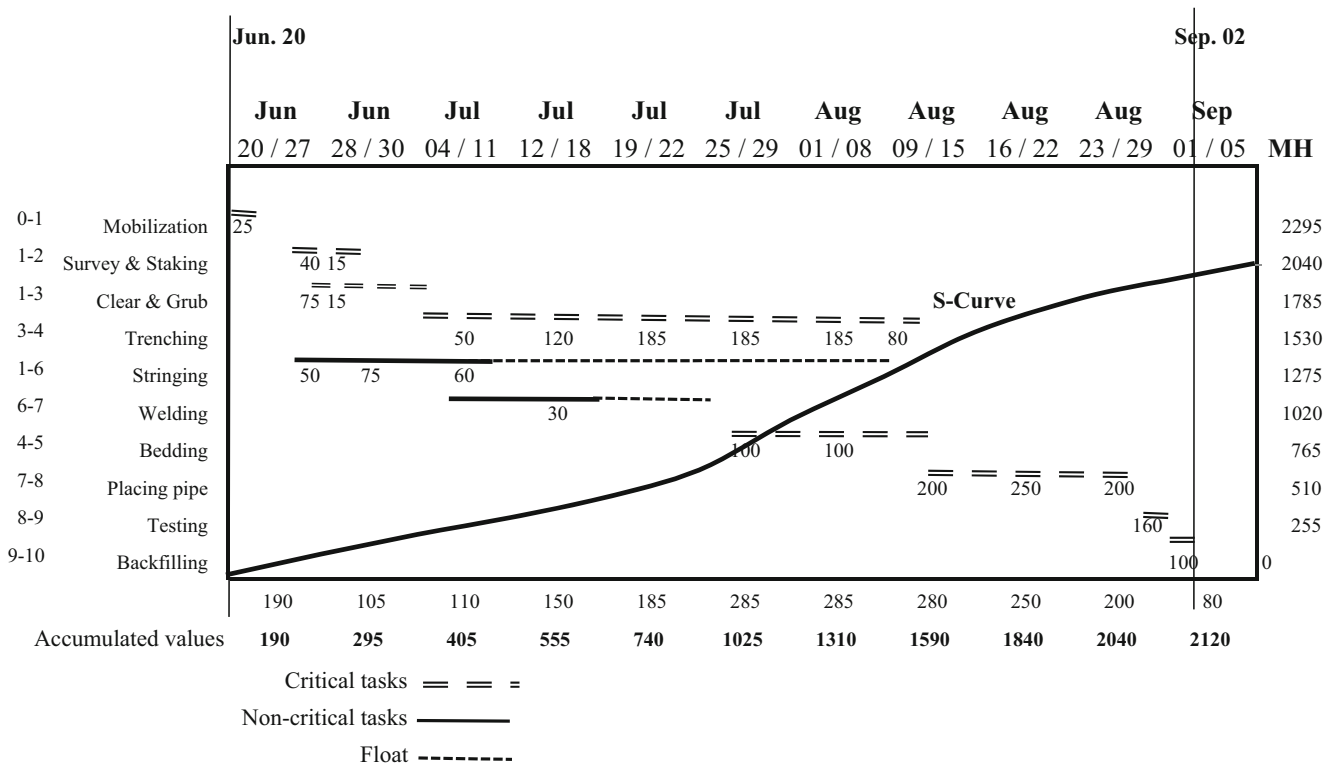


Fig. 9.2 Gantt chart, MH load and S-curve – Planning a water supply system to create a water park

task (0–1) will finish on June 23. Task 1–2 will then start on 24 June and will finish on 27 June, and so on. The completion date of the project spanning 55 working days will correspond to 02 September, assuming that not work is performed on Saturdays and Sundays.

9.2 Scheduling the Job

The logic diagram with days, allows for the construction of the Gantt chart, where tasks are represented by horizontal bars drawn to scale and then spanning the periods that they represent. Since this Gantt chart is produced as a result of the computation of the logic diagram, the bars are in the correct sequence and precedence. However, they can be displaced to the right if so desired, using the floats in the non-critical tasks, in order to get a levelled resources usage. See Fig. 9.2 and notice how the float for task 6–7 (38 – 10 – 14 = 14 days), is represented in the bar chart by a dashed line.

9.2.1 Constructing the S-curve

Once a horizontal bar is drawn representing the duration of a task, the total amount of man-hours estimated for its

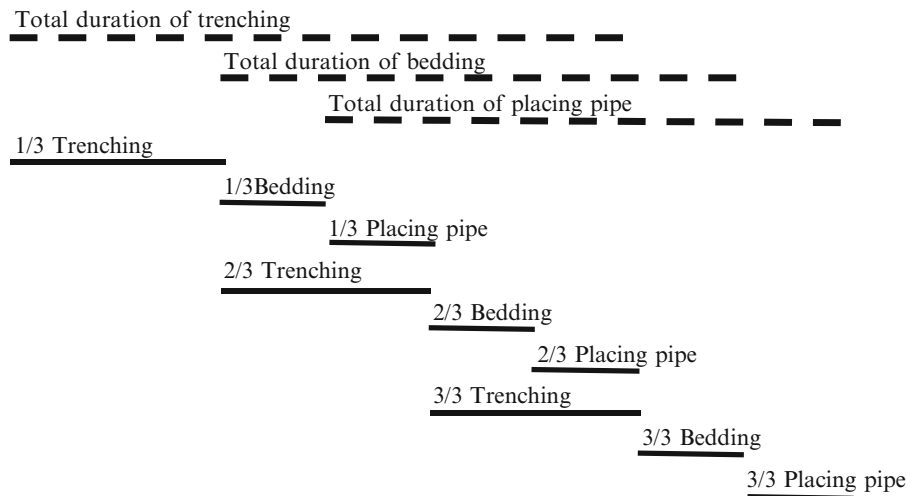
execution is spread along the bar in accordance with the experience of the scheduler as well considering lessons learned from past similar tasks, type of terrain, etc. These values are represented for each task in Fig. 9.2. The monthly amount of man-hours is then added up, and then the accumulative value is computed for each month; these are the values used to draw the S-curve.

The S-curve represents the progressive amount of MH (or money) spent along the length of the project. Along with the logic diagram and the Gantt chart, the S-curve is a contractual document, since it indicates month to month how many man-hours or how much money should have been spent. The main use of the S-curve is to monitor the advance of work, through what is called ‘Earned Value Analysis’, which is explained in Chap. 16.

9.2.2 Working in Parallel

The sole purpose of the example developed has been to illustrate the Critical Path Method used all around the world. However, in an actual scenario there are some other aspects that must be considered; for instance, it is not realistic to plan the project in the way it was in this example, since normally it is not necessary to wait the finish of some task in

Fig. 9.3 Breaking down tasks – Working in ‘cascade’ – Planning a water supply system to create a water park



order to start another. In our example, there is no need to start bedding only when trenching has completely finished, since if this latter task takes say 18 days to complete, in reality it would be possible to start bedding after say the first third length of trenching is completed, while trenching proceeds with the second third. The same can be said about placing pipes, since it can be done when first part of bedding is finished and the trenching is its third length. Sketching this arrangement it would show as in Fig. 9.3 (not at scale). Obviously the total time has been reduced.

9.2.3 Shortening the Duration of a Project

This same procedure may be used if it becomes necessary to shorten the duration of the project; select some critical tasks and try to work in parallel with some successor tasks. For an extensive and deep digging such as for construction of underground parking, excavating machines, trucks and cranes are used. However, the work can be accelerated if the area is attacked simultaneously from several points, using naturally more excavators, trucks and cranes. This naturally translates into larger expenses but everything is conditioned to the importance, characteristics and urgency of the project. However, this is not always possible. If it is a small excavation, probably there is no room for other machinery; therefore this solution might not be possible.

9.3 The Master Schedule

We have analyzed an independent project. However, in large projects there are normally many different networks pertaining to diverse areas or to different contractors. Then, there could be contractors for earth moving and excavation, as well as for civil work, mechanical, electrical installations,

painting, etc. Normally each one of them will produce a logic diagram, a network, using the same time units, which must be approved by the PM and staff.

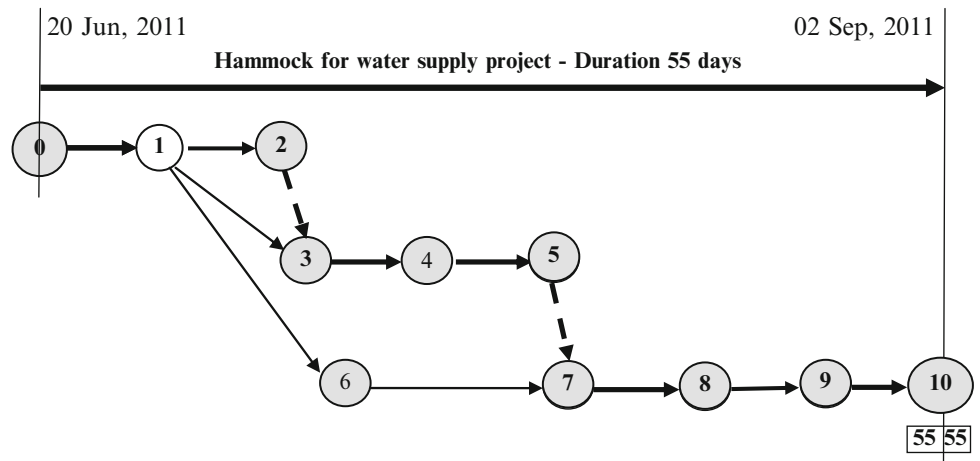
In order to be able to analyze at a glance the whole project, all these subprojects must be integrated. However, it could be very difficult to look at a mix of networks with thousands of activities. For this reason, normally an entire network is replaced by a single bar with a length equal to that found by the critical path method. In this way, a large project can be perhaps displayed in a single sheet of paper, which is very often used for discussion with the client, and which also is a contractual document. This single bar, that can span years, is called a ‘*hammock*’, and it is exemplified in Fig. 9.4. The set of these hammock bars constitutes the **master schedule**.

9.3.1 Merging Networks

Figure 9.5 sketches three merging schedules. In this case it refers to a project for the construction of an electric power station, which will be equipped with two gas turbine-generation sets. Three main contractors are considered here, namely, the civil (A), responsible for earth moving, foundations and buildings. The gas turbines manufacturer (B), located overseas, and the electrical contractor (C), in charge of all wiring, supply and installation of the control panel and ancillary electrical equipment.

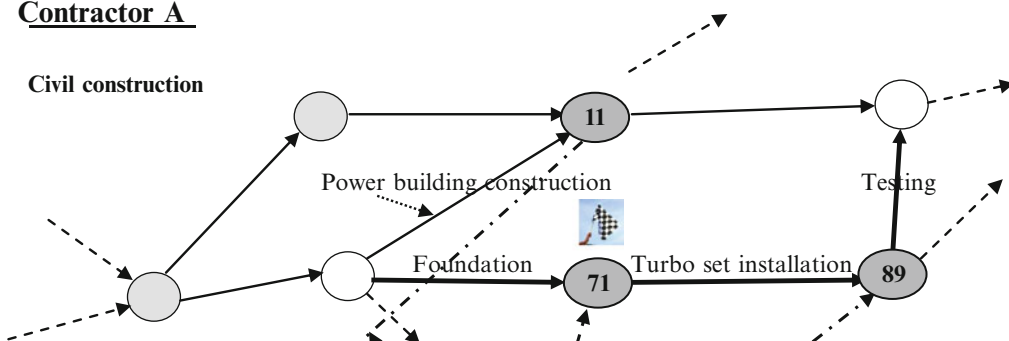
Consequently, there are three independent logic diagrams or networks which have been approved by the consulting firm or by the owner. It can be seen that when the three networks are integrated there is coordination between the three contractors by appropriate links. When solved, there would be start and finish days and dates for each task as seen in Sect. 9.1.3.1, in such a way that every contractor will know when he must deliver or receive something

Fig. 9.4 A hammock spanning the whole length of a project – Planning a water supply system to create a water park



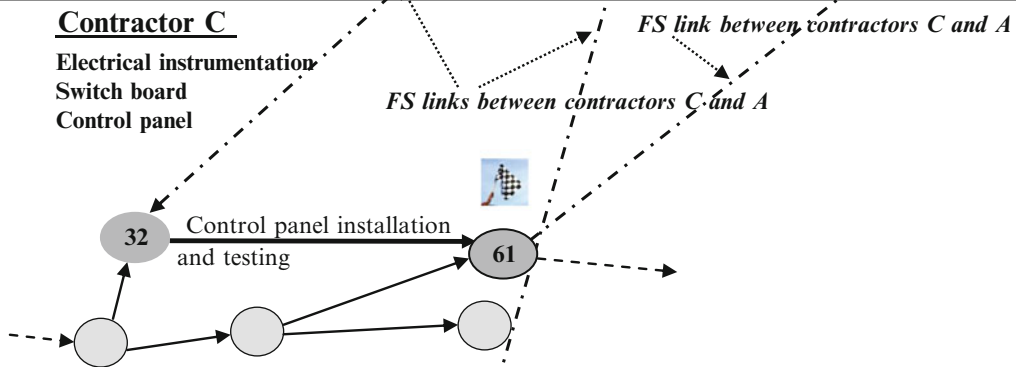
Contractor A

Civil construction



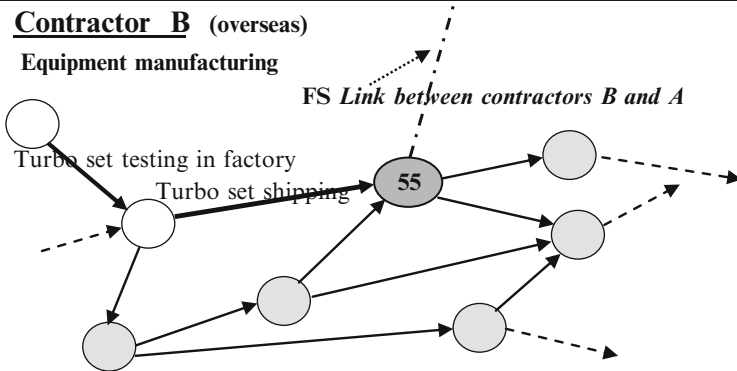
Contractor C

Electrical instrumentation
Switch board
Control panel



Contractor B (overseas)

Equipment manufacturing



Milestone

32

Initiation or completion of a task

→ Task

- - -> Link between contractors

- - -> Other tasks

Fig. 9.5 Merging networks – Electric power station

to/from another contractor. As an example, once contractor A finishes construction of the power building (node 11), the electrical contractor (node 32) can start wiring and installing the control panel.

When the equipment foundations are ready (node 71) (this date is important, notice the flag that identifies this node as a milestone, that is a date that must be honoured, for whatever reasons), contractor B, the turbines generator manufacturer, can start installing them once the equipment has arrived at the site (node 55). The finish to start (FS) link establishes this condition. Possibly at the same time the electrical contractor (C) will be working on the installation of the control panel (node 32), and finishing it in node (61).

In this case, usually constraints are inputted stating for instance that turbo set installation (finishing at node 89), and control panel installation (node 61) should be finished at the same time (which is indicated by the FF link (61–89) allowing for the commencement of testing (node 89). These nodes are very important events and it is usual to consider them as milestones that must be honoured.

There are several conditions that can be imposed to this model, and then it would be extremely difficult to solve it (that is finding the critical and floats) by hand. For this reason, and taking into account that actual networks can run in the thousands of tasks, it is necessary to use dedicated software.

9.3.1.1 Dedicated Software for the Critical Path Method

There is no lack of computer software to solve these networks since there are many different programs, but all of them follow the same principles. However, two of them are usually chosen for large undertakings; one is called 'Primavera'®, by Oracle®, and the other 'Projects'® by Microsoft®. Both are complex software and can manage thousands of tasks, with all kinds of links, using a sort of resources and producing the S-curve, as well as an assortment of different graphic and tabular reports.

An example of the use of one of these programs can be found in Sect. 9.5. In complex projects constituted by a number of subprojects, there are networks and critical paths for each one, however, these subprojects can be integrated as mentioned and then the critical path of the whole project may pass through different subprojects.

9.3.2 Preparing the Master Schedule with All Subprojects Merged

To illustrate the procedure, assume a project where a general contractor is in charge of the construction of an industrial complex in a remote area. The project involves the erection of large industrial buildings and a road to a nearby harbour.

In addition, and because of the remoteness of the place, 22 houses will be built to be used by workers and staff when the plant is in operation, including a small hospital and a school, as well as the supply and installation of production equipment. The general contractor has subcontracted specialized activities which become subprojects, with subcontractors from different European countries. Table 9.5 shows an example of this master schedule which details the names of these subcontractors, the value of their subprojects and the duration in months. The percentage of participation or weight of each one is also shown together with the date when they will take place, from June to January, similar to a Gantt chart, but instead of having bars to indicate the length of a task it uses percentages of completion in each month and its accumulative value. For instance for 'Electrophoresis cell' there is 10% done in June and only 6% in July, therefore the accumulated value at this last month is 16%.

Check that at the end of the project, total percentages for each subcontract must tally the percentage values for each subcontract; the accumulative percentages for each month allow for the construction of the S-curve as explained in Sect. 7.5.2.

9.3.2.1 The Kick-Off Meeting

This is a meeting usually held at the very beginning of the project or at the starting of a very important task. It usually brings together the owner, the constructor, and project management staff, and representatives of the different contractors that will work in the project, which makes a good opportunity to meet each other. Its purpose is to discuss the project, to comment on its different features, difficulties and risks that might be encountered, and establish some sort of agreement about how to conduct the undertaking. This way, everybody knows which of the procedures established by the project manager are, how to submit schedules, reports, claims,¹ etc., and what is expected from each one. The project charter is discussed and analyzed, and it constitutes the opportunity for everybody to ask questions and get answers. In addition it is the time to warn all participants about norms on safety, environment and quality.

9.4 CASE STUDY: Developing the Basic Engineering for an Automobile Plant

A remark about this case:

It is based on an actual complex project, and tries to replicate actions and procedures as in the original case, but it is presented in a very much simplified and limited

¹ 'A legitimate request for additional compensation (cost and/or time) on account of a change in the terms of the contract' (Max's 1990).

format and detail in comparison with the actual one. Its objective is to utilize it as a template to demonstrate the use of each of the tools and procedures explained in this book for the planning phase.

The case starts when a small automobile company (DIN Corp.), calls for bids regarding the provision of project management services for the development of the basic engineering of a new plant project. DIN selected two project management consultants – TEAMIC Corp. – for mechanical installations, and MYCON Corp. for civil works, with the following scope:

- (a) The development of the basic engineering for a new automobile plant (TEAMIC and MYCON), and
- (b) The project management during the construction of the plant based on the basic engineering done by both consultants.

It is believed that in lieu of enumerating and commenting on all the necessary procedures documents and workings, it is more useful to illustrate them when applied to a case; from this point of view a series of subjects are exemplified and arranged chronologically, albeit they are not in a strict sequential order. As posted, the example tries to replicate a situation where two consultants intervene – which is not an unusual case – to show the necessary interactions between them. The work is divided into three phases and this example only considers TEAMIC's actions.

Phase 1. Preparation of cost estimate for submitting a proposal to DIN,

Phase 2. The project management for the development of the basic engineering.

Phase 3. The project management during the construction period.

In so doing the example tries to be a sort of guide for planning and scheduling, albeit does not include execution, monitoring and control, for these aspects are examined in other chapters. Although the whole of these procedures may not be applicable to a specific project, it is expected that the reader will be able to choose the procedure that better fits his/her project and discard the others. The sequence is:

1. *Organization of the project management team.*
Answers the question: *How is TEAMIC organized for this job?* (See Sect. 9.4.3),
2. *Determine the scope of work.*
The scope of work must be clearly defined and included in the TEAMIC contract with the owner.
Answers the question: *Where does the project start and finish from the consultant point of view?* (See Sect. 9.4.4),
3. *Work Breakdown Structure.*
Answers the question: *What are the components of the project for planning, scheduling and cost data purposes?* (See Sect. 9.4.4),
4. *How is the responsibility shared when more than one management consultant is intervening?*
It considers the fact that, since this project implies the working of two different and independent consultants, it is necessary to establish responsibilities, communication channels, coordination, etc., (see Sect. 9.4.6),
5. *Consultant's integration*
Answers the question: *What are the mechanisms implemented to materialize coordination and cooperation between consultants?* (See Sects. 9.4.6 and 9.4.7),
6. *Relationship with owner*
It is related with reaching an understanding with the owner or his representative about lines of communications, getting a list of intervening stakeholders, stipulating periods for analysis and responses, agreeing on type of information required, fixing frequency of reports, etc.
Answers the question: *Who is the owner's representative with authority to make decisions and who are the contacts within the owner's organization? Who are the people authorized to receive information about the project?* (See Sect. 11.2),
7. *Acquiring the project team.*
Answers the question: *What personnel or staff will perform the job?* (See Sect. 9.4.9), and *what are the established qualifications for each one?*,
8. Answers the question: *Who will be responsible for a particular assignment?*, (See Sect. 9.4.10),
9. *Preparing scheduling of meetings with the project team.*
Answers the question: *When to meet – dates and frequency – and for what purpose?* (See Sect. 9.4.11),
10. *Planning and scheduling the work.*
Answers the question: *What must be done, when, and with what resources, to attain the final goal?* (See Sect. 9.4.12),
11. *Budget preparation*, that is, assuming that the individual cost for work package in the WBS is available (see Chap. 12).
(Answers the question: *How much will be the Euro value of work done at certain fixed intervals and along the project, which translates in future progress payments to contractors?* (See Sect. 9.4.12),
12. *Determination of schedule of funds* needed to honour these payments from the cash flow point of view (see Sect. 4.3),
Answers the question: *Will there be enough future funds to guaranty payments when they are due?* (See Sect. 9.4.15),
13. *Preparing the master schedule for coordination between the two consultants*
Answers the question: *How will the interrelationship between consultants be managed?* (See Sect. 9.4.13),
14. *Merging schedules.* (See Sect. 9.4.13)

Answers the question: *In case that there are subcontractors involved, how is it guaranteed that work is handed over in time from one subcontractor to another?*), (see Sect. 9.3.2),

15. *If use of software is possible.*

Answers the question: *How are they used?* (See Sect. 9.5),

16. *Use of dedicated software.*

Answers the question: *Are there computational tools to help in this endeavour?* (See Sect. 9.4.12),

17. Determine the project baseline (The S-curve) (see Sect. 9.4.14),

18. Determine schedule of funds needed (see Sect. 9.4.15),

19. *Shortening the duration of project.*

(Answers the question: *Is it possible to shorten the duration of the project, and if feasible, at what cost?* (See Sect. 9.6).

9.4.1 Project Background Information

DIN Corporation manufactures pick-up trucks. The present day plant employs outdated technology, with excessive manual work and old equipment, affecting costs and efficiency of the manufacturing process, and thus becoming non-competitive; for that reason DIN has decided to build a new and modern plant for a new truck model, coded 'Road-runner', and has already purchased a tract of land in Romania to build the new plant. DIN fabricates the chassis; sheet metal stamps the body, as well as casts molten aluminium to produce some pieces that are further mechanized in the plant, and has a chain of suppliers for parts, subsets and ready to install complete sets; for instance, the engine. DIN also manufactures the rear-cargo box or bed, for a maximum weight of 1,800 kg.

DIN has engaged an external marketing consultant, who, as a result of a survey involving about 5,000 clients has provided some facts perceived by users, as well as suggestions about the necessity of introducing some improvements. This information has allowed DIN's Design Department to propose a more robust vehicle, with better suspension (which is one of the complaints), better design of doors aiming at a better fit, and also adding features unknown to the original vehicle, such as the anti-lock braking system (ABS).

DIN's Board of Directors has given the green light to the project of building the new plant with an estimated cost of 82,500,000 € to produce the new model with chassis and body blueprints completed, and with specs for its different components. Our analysis commences with TEAMIC's proposal answering DIN's call of bids for management consultants.

9.4.2 Bidding for Consultancy Services to Develop the Mechanical Basic Engineering

In this first phase TEAMIC prepares its offer based on its costs estimate (direct and overheads), and including contingencies, profits and taxes. Table 9.2 shows this analysis. Notice how the final cost was computed considering duration for each activity, responsible person, area or department, dedication, number of people involved in each task, and hourly rate.

Using this data TEAMIC builds a logic diagram (not shown here, but following the principles explain in Sect. 9.1.3.1), to determine the length of the work and proposes DIN to develop the basic engineering in 240 working days, at a cost of 3,080,391 Euros.

9.4.3 Teamic Organization for This Project

For this assignment TEAMIC is organized according to the organization chart shown in Fig. 9.6. Notice that DIN has appointed a technical representative (Miquel Piquer) to whom DIN's project manager (Jules Magarell) and MYCON project manager (Gregory Rusk), report.

Observe that TEAMIC has divided the work into six main areas with a corresponding responsible for each one. Naturally there is a lot of interaction between these areas which is mainly accomplished by periodic meetings and informal communications.

9.4.4 Determining Scope of Work

This is one of the first actions taken by the project team in order to be sure about the extent of the work to be accomplished. There must be a clear definition of TEAMIC's responsibility about a task commencement and its completion, especially in order not to conflict or interfere with DIN's technical departments. In addition, it is necessary to clarify what information must TEAMIC receive from DIN, by who, and when. The scope of work for this project involves:

9.4.4.1 First Phase

From the point of view of the *product to be built*, the documentation must be related with these truck components:

- Chassis & body assembly,
- Steering system,
- Engine, gearbox and clutch,
- Brake system,
- Transmission system,
- Rear cargo area (Bed), and must deliver at the completion of the assignment:

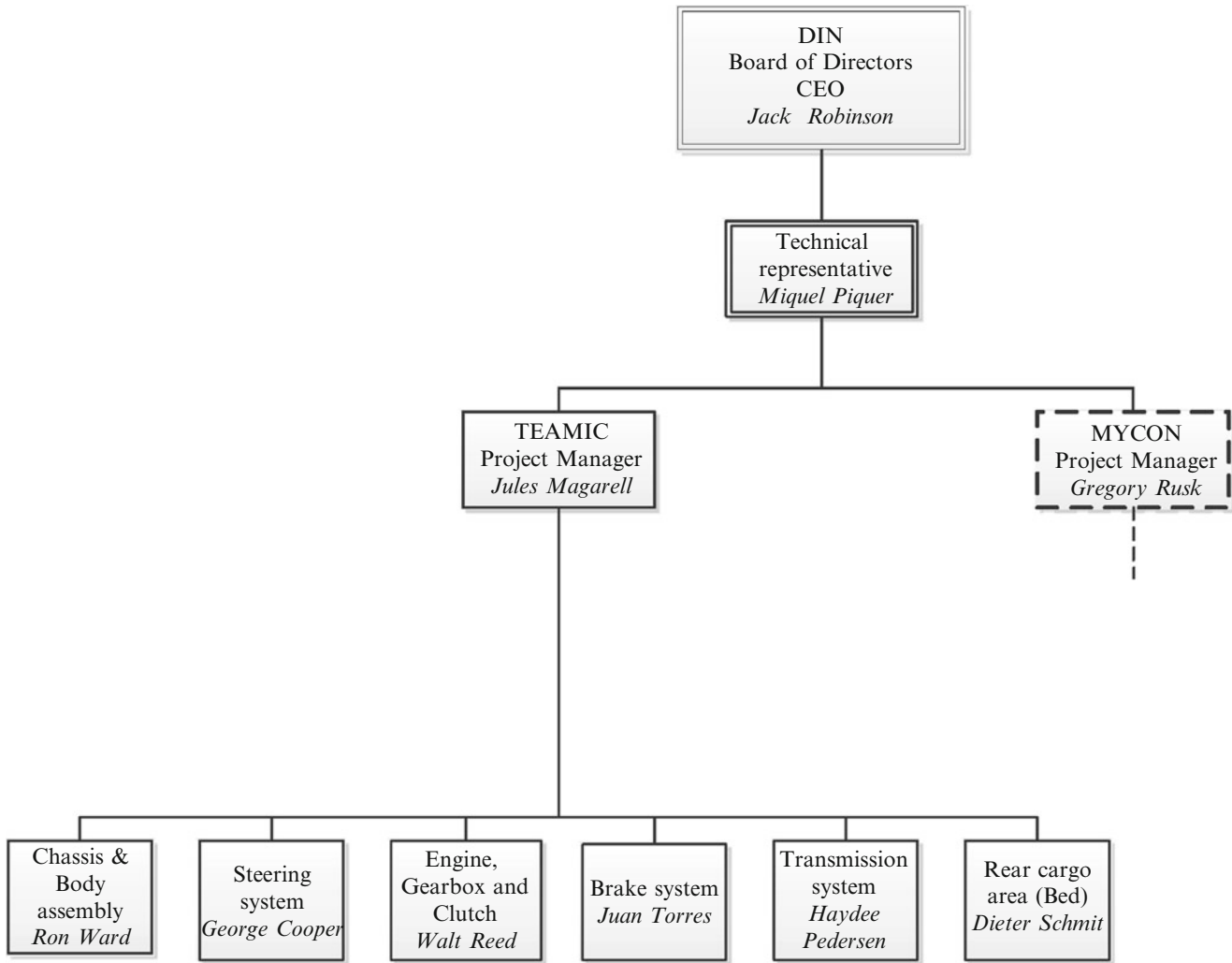


Fig. 9.6 TEAMIC organization chart – Developing the basic engineering for an automobile plant

- Documentation for each main component,
 - Main characteristics,
 - Suggestions that can improve the product (for instance the use of electrophoresis to protect the chassis from corrosion and that was not considered in DIN's initial design),
 - Drawings,
 - Sketches,
 - Calculations,
 - Minutes of conversations and correspondence with suppliers, including those documents that were important during the assignment period,
 - Minutes of visits to potential suppliers workshops, and general opinion about their efficiency, experience and reliability,
 - Since probably most suppliers will be from Western Europe, there must be an appraisal of the best transportation mode, that is by rail, truck or by ship, in order to get the most economic freight cost and also to avoid traffic problems in winter time because of roads that might be blocked by snow.
- From the point of view of *facilities and logistics*, the documentation must include:
- General layout of the plant indicating the location of different buildings,
 - Intra-plant transportation routes with their justification,
 - Contacts and informal quotation from equipment suppliers,
 - Short listing of potential suppliers and their qualifications,
 - Characteristics of equipment offered,
 - Helping DIN in vendor selection, advantages and disadvantages of each supplier as well as a comparison between similar equipment,
 - Quality norms to be followed and required from suppliers,
 - Safety procedures to be installed during manufacturing,
 - Environment regulations that have to be met,
 - Suggestions about manufacturing improvement to avoid contamination, (for instances for the paint shop and foundry ovens).

9.4.4.2 Second Phase

In this phase, that is, once the client has approved the basic engineering submitted, he will call for tenders for construction of civil works and for supplying, installing, testing and guaranteeing equipment purchased. In this phase, TEAMIC will act on behalf of DIN as project and construction manager for the whole project (including civil works), and will be in charge of:

- Issuing of all tenders documentation for civil construction, and for supply, installation and testing of mechanical and electrical equipment. Purchasing will be executed by DIN's Purchasing Department,
- Preparing the Master Schedule linking civil works activities with execution and installation programs from all manufacturers and suppliers,
- Exerting monitoring and control,
- Authorizing progress payments for constructors.

TEAMIC's Project Manager, Jules Magarell, prepares his staff requirements, which are sent to TEAMIC Human Resources Department for recruiting.

9.4.5 Establishing the Work Breakdown Structure (WBS)

DIN's engineers have prepared a Work Breakdown Structure for the new truck. It broke down the project into its components, based on a hierarchy regarding levels of completeness, and in so doing establishing the relationship between components and deliverables. There were four levels structure, as seen in Fig. 9.7.

Fourth level: Raw materials, components and subassemblies (Work packages)

It involves the most basic constituent elements, which are components and subassemblies. In this case they are:

- The sheet stamping of the chassis and body elements, which are coded accordingly as 1.1.1.1 and 1.1.1.2,
- The assembly of different subsets from parts either purchased or produced in the plant. They are: The steering wheel (1.1.2.1), steering rod (1.1.2.2) and locks (1.1.2.3),
- The assembly of the steering system pump (1.1.3.1), brake pump (1.1.3.2) and the windshield wipers system (1.1.3.3),
- The assembly of cardan and its joints (1.1.4.1), cardan (1.1.4.2), differential (1.1.4.3) and rear axle (1.1.4.4),
- The set of bed supports (1.1.5.1) and the construction of the wooden standard bed (1.1.5.2).

Third level: Subsystems assembly.

- Chassis subsystem (1.1.1)
- Steering and suspension system (1.1.2)
- Hydraulic subsystem (1.1.3)
- Transmission subsystem (1.1.4)

- Rear cargo area system (1.1.5)
- Engine, gearbox and clutch (1.2.1)
- Water proof test (1.2.2)
- Noise detection (1.2.3)

Second level: Assembly of vehicle systems

- Assembly line (1.1)
- Circuit testing and protocol (1.2)

First level: Vehicle

- Light truck (1)

Each code is assigned a cost (materials plus labor); for instance there are costs appropriated to work packages coded 1.1.2.1, 1.1.2.2 and 1.1.2.3. Summing them up, the cost of the assembly subsets for subsystem 1.1.2 is obtained. Adding up the cost values from the third level one gets the cost of all the components entering the assembly line. Finally summing the accrued costs from the second level gets the final cost of the vehicle. During the continuous operation phase a comparison (monitoring) can be made between the estimated cost for each package and its actual cost (see Chap. 16).

The WBS (prepared by DIN) has been handed over to TEAMIC, which needs this information for making the fabrication or assembling layout, i.e. deciding where each component, subassembly and assembly will be fabricated or put together, as well as the complete vehicle assembly operations, in order to obtain a coherent flow of materials to the final assembly line. The *purpose is to design the complete logistic system*, that is receiving raw materials from suppliers (such as steel sheets and beams), already fabricated elements (such as tires, but that need to get assembled to wheels, that come from another supplier), and parts (such as windshield wipers, or radios, or mirrors, etc.), and ready to install components such as the engine, and inspect and store them in the main warehouse. From there each element will be sent to the corresponding section following a route as lineal as possible. This task includes the vehicle assembly line where assemblies are attached to the body, and finishes when the truck is complete and rolls off the assembly line.

A WBS is incomplete if a dictionary is not compiled, which exactly details the scope of each task. A complete description of the purpose and extension of this dictionary can be found in Sect. 5.3.3.2 of PMBOK (Project Management Institute 2008).

9.4.6 Establishing Consultants' Responsibilities

Since MYCON is the recipient of TEAMIC's final layout and specs relative to the location of buildings and ancillary civil works, both consultants must work as closely as possible and responsibilities delimited. For instance, issues

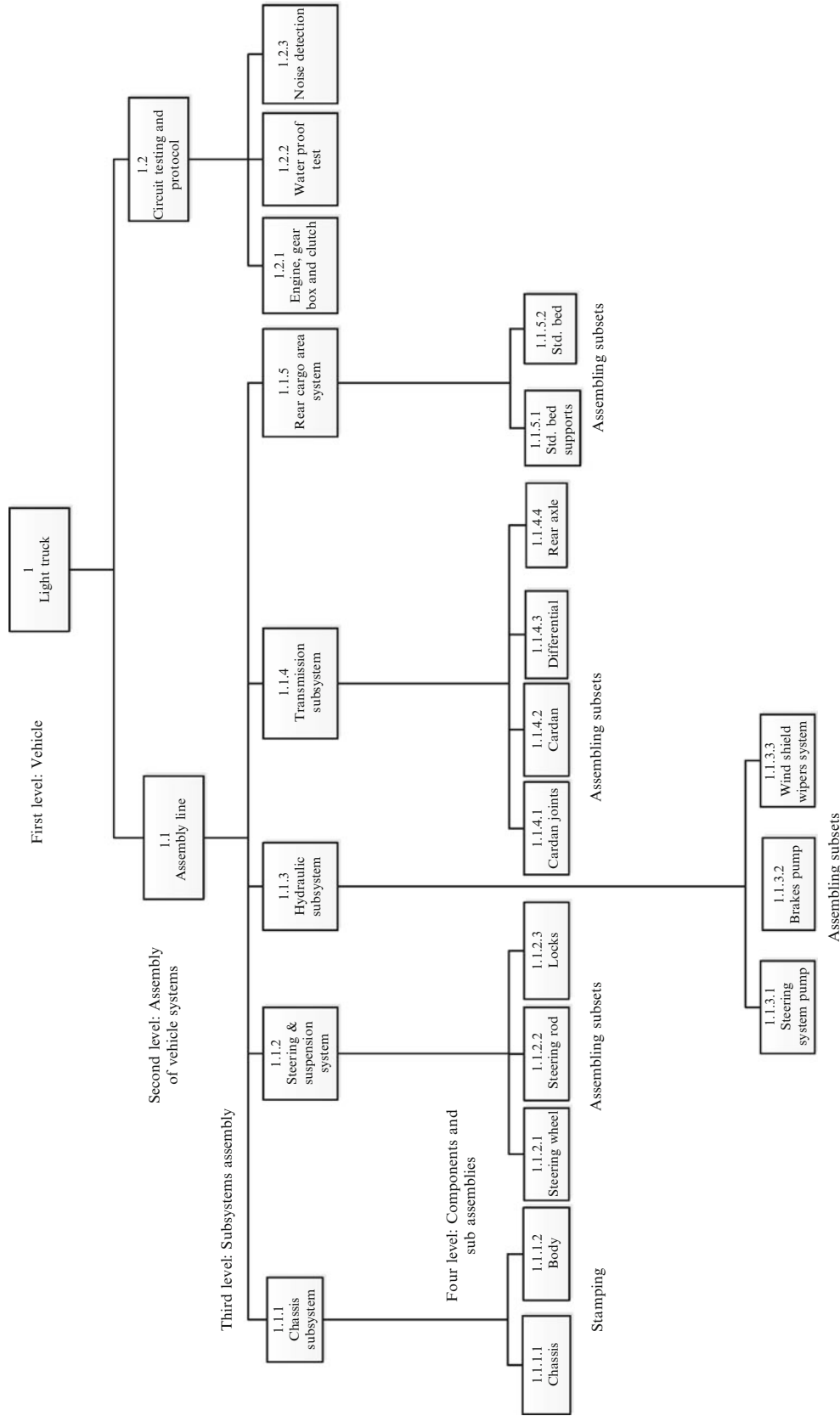


Fig. 9.7 Work breakdown structure – Developing the basic engineering for an automobile plant

such as who will be in charge of supervising the installation of anti-slip flooring in the machines shop area must be properly addressed, as well as many other issues where there could be uncertainty about responsibility.

We have already detailed TEAMIC's scope of work. Even when it is working on its own, there are usually many aspects that are related to the civil works contractor. For instance, TEAMIC is responsible for the design of the foundation needed for a large metal stamping press and has obtained information from its manufacturer about the recommended characteristics (such as depth, length and width, as well as type of steel bars needed). TEAMIC must inform MYCON about this, and probably requiring from this consultant information regarding soil characteristics, and this intelligence conveyed to the press manufacturer. There are also vibration considerations that must be vetted by MYCON and the information passed on to the press manufacturer. In addition, the depth of the excavation is a data that MYCON requires in order to foresee the type of excavation equipment to use.

9.4.7 Integration and Linkages Between Intervening Project Consultants

Jules Magarell as TEAMIC's PM and his counterpart Gregory Rusk from MYCON, have held preliminary conversations and agreed to meet as a minimum twice a month to establish norms and standards common to the two areas. Even when MYCON is charged with the design of civil works, it has been already commented that it needs information from TEAMIC for certain technical aspects, as the mentioned foundation, or low and high voltage circuits, requirements for industrial sewage (as for example sludge from paint and body shops), dimensions for a large excavation to accommodate the concrete tank for the electrophoresis process of the chassis, etc. Similarly, TEAMIC needs information from MYCON, such as completion dates of excavation and foundations for installing heavy equipment, as well as dates of accessibility of building areas for starting electrical installation, etc.

As a consequence, as a starting point, Magarell and Rusk decide to establish a tentative plan contemplating the interactions of both firms, as well as information from suppliers. This agreement materialized in a master plan showing those activities or tasks for which it is necessary to share information and establishing precedence, as is for instance the date in which TEAMIC must deliver technical information for MYCON to start with the civil work. A logic diagram was prepared with the special purpose of determining the sequences for this joint effort, which allowed for the determination of the critical path, which also led to the Gantt chart, used for discussions. The

estimated duration of the work, as per the critical path, was submitted, discussed and approved by the client. This diagram is not shown here since a very similar case was developed in Sect. 9.3.1.

Both PMs have agreed in paying special attention to tasks on the critical path and have established a common data base through their computers that allows each one of them to view on line and in real time the advances (and delays) of the other consultant.

Miquel Piquer – DIN's technical representative – will interact with Magarell and Rusk for the duration of the project. In so doing Piquer demands weekly meetings to analyze the advances of the project, with the presence of the two project managers, and in that circumstance the technical reports from TEAMIC and MYCON will be discussed. These meetings must be attended also by the responsible individual of each functional area of the project to supply the data and detailed information that might be required. Keep in mind the necessity of preparing and sending to attendees and with enough anticipation, a summary about the subjects that will be treated during the next meeting, allowing each participant to be prepared for answering questions from the owner and from other contractors.

At the end of each meeting, minutes must be prepared by the project management team including the main aspects discussed, conclusions, resolutions, and owner's comments.

These minutes must be sent to each attendee with a request for its signed acknowledgement.

9.4.8 Relationship and Communication with Owner

Prior to the signature of the consultancy contract with DIN, Magarell has insisted on a clause by which assumptions and conclusions submitted by TEAMIC must be approved by DIN's engineers within 20 days in order to continue with the work. Assessed by the Legal Department, Magarell wants to protect TEAMIC from future rejections of work already done. In this form the submittal to the client is defined by milestones and the approval of each stage is a sine qua non condition to continue with more advanced work. These milestones are displayed in the contractual Gantt chart.

9.4.9 Acquiring Project Team – Determining Type and Qualification of Staff Needed

Once these subjects have been defined by DIN and MYCON, Magarell begins to determine the qualification and availability

Table 9.3 Responsibility matrix – Developing the basic engineering for an automobile plant

Function/Area	Responsible	Tasks
Project manager	Jules Magarell	TEAMIC's project manager and responsible for the whole mechanical area of the project. Works together with TEAMIC's Human Resources for selection of middle management. Prepares the functions manual and assesses in the writing of documents for the bidding for electro mechanical equipment and installation
Chassis and body systems	Ron Ward	Responsible for chassis and body. The chassis involves using C-shaped rails (from supplier), held by welded crossbars to form a ladder type rigid frame. The body is made up from stamped (by DIN), of steel sheet. Also responsible for the electrophoresis treatment for corrosion protection
Steering system	George Cooper	The steering system is assembled by DIN from parts and components by suppliers. This area is also responsible for the independent suspension and chock absorbers system in the four wheels
Engine, gear box and clutch	Walt Reed	The Diesel engine is imported from Germany together with the gear box. There are several components and parts, some manufactured by DIN and others by suppliers
Brake system	Juan Torres	Responsible for the two brake systems (front disk and rear drum brakes, including the hand brake), as well as the hydraulic system, anti-lock braking, and fuel tank
Transmission system	Haydee Pedersen	Comprises the cardan shaft, universal joints, and differential, rear axle as well as the exhaust system including muffler, and supports
Rear cargo area (Bed)	Dieter Schmidt	Responsible for the rear cargo area comprising the bed (by DIN) as well as its assembling and fixing to chassis using some parts manufactured by DIN

of the personnel he needs, and even the necessity for hiring new people, since TEAMIC is a medium size consulting firm, and its roster does not have the additional number of engineers and technical staff for this project.

9.4.10 Team Responsibility Matrix

Table 9.3 shows the six operative areas and gives a brief description of responsible staff and their duties. This is also an important document to avoid misinterpretation in the future, and especially in forestalling that work from one area encroaches into the work of another area, or even replicating something already done. It is also convenient to prepare a '*functions manual*' detailing for each one of the main positions the scope of work, and procedures to interact with others.

9.4.11 Preparing Schedule of Meetings for the Project Team and Suppliers

A schedule of meetings is prepared for each task, as shown in Table 9.4.

9.4.12 Planning and Scheduling TEAMIC's Own Work

It is done using MS Project® (from Microsoft) computer software (albeit in this simple case it can also be made by hand). Figure 9.8 shows the logic for TEAMIC's work using the precedence between tasks given by the PM or analyst as explained in Sect. 9.1.3.1. The software draws the logic diagram (see Fig. 9.8) and from it depicts the bar or Gantt

chart as portrayed in Fig. 9.9, (can also be drawn by hand in this scenario). A brief examination shows that:

- In the logic diagram, critical activities are indicated by rhomboids (or by rectangles with a different color) representing critical tasks 1–17–18–19, 21. They are linked by precedence arrows and the complete set constitutes the critical path,
- There are labels on the links between tasks indicating the dependency established by the analyst, such as FS (Finish to Start), and SS (Start to Start),
- Tasks 6, 11, 17 were scheduled to start on April 18, (look at the Start to Start label (SS) in the corresponding links. They do, except task 17, which starts August 08. Why? Because for some reason, perhaps resources availability, task 17 cannot start immediately after its predecessor (task 1) finishes, that is, August 07, but later. However, in addition to resources there could be other reasons that explain the delay in starting task 17 (and in others such as 16 and 20). It could be for instance that a '*Do not start earlier than*' constraint was introduced for this task (or a '*lag*' in days included), because the responsible department needs to have some information and tests performed on materials, and they will be only due on August 07 for task 17. Of course this constraint could have been indicated as another task in the diagram, but the Transmission Department chose to place it as a restriction instead.
- The software also allows for indicating priorities in assigning resources. That is, some activities may allow postponing the use of the needed and competing resource in comparison with others which do not have that leeway. This is what apparently happened here, since as seen in Fig. 9.8 the assigned priority for task 17 has a value half the priority assigned to other tasks. Under this circumstance, naturally, the software prioritizes the execution of other tasks over task 17.

Table 9.4 Schedule of meetings – Developing the basic engineering for an automobile plant

Task number	Task duration	Initial meetings (a week before the task starting date)	Initiation dates	Follow up meetings: every 15 days from initiation dates until closing dates, except where indicated	Closing meeting
1	60	11 Apr 11	18 Apr 11		08 Jul 11
2	15	26 Sep 11	03 Oct 11	Every 10 days	21 Oct 11
3	45	04 Jul 11	11 Jul 11	Every 10 days	09 Sep 11
4	15	17 Oct 11	24 Oct 11		11 Nov 11
5	60	05 Sep 11	12 Sep 11		02 Dec 11
6	35	11 Apr 11	18 Apr 11	Every 10 days	03 Jun 11
7	45	31 May 11	06 Jun 11		05 Aug 11
8	15	05 Sep 11	12 Sep 11		30 Sep 11
9	20	09 Nov 11	16 Nov 11		06 Jan 12
10	10	02 Jan 12	09 Jan 12		20 Jan 12
11	35	11 Apr 11	18 Apr 11		03 Jun 11
12	35	03 Aug 11	10 Aug 11		11 Nov 11
13	10	07 Nov 11	14 Nov 11	Every 10 days	25 Nov 11
14	10	02 Jan 12	09 Jan 12		20 Jan 12
15	10	15 Feb 12	22 Feb 12		06 Mar 12
16	30	16 Feb 12	23 Feb 12		23 Mar 12
17	90	01 Aug 11	08 Aug 11		09 Dec 11
18	45	05 Dec 11	12 Dec 11		24 Feb 12
19	7	20 Feb 12	27 Feb 12		06 Mar 12
20	15	16 Jan 12	23 Jan 12	Every 10 days	10 Feb 12
21	60	29 Feb 12	07 Mar 12		29 May 12

- Look now at Fig. 9.9 which depicts the Gantt chart, and be also aware that the second column is blank. This column is used by the software to show information regarding each task; different icons indicate different issues, for instance that the task is completed, or that there is some sort of constraints established by the analysts, or that it belongs to a milestone, etc.
- Observe too that the start and finish dates established by the software are based on a calendar whose format was specified by the analyst. In this case, notice for instance that task number 3, that should start immediately after the finishing of task 1 (Friday, July 08), really is scheduled to commence later (on Monday, July 11), because Saturdays and Sundays are considered non-working days. The user can change this and specify other calendars if needed, as well as the number of working hours per day and holidays. This is very useful considering for instance that May 1st is a statutory holiday in most countries (Labor's Day), while it is a working day in the USA and Canada; therefore, if the planning for a project is done in the USA or Canada, and the job location is say, Argentina, make sure that the software considers May 1st as a holiday. In addition each country has a different set of religious and national holidays and not all of them consider Sundays as holidays, but rather Fridays or Saturdays or whatever other day; this is another fact that should be taken into account when planning and scheduling, and can be easily done with these programs.

Other columns can be created at will depicting aspects such as percentage of completion, WBS, costs, floats, dedication, etc. There are many other useful features in this program as well as in others widely used such as Primavera® (from Oracle), and then the reader should read carefully their operating manuals in order to extract the maximum benefit.

The next step is the calculation of the S-curve, done by computer or by hand considering either a Euro value for each task or block of man-hours (see Sect. 9.2.1).

Look at the information provided by Fig. 9.9. It shows for each task, its duration in working days (information produced by the PM or analyst, and the precedence, also from the same sources). The Early Start and Early Finish dates can be computed by hand in this not complicated example (also it is possible to have columns with Late Starts and Late Finish dates); however, here they have been obtained by computer.

9.4.13 Preparing the Master Schedule Including Merging Programs from Different Contractors

We are now in the second phase of our case, that is, assuming that subcontractors, manufacturers and suppliers have been chosen. Table 9.5 shows the master schedule prepared by TEAMIC considering all the intervening parties (general

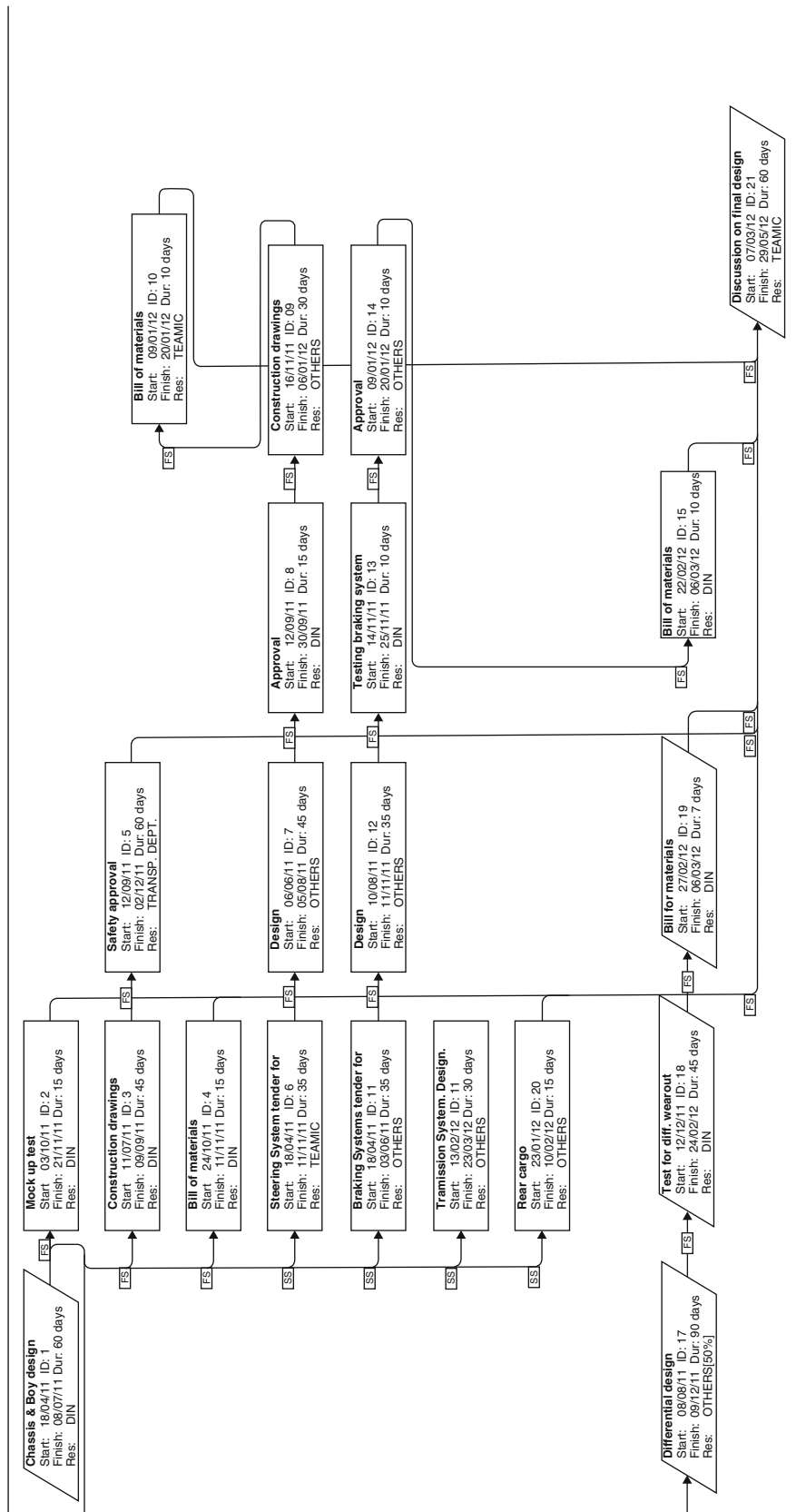


Fig. 9.8 Logic diagram for TEAMIC activities – Developing the basic engineering for an automobile plant

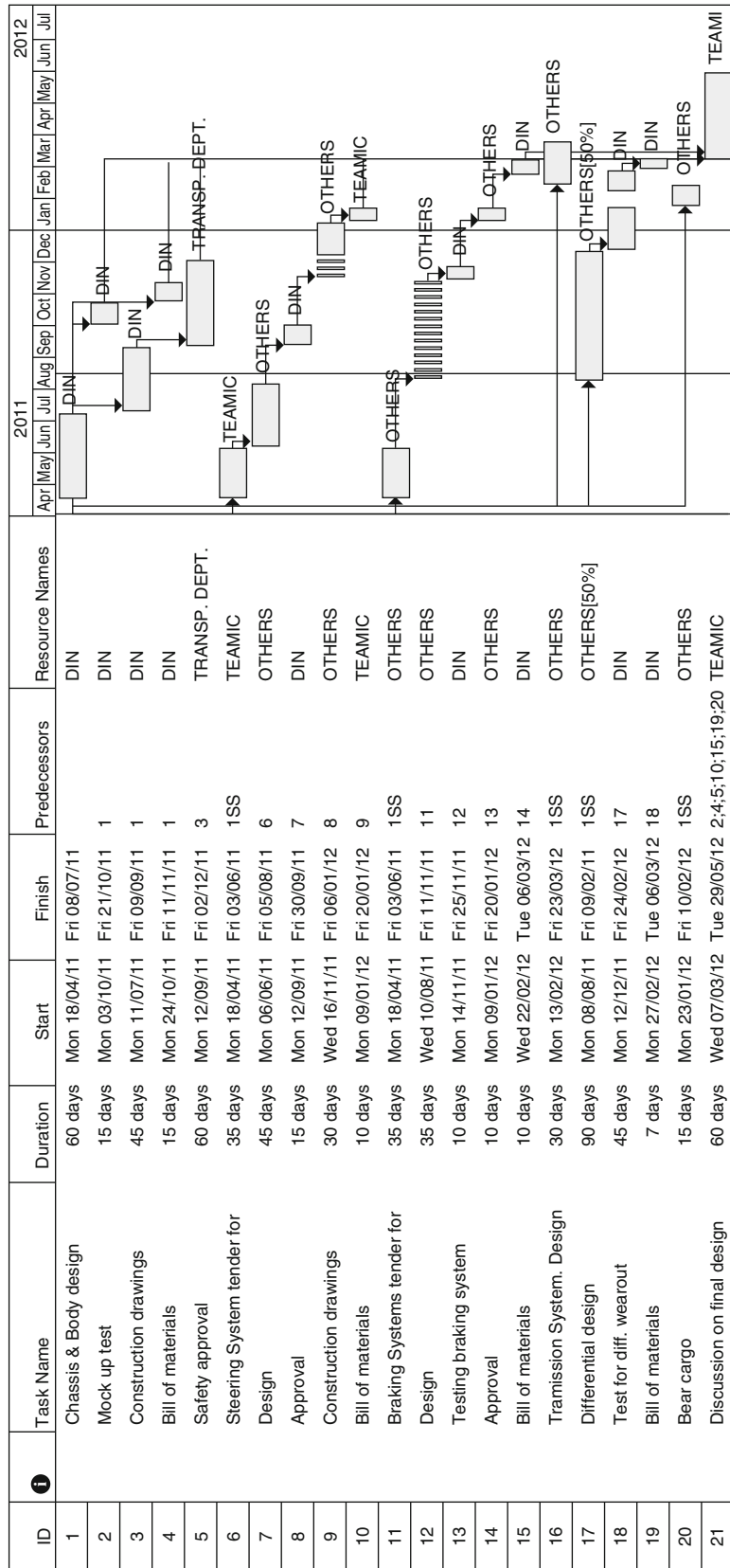


Fig. 9.9 Bar chart for TEAMIC activities – Developing the basic engineering for an automobile plant

Table 9.5 Teamic master schedule including contractor's programs merged – Construction phase of an automobile plant

Subprojects	Contractors, manufacturers, suppliers	Value [€]	Subproject weight in percentage	Duration [months]	June		July		August	
					Completed this month (%)	Accum. weighted decimal value completed at end of this month	Completed this month (%)	Accum. weighted decimal value completed at end of this month	Completed this month (%)	Accum. weighted decimal value completed at end of this month
Civil works	European constructions	30,938,294	70.32	7			5	3.52	15	14.06
Electrophoresis cell	Vehicle plant design	459,876	1.05	6	10	0.10	5	0.16	30	0.47
Control equipment	Vehicle plant design	198,056	0.45	1	100	0.45		0.45		0.45
Automotive cable sets	Buratti ApA- Milano	1,620,587	3.68	5					10	0.37
Bridge cranes	Vehicle plant design	329,107	0.75	4						
Special floors	Automotriz española	93,076	0.21	1						
Industrial transformers	Schengen GmbH-Köln	5,380,919	12.23	5			15	1.83	15	1.98
Electrical network	Schengen GmbH-Köln	2,717,684	6.18	5			20	1.24	20	2.47
Foundry laboratory	Utrecht laboratorium	589,028	1.34	2						
Truck assembly line	Vehicle plant design	290,178	0.66	4						
Truck testing facility	Automotriz española	156,493	0.36	4			10	0.04	20	0.11
Paint shop	Vehicle plant design	289,634	0.66	5			15	0.10		
Rear axle assembly	Vehicle plant design	98,327	0.22	4	15	0.03	15	0.07		
Sub assembly lines	Vehicle plant design	158,776	0.36	5			5	0.02	20	0.09
Engine test equipment	Automotriz española	356,355	0.81	4						
Industrial furnaces	Schengen GmbH-Köln	219,879	0.50	5					15	0.07
Heat treatment equip.	Schengen GmbH-Köln	98,146	0.22	5	5	0.01	20	0.06	25	0.11
	Total project	43,994,415	100			0.59		7.47		20.19

September		October		November		December		January	
Completed this month (%)	Accum. weighted decimal value completed at end of this month	Completed this month (%)	Accum. weighted decimal value completed at end of this month	Completed this month (%)	Accum. weighted decimal value completed at end of this month	Completed this month (%)	Accum. weighted decimal value completed at end of this month	Completed this month (%)	Accum. weighted decimal value completed at end of this month
20	28.13	15	38.68	15	49.23	20	63.29	10	70.32
45	0.94	5	0.99	5	1.05		1.05		1.05
	0.45		0.45		0.45		0.45		0.45
20	1.11	30	2.21	25	3.13	15	3.68		3.68
		35	0.26	20	0.41	20	0.56	25	0.75
				100	0.21		0.21		0.21
5	0.91	50	6.47	15	12.23		12.23		12.23
15	3.40	25	4.94	20	6.18		6.18		6.18
45	0.60	55	1.34		1.34		1.34		1.34
		35	0.23	25	0.40	20	0.53	20	0.66
35	0.23	35	0.36		0.36		0.36		0.36
30	0.20	30	0.49	10	0.56	15	0.66		0.66
40	0.16	30	0.22		0.22		0.22		0.22
30	0.20	25	0.29	20	0.36		0.36		0.36
30	0.24	30	0.49	20	0.41	20	0.81		0.81
25	0.20	25	0.32	20	0.42	15	0.50		0.5
30	0.18	20	0.22		0.22		0.22		0.22
	36.94		57.97		77.17		92.65		100.00

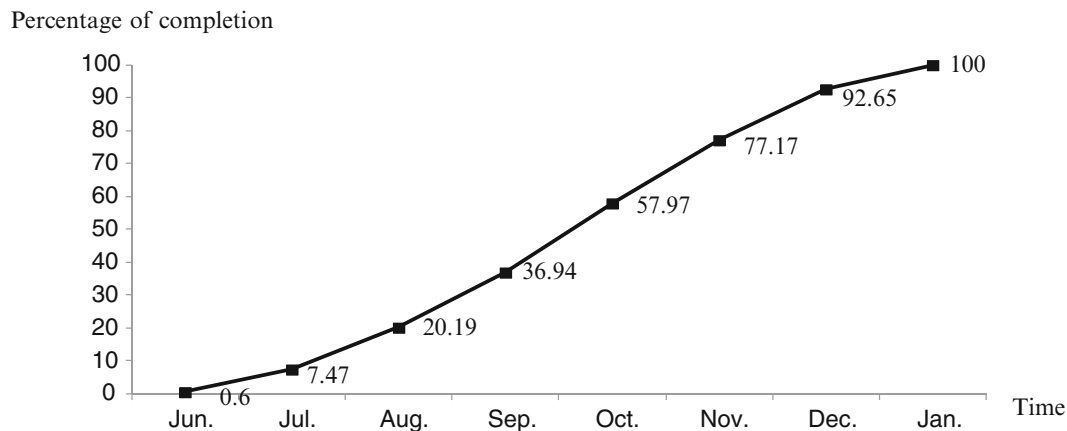


Fig. 9.10 The budget curve (BCWS) based in percentages of completion – Construction phase of an automobile plant

contractor, suppliers, manufacturers, studies, etc.) that participate in the construction of the new plant. This is the instrument that TEAMIC will use to monitor and control the work, as explained in Chap. 16.

Notice that the work has been divided into 17 subprojects, which will be executed by five subcontractors, manufacturers and suppliers, and with a general contractor (European Constructions). Observe that in general a subcontractor is responsible for more than a subproject. The table shows the value of their proposals, the weight of each subcontractor and the duration in months. At the right of the table, and for each month, there are two columns; the left one shows the percentage to be completed at the end of the corresponding month. The right column indicates in decimals the accrued percentage. At the bottom of each right column is the total cumulative amount obtained adding up the corresponding values. These are used to build the S-curve.

9.4.14 The S-curve

This is the document that will be used as a monitor and control as explained in Chap. 16. The S-curve is known under several names such as 'Baseline curve', 'Budget line' and *Budget Cost of Work Scheduled* (BCWS), and Fig. 9.10 portrays the curve for this case.

9.4.15 Budget Preparation and Schedule of Funds Needed

The S-curve shows percentages of completion along the timeline. It has two main purposes a) to determine the necessary amount of funds, and the time when they will be needed to pay the contractors, and b) it is used for monitoring the advance of work and to apply, if necessary, corrective control measures.

9.5 Data Needed When Using Dedicated Computer Software for Planning, Scheduling and Budgeting

The data needed for using project management software generally involves:

- Task I.D.
- Description of each task,
- Predecessor/s,
- Successor/s,
- It is necessary to indicate the model about the links between activities. They are:
 - Finish to start (FS): Indicates a direct precedence to a successor. It is the most usual relationship, and is the default relationship used by programs,
 - Finish to Finish (FF): When a task must finish at the same time as another; however it is also possible to indicate if it is allowed to finish a certain number of days in advance or after another (lag), which is indicated as, for instance (FF + 12 days) or (FF – 12 days) respectively,
 - Start to Finish (SF), when an activity cannot finish if another task has not started. For instance if a task needs validation when finished, it cannot be completed until the necessary procedures for validation have started,
 - Start to Start (SS): When a task must start together with another, but if there is a lag, it is indicated as explained. In this case it would be SS + 12 days) or (SS – 12 days).
- Work Breakdown Structure code for each task,
- Project starting date,
- Calendars adopted, i.e. it is necessary to specify how many days during a week are considered working days, the number of hours per day, if there is a night shift, which days are statutory holidays such as Christmas, New Year's Day, vacations, exceptions (when a normal non-working day, such as Sunday, must be considered as a working day), etc.,

- If instead of Euros other resources are used it is also necessary to break them down by trade and availability, that is a resource calendar,
- Working and non-working days. In this case work days are from Mondays to Fridays inclusive. Saturdays and Sundays are considered non-working days as well as some optional days, for instance national, regional or city holidays,
- Number of hours worked per day and time, including night-shift,
- Resources for each task, such as man-hours, equipment hours, space, etc.
- Location of working areas, for instance in a project where tasks are performed in different places, such as in the construction of roads, transmission lines, pipelines, etc.
- The cost of man-hours column is used by the software to draw the S-Curve, but it is not included in this example, since it does not add anything to what was already explained at the beginning of this chapter,
- Milestones, that is dates for which special results must be obtained, must also be indicated (they are considered tasks with zero duration, and are represented in the diagram with a certain icon),
- Responsible individual for each task and if necessary, location (which is useful when a large project depends on different individuals who work in different locations),
- The software allows sorting this information in several ways, such as by ID, early start, late start, resources by type, costs, etc.

Software manuals are very explicit about what information can be introduced. In addition, it is understood that a complex project with many different characteristics needs to use elaborated software, therefore the selection of the program to employ depends on the project complexity and the different variables that it includes.

All this data allows the software to draw the logical network shown in Fig. 9.8, the Gantt chart (Fig. 9.9), and the S-curve (Fig. 9.10).

Notice that MS Project places the tasks or activities in the nodes or rectangles instead of the method explained in Sect. 9.1.3.1 in this chapter, but it does not alter the result which is the same no matter which representation is used.

9.6 Shortening the Duration of a Project

If it is foreseen that the project will not finish on time, that is, if it is predicted that the completion date will extend beyond the finish date shown in the base line schedule, one can consider shortening the total duration of the project. There are several means to accomplish this shortening, such as:

- Look first at the critical tasks, and find out if some of them can be shortened by modifying their scope, or employing more resources. However, the use of more resources, such

as an increase in man-hours, or using additional equipment (for instance another backhoe), or adding a night shift, etc., will increase the task cost. Therefore this cost increase must be taken into account when computing the total cost of the project,

- Try to determine if a critical task may be done in parallel with another, probably using more resources,
- Work with the '*lead times*' that is the number of days between one task and another. We know that a critical task is a successor of another critical task, with for instance a FS sequence, and with '0' lead time, which means that only when the precedent task is finished must one immediately commence with the successor. However, it could be that by examining both tasks one realizes that it is not necessary to wait until the predecessor is complete, and that the successor can start say 20 days before the predecessor finishes. In this case the link would be FS – 20 days. This probably is an economical way to do the shortening, provided that the corresponding resource is available,
- Break up a large task. For instance in the example proposed in Sect. 9.2.2 the '*Trenching*', was partitioned by three. See Fig. 9.3.
- There are no floats in the series of tasks that form the critical path. However, in MS Project, it is possible to modify that rule instructing the software to consider a task critical when it has some small float, say 3 days. If the project is delayed, then there will be some float that can be used. Naturally, in so doing in the base line schedule, it will produce an increase in the completion time, which may be not acceptable.

9.7 Updating the Progress of Work

The explained procedures give a fair good idea of how *theoretically* the project should develop; however, these tools are almost useless if the project is not periodically updated at established dates, usually called '*Status dates*' and normally between fixed periods. At these dates *actual* progress is measured (in m^2 , m^3 , man-hours, manpower, costs, percentages, etc.), compared with those of the base line, and the degree of completeness in percentage computed. The whole process is called '*Monitoring*'.

Very rarely do projects develop as planned; there are a lot of factors that normally alter the original or base line schedule, such as a greater duration than expected for a task and due to many different reasons, which can produce time slippage and more important, delay the whole project. The update is thus very important to check compliance and must be done with a frequency normally fixed by the project manager, although it is customarily updated it on a monthly basis. The update records the variations, analyzes them and

takes measures, if necessary to correct them; this later action is called ‘Control’.

Once the updated information is available it must be entered into the software to process it. The progress input for each task can adopt different forms such as:

- Percent complete,
- Actual start and actual finish (in case a task is 100% complete),
- Estimated remaining duration,
- Actual duration,
- Actual cost, MH or manpower.

The software does the computation (that is, uses the CPM algorithm and finds the critical path), and delivers results sorted as per the analyst selection and according to the data entered. Thus, if for instance the percent completed is estimated and entered by the analyst, the result can indicate actual starts and finishes; conversely, if these dates are entered the result can show percent complete, remaining duration, etc.

In any case, when entering this basic data the result can show at status date (not a complete list):

- Budget Cost of Work Scheduled (BCWS). That is, the planned or baseline value for that date,
- Budget Cost of Work Performed (BCWP). That is, the work actually done valued at *budget cost*,
- Actual Cost of Work Performed (ACWP). That is, the work actually done valued at its *actual cost*.
- Cost variance (CV). It is the difference between BCWP and ACWP,
- Schedule variance (SV). It is the difference between BCWP and BCWS,
- Estimate at completion (VAC). It is the estimated date when the project will be completed.

Figure 9.11 displays the simulated updating for this project on the August 31 status date. Solid lines superimposed on original tasks indicate the advance of work. Notice that the second column indicates with ‘’ those tasks that have been 100% completed by the status date, which is also depicted in percentage in column ‘% Complete’.

Now, observe that:

- Task number 1, started as scheduled on April 18; it is 100% complete and finished on July 13, taking 63 days instead of 60 as scheduled,
- Task number 3, started on July 06, 5 days ahead of schedule. The drawings department saw that there was no need to wait for completion of task 1 to start. It registers an advance of 60% and it is considered to be on schedule.
- Task number 6, started on May 02, that is, delayed with respect to the scheduled start date. It should have finished on June 03, and at status day of August 31 it is 80% done. Therefore it is grossly behind schedule,
- Task number 7 is a successor of task 2. It should have started on June 06, but because the delay of task 6, started

on June 20, even when its predecessor had not finished. It has a 20% advance.

- Task number 11, started as scheduled and also finished as scheduled. It is then 100% complete.
- Task 12. Should have started on August 10, however it commenced on July 14 and it registers an advance of 15%.
- Task 17. Scheduled to start on August 8, but started on August 15 and at status date has an advance of 10%. Since according to the baseline it should have at status date an advance of 20%, the task is delayed,
- Task 20. Started and completed very early.

The final date for completion is now November 20, 2012 which compares with the scheduled date of May 29, 2012. The software compares the total schedule percentage as of status date and also the actual total percentage of completion. The difference in this percentage tells the analyst how the project is going time-wise.

In this example at status date the scheduled percentage was 32%. Actual progress was 34%, therefore, the project is slightly ahead of schedule

9.8 Finishing the Project

Twenty months after starting the project TEAMIC and MYCON submitted to DIN the complete package of manuals, drawings, costs, recommendations, and calculations considering information from suppliers and its integration in time and cost. There has been a 2 months delay, but it was attributable to DIN and thus recognized, due to a change of DIN authorities 7 months after the signature of the contract, because the new authorities wanted to have a better idea of this project and had momentarily put it on hold.

9.9 Closing This Project

All relevant documentation was delivered, together with all supporting documents.

TEAMIC and MYCON prepared memoirs about the project outlining its main points, difficulties and special problems, as well as pinpointing the causes for delays and alterations of the original schedule, and also changes or deviations from the original plan. This report was prepared by the respective directors from information from all sectors involved in the project including the client, suppliers, and stakeholders.

Lessons learned were also documented as well as aspects to be considered in the future.

This was a very important step because TEAMIC is now ready to execute the second phase of the project, that is, its physical execution.

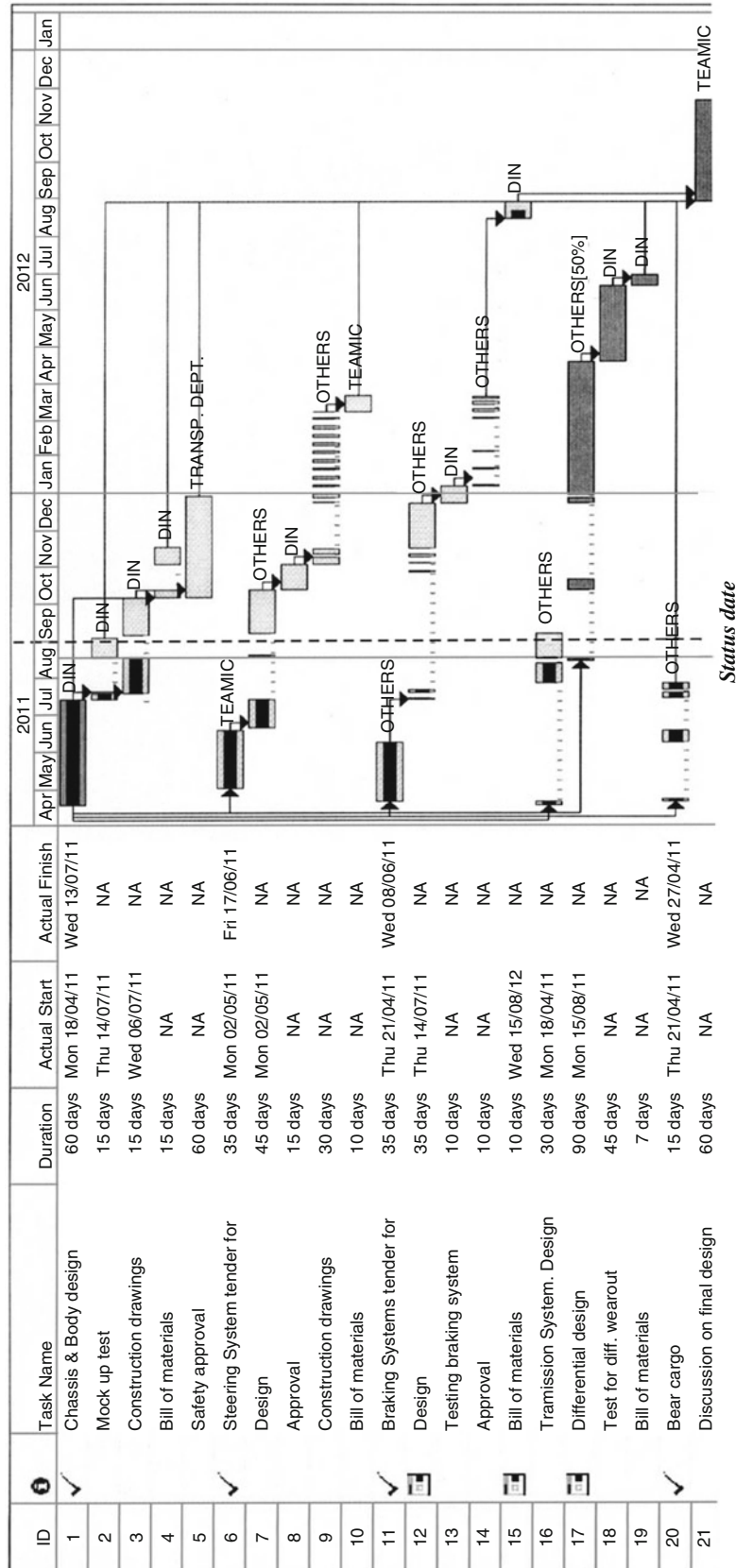


Fig. 9.11 Updating at August 31st status date – Developing the basic engineering for an automobile plant

9.10 Managing Uncertainty – The PERT Approach

There is no doubt that the results obtained by the use of the Critical Path Method depend on the accuracy and reliability of the information furnished to the model. In many cases, the most important data, which is the estimated duration of a task, can be determined with enough certitude, based in past history, using project management estimating software (see Sect. 12.1.7.4), and nature of the job, as well as a good knowledge of external conditions such as the market, regulations regarding the environmental, social issues, political aspects, geological conditions, risks, etc. But it is also true that most projects whatever their nature fall behind schedule and over budget. Why?

Because in many cases it is difficult to determine the correct duration of many tasks, since, even when there could be enough information about them perhaps from other projects, no project is equal to another even considering the same tasks. There are many circumstances that conspire against this relationship, such as the manpower factor and its efficiency, as well as location, task difficulty, weather, etc. Consequently, to have a unique fixed value for duration is not always the best procedure. The '*Pert Method*' (Program Evaluation and Review Technique), developed by the US Navy in 1957 for its Polaris nuclear submarine project, is designed to work with uncertainties, using not one but three estimates for the duration of a task, which are '*Optimistic duration*', '*Probable or expected duration*', and '*Pessimistic duration*'. This way, uncertainty, which is always present, can be introduced.

9.10.1 The Workings of the Pert Method

The working of the Pert method is the same as the CPM, however the latter works with fixed durations, that is it is *deterministic*,² while Pert is *probabilistic*. Consequently, the same procedure and steps of the CPM method are followed, that is the listing of activities, the construction of the logic network, the computation of the total duration, the appearance of critical and non-critical activities, the constitution of a critical path, and the construction of the Gantt diagram.

As said, the duration of a task is established considering three durations, a mean found according to formula (9.1) and

its standard deviation – that is a measure of distance from the mean – found using formula (9.2).

$$\text{Mean } (\mu) = \frac{\text{Optimistic duration} + 4(\text{Expected duration}) + \text{Pesimistic duration}}{6} \quad (9.1)$$

$$\text{Standard deviation } (\sigma) = \frac{\text{Pesimistic duration} - \text{Optimistic duration}}{6} \quad (9.2)$$

These formulas correspond to a β distribution,³ which is suitable for events that are defined not for a fixed value but for a range, that is a maximum and a minimum, which is precisely the case in Pert. Now, when we have a series of activities or tasks like these, with subjective durations, the final result, which is the distribution of frequencies of occurrences of the different durations, follows the normal or Gauss curve distribution. This is due to the '*Central Limit Theorem*' that very broadly states that when there are many random measurements subject to many different and random causes, the distribution follows a normal distribution.

Here it is necessary to calculate the '*Z score*' which is a number related with the amount of standard deviation of the whole population, and obeying formula (9.3).

$$Z = \frac{(x - \mu)}{\sigma} \quad (9.3)$$

Where:

μ : Mean of the whole population of data

σ : Standard deviation

x : Duration for which we want to know its probability of occurrence.

With the Z value from equation (9.3) we can enter a table for normal distribution and find the probability that our project finishes in a time 'x'.

9.10.2 CASE STUDY: Uncertainty in the High Valley Remediation Project

The High Valley Nuclear Plant, an old chemical works, was decommissioned in 1974. The place was used to process uranium ore into uranium trioxide and tetra fluoride. As a consequence of that activity large areas of the site were contaminated with radioactive waste, which permeated the soil and also contaminated a creek and an aquifer. In 2003 an

²From 'determinism'. "Theory or doctrine that acts of the will, occurrences in nature, or social or psychological phenomena are causally determined by preceding events or natural laws".

Merriam-Webster Dictionary.

³Family of statistical curves that consider events that take place between two limit values

Table 9.6 The three duration estimates for studies – High Valley Remediation Project

Task ID ^a	Task name	Optimistic duration	Expected duration	Pessimistic duration	Mean duration	Standard deviation (S)	S ²
1	Determine safety approach to underground debris	35	45	60	42.83	4.17	17.36
2	Determine radioactive waste disposal site	100	105	120	106.67	3.33	11.11
3	Decision taken on disposal site	0 ^b	0 ^b	0 ^a	0		
4	Determine test for soil compacting	35	38	42	38.17	1.17	1.36
5	Determine system for leachate collection	45	55	70	55.83	4.17	17.36
6	Measures for leachate monitoring, analysis and disposal	40	48	55	47.83	2.5	6.25
7	Radon barrier	60	65	70	65	1.67	2.78
8	Radon movement on leachate	60	70	80	70	3.33	11.11
9	Decision on leachate treatment	0 ^b	0 ^b	0 ^b	0		
10	Determine type of geoliner	75	90	110	90.83	5.83	34.03
11	Determine organic waste disposal site	30	37	48	37.67	3	9

^aIn this example tasks are represented by nodes (see Sect. 9.1.3.1)

^bCorrespond to milestones with ‘0’ durations

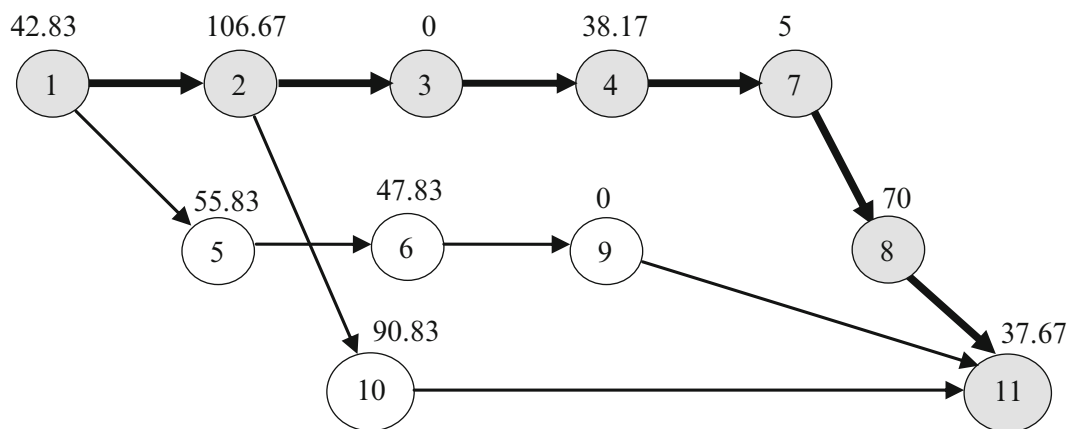


Fig. 9.12 Logic diagram for per – High Valley Remediation Project

effort was initiated to clean up the site and to convert it into a park and recreational area.

The planning included the demolition of office buildings and warehouses with roofs made of asbestos sheets (asbestos waves) as well as with asbestos plates for partitions, and the construction of a new building for the park offices, a Fine Arts museum and play area.

This part of the job did not offer any difficulty in planning, even considering the safety measures to be taken when dismantling the asbestos roofs and new constructions, however, it was necessary to perform a series of technical studies, in order to be in the condition to evaluate different solutions for the remediation of the contaminated soil and creek and their potential further use. The problem was that no background information existed about the duration of such studies, which were assigned to scientific researches and very specialized environmental companies.

The first step consisted in establishing the scope of contamination at each site and determining which studies must

be performed, a sample of which is depicted in Table 9.6. Figure 9.12 shows the logic diagram for the development of these studies.

Then, applying formula (9.1) for computing the mean, for each task, for instance for the first one (*Safety approach to underground debris*):

$$\text{Mean (M)} = \frac{35 + (4 \times 45) + 60}{6} = 42.83.$$

$$\text{Standard deviation (S)} = \frac{(60 - 35)}{6} = 4.17.$$

$$\sum S^2 \text{ on critical path} = 43.72.$$

$$\sqrt{\sum S^2} \text{ on critical path} = 6.61.$$

This diagram shows a critical path formed by tasks 1–2–3–4–7–8–11 which are shown in boldface in Table 9.6.



Fig. 9.13 Schedule of technical studies – High Valley Remediation Project

This diagram obtained from Project®, allows for drawing the Gantt chart as depicted in Fig. 9.13. Observe the two milestones identified with black diamonds: one of them on task 3 indicates that by December 26, 2011 a decision has to be taken about the disposal site. The other one corresponds to task 9 signalling that by August 11, 2012 a decision has to be reached for leachate treatment.

The total path has duration of $42.83 + 106.67 + 38.17 + 65 + 70 + 37.67 = 360.34$ days.

The probability of doing the job in this time is only 50%, (because it is a mean value), therefore it is important to find out how many days will be needed to increase this probability. To do that it is necessary to work with the Z score formula (9.3).

Suppose that we consider 365 days to finish the work instead of 360 days. Then, using formula (9.3)

$$Z = \frac{(x - \mu)}{\sigma} = \frac{(365 - 360.34)}{6.61} = 0.70.$$

Entering with this value in a normal or Gauss distribution table, we found a value of 0.758, which means that with 365 days there is 75.8% probability to complete the work.

What happens if we are looking for fewer days than the mean, for instance 355 days; then:

$$Z = \frac{(x - \mu)}{\sigma} = \frac{(355 - 360.34)}{6.61} = -0.807.$$

Entering with this value in a normal distribution table, we found a value of 0.288, which means that with 355 days there is a probability of 29% to complete the work.

Suppose now that we are not happy with that probability for 365 days because the project has to finish by a certain date and not after. Say that we want a 95% probability of

finishing by a certain date so that it can be confirmed to the project owners. The question is now, how many days we can consider for that?

The procedure is just the reverse. That is entering in a normal table with a probability of 0.95 and finding the corresponding Z score, which in this case is 1.65. Now apply formula (9.3) to find x.

$$Z = \frac{(x - \mu)}{\sigma} = \frac{(x - 360.34)}{6.61} = 1.65.$$

$$x = (1.65 \times 6.61) + 360.34 = 371 \text{ days.}$$

9.11 Crashing the Schedule

This expression means the acceleration of a project, i.e. reducing the time needed to complete the work. There are several ways to shorten the total duration, as mentioned in Sect. 9.6, but naturally crashing takes place only on critical tasks since to crash a task with float does not produce the desired effect.

However, even when the reduction in any critical task will have the same effect in reducing the duration of the project, it is logical to select, if possible, the critical task with the lowest cost per unit of time reduction; consequently, the decrease in time means an increase in the total cost of the project, or, which is the same, an inverse relationship between reduction in time and total cost, and most probably of the non-linear type.

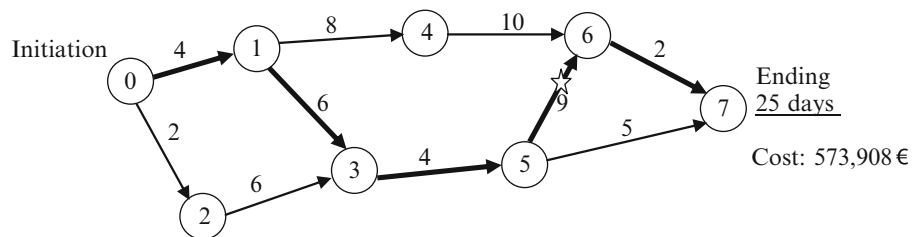
When the reduction is done, maybe there is still room for further reduction of the same task; if this is not possible for whatever reason, it is necessary to look for other critical tasks. In addition, it is essential to take into account that generally, the reduction in time of a critical task will trigger

Table 9.7 Characteristics of tasks – Accelerating the launching of an industrial product

Task	t_{ij} (days)	Minimum time for execution (days)	Cost to crash a task 1 day (€)	After first crash (days)	After second crash (days)	After third crash (days)	After fourth crash (days)
0-1	4	2	8,231	4	4	3	3
0-2	3	2	8,094	2	2	2	2
1-3	6	5	6,517	6	6	6	6
1-4	8	7	1,209	8	7	7	7
2-3	6	6	10,223	6	6	6	6
3-5	4	2	4,520	4	3	3	3
4-6	10	8	9,219	10	10	10	10
5-6	9	8	4,350	8	8	8	8
5-7	5	4	4,908	5	5	5	5
6-7	2	1	8,754	2	2	2	1

Shaded boxes indicate that the corresponding task cannot be further reduced

Fig. 9.14 Original duration – Accelerating the launching of an industrial product



the appearance of more critical activities, especially those with a small float. Because of this, a reduction in a certain critical task may or may not generate more critical tasks, and considering that each critical task reduction may trigger different new critical activities, it can be seen that the procedure involves a highly combinatorial problem, for which perhaps there is not an optimal or best solution.

The problem is in reality more complex, due to amongst others, the following issues:

- (a) The cost to reduce a task could be non-linear. For instance, using for 30 days a backhoe that already has a fixed cost component and assuming a linear cost relationship for each day of work; another difference could be to utilize two backhoes to reduce the time.
- (b) It is not always possible to use more resources, even with the lowest cost per day. This is the case for instance when there is no physical room for more workers or machinery to work.
- (c) Sometimes, even when it is possible to operate say a second machine, it is necessary to consider if that second machine will be used again in the short time in the same jobsite. If it is not, obviously it will stay idle, also increasing costs by not performing any work.
- (d) Another way to consider shortening duration is by adding another shift, such as a night shift, if it is possible. However, because the night shift usually carries an increasing cost per unit of work done, because of existing regulations for workers working at night, the cost could be very high, and it is also necessary to add lighting, security, catering services, etc.

- (e) A very important fact to consider when crashing is to make sure that bulk material, off-the-shelf material, fabricated elements, and equipment that has to be installed or used (see Sects. 10.1 and 10.2) will be available when needed and in the required quantity.

As a summary, it is believed that crashing a large schedule, with perhaps hundreds of critical tasks, is more an art than a science. It also depends on the stage of advance of the project since it appears that crashing activities near the end of the project, with the same effect in reduction as others in the early and medium stages, allow for fewer effects on other activities and then with more chances to work with the less expensive tasks.

9.11.1 CASE STUDY: Accelerating the Launching of an Industrial Product

This case is a small fictitious case, but it will serve to illustrate the reduction procedure which is in reality a trade-off between time and cost. It assumes that an established paint manufacturer has performed lengthy studies for developing a new antirust paint, and now is launching a small pre-series of the product to test the market. Table 9.7 shows the different characteristics for each task. Notice the third column that establishes the minimum time in days that a task can be performed.

Figure 9.14 shows a logic diagram for this project with total duration of 25 days and a total cost of 573,908 €. Observe that it uses the other format for the logic diagram,

Fig. 9.15 Reduction to 24 days –
Accelerating the launching of an
industrial product

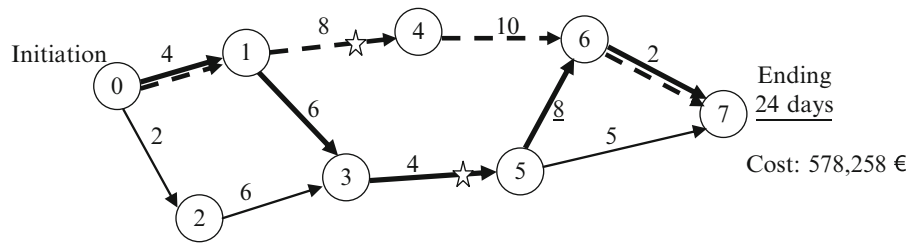


Fig. 9.16 Reduction to 23 days –
Accelerating the launching of an
industrial product

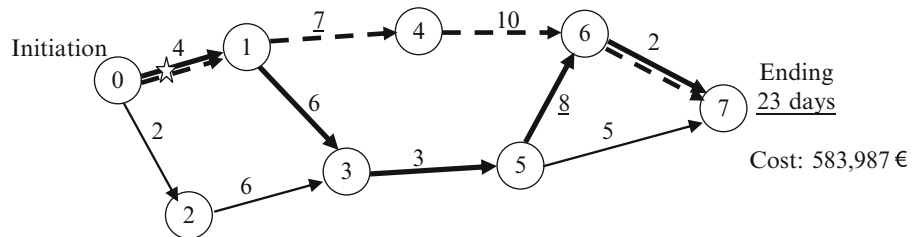


Fig. 9.17 Reduction to 22 days –
Accelerating the launching of an
industrial product

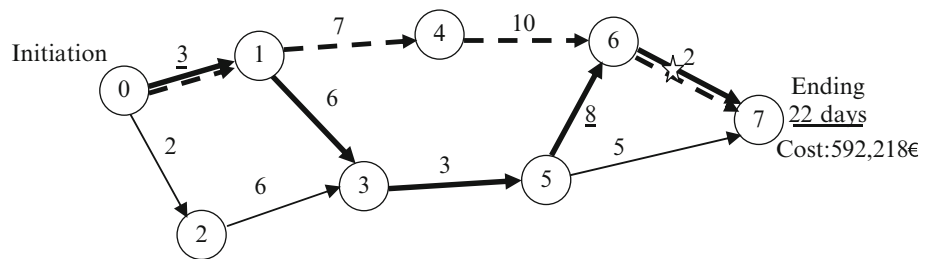
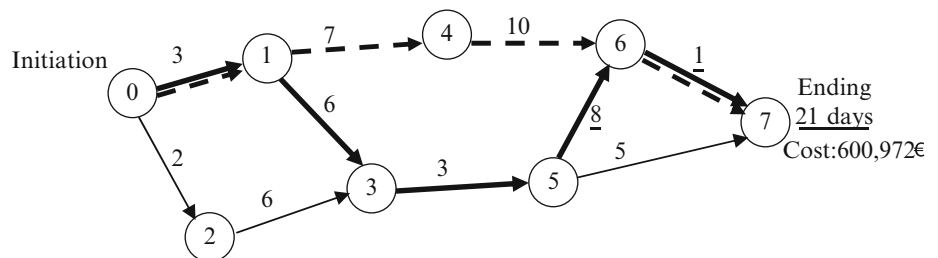


Fig. 9.18 Reduction to 21 days –
Accelerating the launching of an
industrial product



in the sense that each task is depicted by an arrow – instead of a node – which at the same time, indicates precedence, but of course, the result is the same. Numbers on each task correspond to their normal duration in days. Once the computation is done the total duration of the work is 25 days. The critical path is formed by tasks: 0–1, 1–3, 3–5, 5–6 and 6–7.

First reduction to 24 days (Fig. 9.15)

The best candidate amongst the critical tasks is the task with the lowest cost that is task 5–6 (indicated with a star). It can be reduced to 8 days at a cost of 4,350 Euros (Fig. 9.15), and notice that by so doing, a new critical path appears, together with the first one, and formed by tasks: 0–1, 1–4, 4–6, 6–7 (dashed line), as shown in Fig. 9.15.

Second reduction to 23 days (Fig. 9.16)

The best candidates amongst the critical paths are now tasks 1–4 and 3–5. Be aware that we cannot decrease again task 5–6, because technically it cannot be reduced further

(see third column in Table 9.7), but even if we could, it would be useless, since because of critical path 0–1–4–6–7 we still would have 24 days.

Reducing 1 day each of activities 1–4 and 3–5, the final duration will come to 23 days, but at a cost of 1,209 for task 1–4 and 4,520 for task 3–5, that is the total cost will be incremented by 5,729 Euros.

Third reduction to 22 days (Fig. 9.17)

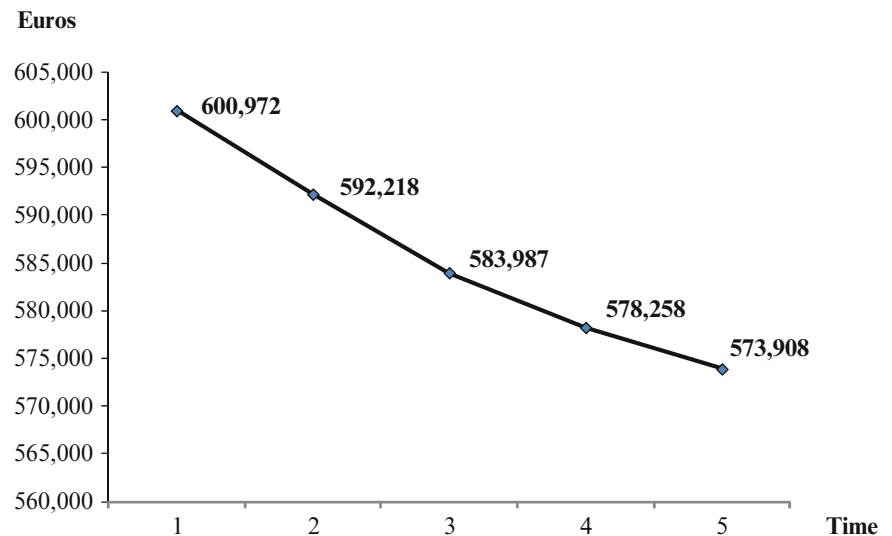
The best candidate is task 3–5, however its reduction does not produce any effect because it does not affect the other critical path. We can decrease task 6–7 but it is not the least expensive. The only alternative is to reduce task 0–1 at a cost of 8,231 Euros, which affects both critical paths.

Fourth reduction to 21 days (Fig. 9.18)

The only alternative is task 6–7 at a cost of 8,754 Euros.

The whole project considering normal costs amounts to 573,908 Euros. Figure 9.19 depicts the plotting of total time against the computed increases in costs by crashing.

Fig. 9.19 Trade-off curve between Euros and time



9.12 Critical Chain Project Management (CCPM)

This is in essence a similar technique to CPM but different in its conception regarding durations and resources. It was developed by Eliyahu Goldratt in 1997, and was the last addition to the battery of tools for project planning. The method essentially drifts from the CPM philosophy in the way it manages floats, which somehow equates to 'buffers', and then it is thought as a buffer management method. Its main differences with CPM are:

The CCPM works with average durations (and even in some programs with a pessimistic one), which is sensibly shorter than the duration used in the CPM. It also can use the Monte Carlo computational method.⁴ It starts with the final date, that is, considers the date when the project must be completed, and works backwards to determine the initiation date. Conversely, the CPM starts with the initiation date and works forwards to determine the final date. From this point of view it seems that the CCPM approach is more down to earth since it commences with the date the owner or the sponsor of the project wants it finished.

The CCPM determines the critical path as a function of two parameters: time and resources, while the CPM determines it as only a function of time, and then assigns resources. However, both parameters may vary independently, and this means that the task can perhaps be done in the stipulated time but it also depends on corresponding resources being there when needed. For instance, in the construction of a concrete road the time it takes to place

concrete for 400 m of road has been calculated, and most probably it can be honored. However, this time depends not only on the velocity with which the concrete is poured, vibrated and smoothed out, but also that the ready mix concrete or the concrete mixers trucks are there in time. If for whatever reasons concrete production (the resource) is delayed, there is no doubt that this delay will be reflected in the completion of the work. It sounds then logical to assign to this concrete feeding task a certain float. The introduction of this feeding buffer is one of the features that characterize the CCPM. It proceeds in a series of steps as follows:

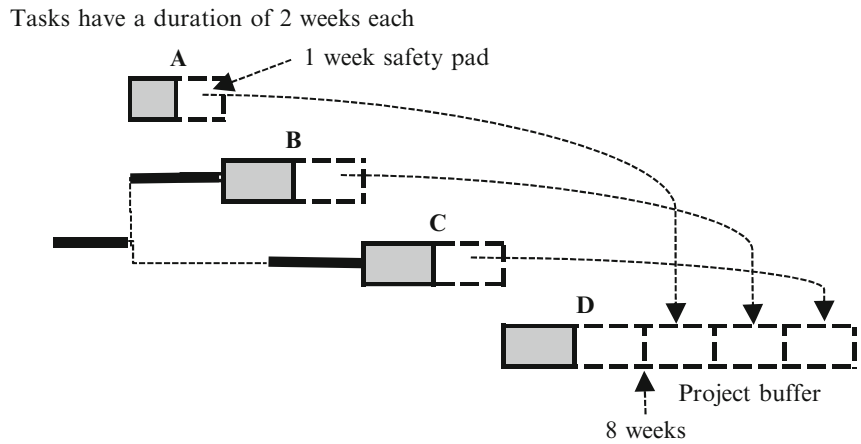
It assumes that when somebody makes an estimate for task duration, that estimate is normally too generous (for a series of alleged reasons according to Goldratt), and thus exceeding actual values. For this reason CCPM commences by halving this estimate, and in so doing reducing by 50% the duration of the project. The remaining 50% is used as a buffer and added at the end of the project, and constitutes the 'project buffer'. (See Fig. 9.20). This buffer is located after the last task and before the agreed completion date. Any delay in the critical chain will take time from the project buffer but not influence the completion date, unless the total buffer time is consumed.

Due to the halving, critical activities now possess float, which is equal to half of the duration, and consequently depend on their initial estimates, therefore it is reasonable to concentrate efforts in checking those critical tasks with the least float. Adding-up these floats makes the global or project buffer that is placed following the last task of the project.

A 'critical chain' is identified considering the kind of resource it uses. It is defined as the longest chain composed of tasks that are not only arranged in sequence but too dependent on available resources. There is also a 'Resources buffer', which function is to make sure that a precedent task finishes with a resource before this can be used in another task.

⁴The Monte Carlo method is a computational simulation procedure based on a large number of repetitions, using random numbers, and according to a probabilistic function. The method is widely applied in many different disciplines.

Fig. 9.20 The CCPM method – Building the project buffer



whatever reasons the merchandise is not ready for pickup, the truck will have to wait and the arrival at its final destination will suffer.

There are several dedicated software packages containing this method, many of them implemented in MS Project®, which is the same as the one we are using in this book. Some software for CCPM are ProChain Solutions, Scitor PS Suite 8, Primavera, and others.

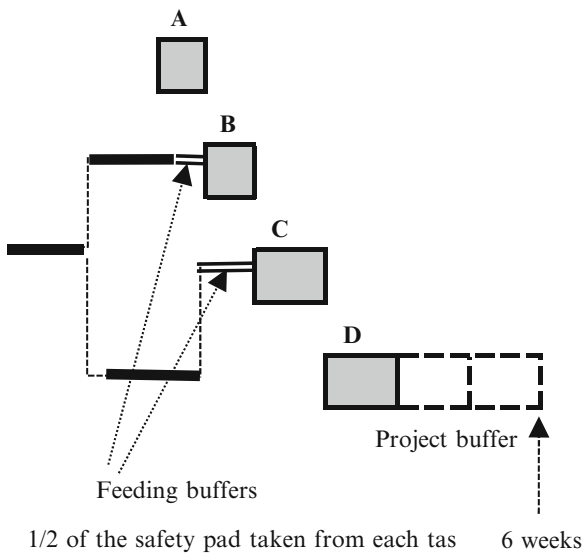


Fig. 9.21 The CCPM method – Building the feeding buffer

Another feature of this method is that it studies all those paths than finish or ‘feed’ a critical chain, and in so doing establish ‘feeding buffers’ (see Fig. 9.21), at the end of the non-critical path and consequently, before the commencement of the critical activity they ‘feed’. The times assigned to these buffers come from the project buffer and it is necessary to take into account that not all tasks consume the buffer time at the same rate.

Tasks are initiated as late as possible. One of the purposes of this procedure is to allow the continuous use of resources, which finishing in one task are immediately applied to another one.

This feeding process of paths to a critical path can be compared with a truck transportation system that has a few stops between origin A and destination B, but with obligation to stop at intermediate locations C, D, E and F to pick up more cargo, and that cannot proceed in its journey until this cargo is loaded at each intermediate stop. Clearly, if for

9.13 Conclusion of This Chapter

This chapter reviewed the standard procedure for planning and scheduling and proposed a simple example to illustrate its solving by hand, as well as demonstrated the preparation of pre-starting documents such as schedule of meetings and responsibilities. In so doing the network diagram was used for planning, the Gantt chart for scheduling and also for the drawing of the very important baseline or S-curve, which is a basic document for development and control. Once the schedule was complete it was analyzed regarding the way to shorten it, as well as the relationship between this shortening and costs. The construction of the master schedule was also demonstrated as well as the merging of different contractors. To exemplify the use of these tools a complex and actual case was proposed and solved by using dedicated software. Pert philosophy and workings was also exemplified as well as the principles of the Critical Chain Method.

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Abstract

Every project needs materials inputs; there are a large variety of them as well as different types. These materials must be in the job site when needed, in the correct quantity or amount and with the required quality. Their management is a fundamental part of project management not only from the cost point of view but especially because their unavailability in quantity and on time can produce delays in the whole project, as well as increasing costs with a loss of productivity.

Keywords

Materials category • Bill of materials • Bill of quantities • Procurement • Equipment deliveries • Inspection • Selecting suppliers/Contractor

10.1 Determining Materials and Equipment Needs

Probably the first step regarding materials in a project is determining what is needed. This is normally done by the Engineering Department based on documents such as the project charter (Sect. 1.7), the quantities takeoff (Sect. 12.1.5), the Gozinto diagram for manufacturing (Sect. 10.6), and especially from the Work Breakdown Structure (Sect. 9.4.5), as well as from drawings. The outcome of these procedures is a list called '*Bill of Materials*' (BOM). It describes in a precise format all the components of a product, quantities involved, subassemblies, assemblies and sequence. This document is essential in all kinds of projects, and it is similar to the '*Bill of Quantities*' (BOQ) common in the construction industry and used for tendering.

When possible it is recommended to maintain meetings with potential sellers to keep them duly and uniformly informed about the scope of a bid, quality demanded, adherence and compliance to ISO quality norms (see Sect. 15.2), technical aspects that may need clarification, necessity to meet the terms for agreed delivery dates, advance reports on fabrication, dates for inspection at the factory, etc. This way all bidders receive the same information and know exactly what the buyer wants. Normally there are several bidders

for certain equipment, all competing in costs, quality, price and delivery time, therefore a selection must usually be done not only based on the above mentioned aspects but also in intangibles such as prestige, past performance, experience, etc. Section 10.7 proposes a case exemplifying how this selection can be done.

Another aspect to be considered is that of deciding on fabricating some parts, components, etc., or finding it more convenient to purchase them. This assessment is not a simple one and normally many factors are taken into account to reach a conclusion, such as company facilities and their potential use, experience, availability of a similar product in the market, quality of the product made by others, etc., and of course a cost-effective analysis to determine if it is more convenient to buy or to manufacture. This calculation is more related with production and thus is not analyzed here.

Considering the large variety of conceivable projects, there is an enormous diversity of possible inputs. However, they can be classified into five main categories.

1. Bulk materials, such as sand, water, bricks, cement, ready mix concrete, etc.,
2. Off-the shelf materials, such as electrical cables and switches, bolts, screws, piping, piping accessories, pallets, spare parts, hand tools, etc.,

3. Fabricated elements, such as assembled parts and subparts, air conditioning units, vessels, steel beams, panels, control equipment, kitchen appliances, air compressors, laboratory equipment, Formica sheets, etc.,
4. Specially fabricated equipment (custom made), such as elevators, hydraulic turbines, sluice gates for dams, assembled parts for cracking towers, large refrigeration equipment, desalting plants, large engines for ships, transformers, electronic devices, fabrication lines, robots, electric switchboards, etc.,
5. Construction equipment either purchased or rented such as backhoes, pile drivers, grid rollers, trucks, pneumatic drills, cranes, derricks, forklifts, etc.

10.2 Delivery at Job Site

The type of equipment and the time when it will be needed can be extracted from information provided by the Mechanical and Electrical Departments as shown in the case described in Sect. 9.1.1 and in Sect. 9.1.3, where an example for excavating a trench for a water supply system is proposed. If in that case trenching is scheduled to take place between June 30 and July 25, as shown in the Gantt Chart of Fig. 9.2 (Sect. 9.2), there will be a need for a trencher of certain type (rock wheel, chain trencher, etc.), and with a specific width, as well as a wall support system. That is, information regarding equipment needed and when, can be extracted from here.

The date when this piece of equipment is needed is obtained from the project schedule, as seen in Sect. 9.2, while quantities can be extracted from work packages in Work Breakdown Structure, or from several sources (see Sect. 12.1.7), especially for bulk materials and equipment to use.

From the point of view of preventing a risk of delays it would be ideal to have the equipment in site days before the date of commencement. However, this is not practical because if a special piece of equipment is rented there could happen that it is kept idle during several days, naturally not convenient because it has a daily cost. If the constructor owns equipment, say for instance a backhoe, there could be the possibility that while idling in this project it is needed for another job, a circumstance that also may delay this second undertaking.

This circumstance is possibly repeated in any type of material, especially for fabricated elements as well as for manufactured equipment, because their sellers and suppliers must be paid, even if the equipment is not installed – that is, received and stored in a warehouse – which in addition generates insurance and holding costs. Sometimes, it is advantageous to negotiate storage of goods with the sellers until needed, thus transferring to them the insurance and holding costs, albeit probably at a certain fee.

Make sure to inspect the material and equipment in the seller's premises, to be sure that the material matches all technical requirements and conditions as specified in the contractual documents, as well as its compliance with the shop drawings sent by the seller, and approved by the owner or his representative. Such checking is not limited to visual inspection for proper finishing, possible damages and completeness, for instance using a video borescope¹ to inspect internal parts, but especially involves tests to make sure that certain parameters are observed. For instance, for an industrial fan, request reports on tests of airflow rate vs. static pressure.

There are two competing costs:

- (a) The depredation of not having the equipment available when needed, which, in addition to delaying the task or even the project, may provoke another cost such as having specialized workers idling, if they cannot be assigned to another similar task,
- (b) In competition for funding of this cost, which can be high, is that of insurance and holding costs, which can also be significant, because of the necessity for special protection as in the case of electric equipment, danger of fire, or damages, etc.

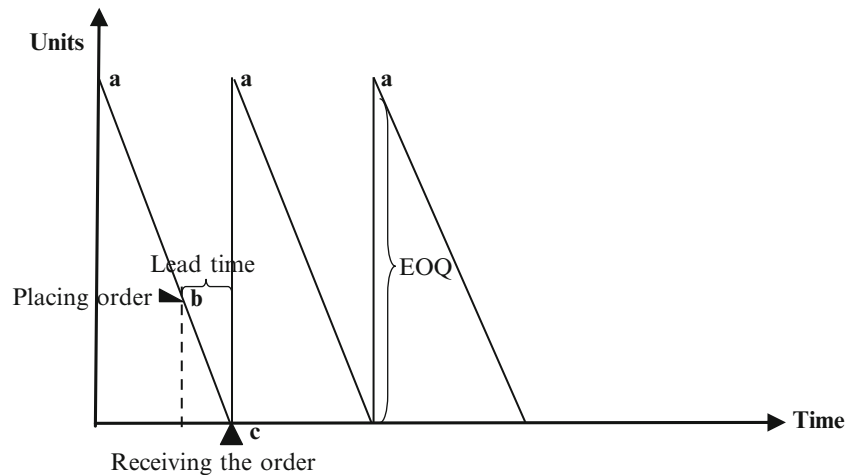
The Project Manager thus faces the dilemma of deciding the best policy; without a doubt a tradeoff must be made between these different costs in order to reach a compromised or balanced solution, and considering that the problem varies according to the type of project. A typical example pertains to elements fabricated on the job site or nearby, which must be installed in large quantities and on a continuous rate this can happen for instance in river tunneling where prefabricated concrete tunnel segments are transported to their position, then sunk, and further attached to precedent segments already laid at the bottom of the river, normally in an excavated trench. These segments are normally built nearby and their fabrication could be part of the project. It possibly calls for an analysis to be made for determining which is the best rate for segments fabrication, and perhaps studying the strategy of having a certain stock of them, which could be used, if for any reasons the segments fabrication stops or is delayed.

10.3 Manufacturing Projects

Something similar occurs in manufacturing projects² where an input is needed many times throughout a year. For instance, this is the case of a motorcycle manufacturer that

¹ Optical device consisting in a flexible tube, a lens and light to inspect the interior of tubes and machines. It is similar to endoscopes.

² However, in manufacturing an item can be requested many times, which is not the case in construction for instance, where the item is solicited only once.

Fig. 10.1 Cycle for reordering

produces these vehicles at a certain rate. He receives from his suppliers motorcycle wheels assemblies which are ordered at regular intervals. Based on his production the manufacturer periodically orders a certain number of these assemblies in a fixed quantity or batches which is called 'Economic Order Quantity' (EOQ). This EOQ is determined using a mathematical formula that considers annual demand (D), cost of issuing a purchase order (K), and cost of holding 1 unit for 1 year (P). The formula is:

$$EOQ = \sqrt{\frac{2KD}{P}} \quad (10.1)$$

And the frequency of ordering (n) is:

$$n = \frac{D}{EOQ} \quad (10.2)$$

A 'lead time' must be considered, that is, the necessary time since the order is placed until the material is received. This lead time means that the EOQ order must be placed when there is still enough stocked material to cover the demand during such periods Fig. 10.1.

Assume that the warehouse has in stock a certain amount 'a' of an item. Each time a batch of pieces is withdrawn from the warehouse, the computer software deducts it from the inventory (see Sect. 11.4.2 about on line computer systems to keep track of materials entering and leaving the warehouse). When these inventories reach a level already fixed 'b' considering the lead time, that is, the time the vendor needs to fabricate and supply the item, the computer issues a purchase order for the EOQ. When it arrives at 'c', theoretically the inventory should be zero, and then increases with the received EOQ at a new level 'a', and the cycle reinitiates. There is generally a safety level that can be considered together with the lead time, since variations and contingencies occur.

10.4 Steps in the Procurement Process

Table 10.1 details the necessary steps to consider in materials management for acquiring materials.

10.4.1 E-procurement

This is the term used for the procurement process when it takes place via electronic means. It has many advantages such as:

- Every transaction is documented, avoiding 'personal arrangements' between purchaser and supplier,
- Greatly reduces overheads because requires less purchasing agents,
- Provides on-line information to Accounting and Finance
- Reduces delays since the supplier receives the order at the moment it is placed, therefore there are not missing forms and purchasing dates are neatly documented,

10.5 Equipment Delivery Status Report

Special care should be taken for controlling deliveries of items, when they come from outside the jobsite, and cannot have a direct and daily inspection. In this case control does not stop at assuring on-time delivery, since some equipment must be tested at the factory before shipping to the job site, as well as inspecting material quality.

10.5.1 CASE STUDY: Controlling Equipment Delivery for a Mall Construction

For instance, assume that a general contractor is building a commercial mall. He subcontracted many of the specialized activities – which became sub projects – such as the

Table 10.1 Steps for acquiring materials

Activity	Aspects to be considered and sources	Documents	Use	Example in book
Preparation of schedule to permit engaging contractors and subcontractors	<p>Information needed from the engineering or design department</p> <ul style="list-style-type: none"> – Characteristics of the job to be done – Establish minimum qualifications required for contractors [Expertise in this type of project – years in business – work done in the last 5 years – equipment available – payroll, etc.] – Listing most important qualifications and weighting each one to be used to select contractors – Project charter 	Ask all departments involved in the project about their personnel needs, in all categories, engineers, planners, draftsmen, computer specialists, etc.	Responsibility matrix prepared by Planning Department	See Sect. 9.4.10 (Responsibility matrix)
Shortlist potential candidates	Make a shortlist based on diverse information and data gathered for each potential contractor.	References in the industry, colleagues, etc.		
Preparation of tender documents	<ul style="list-style-type: none"> – Request contractor's information about using own resources in personnel and ancillary equipment (for instance a stone production line for making concrete) – Request a listing of contractor's personnel roster in project site – Request a listing of contractor's equipment in project site – Specify if joint ventures are allowed – Request information about how many subcontractors will employ the main contractor – Inform bidders about project site conditions [urban site, construction camp and living facilities, access, R&R policy, etc.] – Inform bidders about the criteria that will be used for selecting the winner – Inform bidders about site regulations regarding alcohol and drugs consumption, as well any other safety regulations, for instance related with a nearby population, or linked with the environment or concerning hunting, etc. – Request bidders to detail safeguards and mechanisms (preventive and healing) (see Sect. 6.4.6), regarding potential threats that can put at risk the project or a part of it – If the project site is in a remote site inform bidders about transportation to the site 	Tender documents		See Sects. 1.7 (Project charter) 1.8 (Project management plan) 1.10

(continued)

Table 10.1 (continued)

Activity	Aspects to be considered and sources	Documents	Use	Example in book
	<ul style="list-style-type: none"> – Warn bidders about the rigid enforcement of safety procedures, as well as the environment protection – Inform bidders about type of contract 			
Call for bids	Analyze tenders and select winner		Decision-making tools	See Sect. 8.6 (Vendor selection)
Awarding and contract signing			Legal department	
Preparation of a procurement schedule for equipment, materials, raw materials, services, etc.	<p>Information needed from the engineering or design department</p> <ul style="list-style-type: none"> – Characteristics of equipment to be purchased – Earliest date when purchased elements are needed at the project site – What about partial deliveries? – List of different elements from the same or different vendor that must come assembled to the project site – Necessity of testing equipment at the factory before shipping – If a large equipment must be assembled at the project site, request information about time length needed for that operation, as well as who is the final responsible for the item to be fully operational and in the scheduled time – Capacity of personnel needed for assembling at project site – Need for the vendor to provide assembling personnel and number of people involved in that operation – Establish work certification procedures 	<ul style="list-style-type: none"> – Project technical report – Project drawings – Project schedule 		See Sect. 1.7 (Project charter) 1.10 (SOW) Chap. 9 (Project schedule) 16.12 (Drawings)
Short listing suppliers to acquire equipment, materials or services	<ul style="list-style-type: none"> – List of qualified suppliers – Background information on suppliers – Previous experience with some suppliers 	<ul style="list-style-type: none"> – Equipment list – Equipment specifications – Equipment specifications 		
Offers evaluation (Technical and economical). Selecting suppliers and vendors	Check and compare contractor's schedule with project schedule as well as costs	<ul style="list-style-type: none"> – Technical offer – Total price – Delivery time – Guaranty – Financing conditions 	Decision-making tools	Sect. 8.6 (Vendor selection)
Contracts awarding	Management plan updates	Updates management plan		Sect. 8.6 (Vendor selection)
Placing purchases orders	<ul style="list-style-type: none"> – Project schedule – Project milestones – Risk in deliveries due to overseas sellers 			

(continued)

Table 10.1 (continued)

Activity	Aspects to be considered and sources	Documents	Use	Example in book
Communication with suppliers		Enterprise Resource Planning (ERP)	Any of existing several ERP packages, but make sure the selected one covers all required areas	Sect. 11.2 (Other communication means)
Procurement running and administration-Following and control Materials tracking	<ul style="list-style-type: none"> – Conduct procurement negotiations – Communicate the respective department about any variation in time for deliverables from vendors, as well as potential variations in the items ordered – Coordinate with vendors and the engineering department on visits to verify advance of work (such as in complex equipment), tests, quality control, etc. – Organize when necessary video-conferences with the engineering department and vendors – Demand suppliers' performance reporting – There must be in place a system for materials tracking allowing learning on-line the location, position and state of any element. 	<ul style="list-style-type: none"> – Consult engineering department about nature of inspections needed (for instance large pumps output, electronic equipment performance, safety devices tests, ERP. software, etc.) – Use ERP. for materials tracking 	ERP. to register: <ul style="list-style-type: none"> – Suppliers' deliveries, – Temporary storage in site warehouse, – Result of inspection; – Dates when items are removed from warehouse, to be used, installed or returned 	See Chap. 11 (Project communications)
Delivering – inspection	<ul style="list-style-type: none"> – Inspect all material received and at manufacturer premises – Implant a system for test on bulk materials 			Sect. 10.5 (Equipment delivery report)

construction of a dedicated sewage treatment system to treat discharges from the 15 restaurant kitchens that will operate in the mall. This work is awarded to 'Water and Sewage Industrial Installations Inc' (WSII), however, all equipment is purchased by the main contractor's procurement department.

The main contractor's monitoring and control office is in charge of compliance of the delivery dates of equipment to WSII. For this they use the Equipment Delivery Status Report, as shown in Table 10.2. Notice that most of the information comes from the planning and scheduling department when they developed the logic diagram and the Gantt chart, however there is also information from other departments such as procurement purchase orders (P.O.) (column 1). Notice that there are variations concerning who supplies and who installs the respective equipment, since some times it is the same company and other times it is the main contractor (columns 3 and 4).

Column 5 is the agreed delivery date as per the purchase order; however, later on some suppliers confirm deliverance on time or else they inform that there will be advances or delays of their supplies (column 6). This information has to be passed to the planning and scheduling department for them to modify the schedule, especially if the installer is not the

supplier, for him to adjust his own work (column 7), since they are based on the original scheduled dates. If a supplier changes his delivery time, as is the case of 'Clarifier mechanism', where Amex informs that the final delivery will take place on June 23 (column 8) – instead of June 09 (column 7), that is with 2 weeks delay – this information must be passed onto the installer WSII for him to modify his schedule.

However, once WSII receives notice he informs both the procurement and the planning departments that this supplier delay will cause the installation activity to become critical and consequently, will affect the completion date of his own work. Because of that WSII requests the main contractor to exert some pressure on the supplier in order to have the item delivered on time.

This example of delays is very common in many projects due to a large number of unforeseen circumstances, either from the suppliers' point of view, who usually depend on others, but also from unavoidable and unforeseeable circumstances such as those provoked by nature, strikes, accidents, blackouts, etc. For this reason it is common especially in manufacturing processes, to work with a safety reserve or 'cushion' or safety stock, for some materials, parts, subsets, etc., as mentioned in Sect. 10.3.

Table 10.2 Equipment delivery status report – Controlling equipment delivery for a mall construction

Sub project: Sewage system for Mall kitchens			Contract # 17		Contractor: Water and Sewage Industrial Installations Inc. (WSII)			
Week ending June 23, 2012			Page 1 of 1					
Purchase order (P.O.)								
1	2	3	4	5	6	7	8	9
Number	Description	Responsible/Supplier	To be installed by	Delivered date as per P.O	Delivered promised date	Scheduled date to be delivered to contractor	Estimated date for delivery to contractor	Remarks
Sew 17001	Excavation for tank	WSII	WSII	Apr 09/12	Apr 14/12	Apr 09/12	Apr 14/12	Job complete
Sew 17002	Concrete encasement	WSII	WSII	Apr 19/12	Apr 19/12	Apr 21/12	Apr 20/12	Job complete
Sew 17009	Kitchen effluent grease removal systems	Removal Systems	Removal Systems	May 18/12	May 16/12	May 31/12	May 28 /12	Floor drains and grease traps by WSII
Sew 17006	Ducts	Thomas ducts	WSII	May 12 /12	May 11/12	May 14/12	May 11 /12	Ducts are in the jobsite
Sew 17008	Clarifier mechanism	Amex	WSII	Jun 09/12	Jun 09/12	Jun 09/12	Jun 23/12	CRITICAL – WSII informed
Sew 17003	Sludge recycling pumps	The Pump Co.	WSII	Apr 12/12	May 02/12	Apr 19/12	Apr 19/12	Not Critical – WSII informed
Sew 17004	Holding tank for biotreatment	Bio & Waste Inc.	WSII	Apr 21/12	Ap. 28/12	May 10/12	May 11/12	Vendor working at the jobsite with WSII
Sew 17005	Inflow pumps	The Pump Co.	WSII	Jun 15/12	Jun 15/12	Jun 15/12	Jun 15/12	Pumps shipped June 16
Sew 17007	Outflow pumps	The Pump Co.	WSII	Jun 17/12	Jun 15/12	Jun 17/12	Jun 18/12	5 out of 6 pumps are delivered, but pump 6 is 1 week behind schedule
Sew 17006	Turborators	Amex	WSII	May 31/12	Jun 02/12	May 31/12	Jun 18/12	Vendor with delay because a fire – WSII informed

10.5.2 Inspection

The process of acquiring some equipment can be broken-down for control at different times as follows:

- At the factory
 - For instance, for a welded rotary kiln for Portland cement, there may be need to inspect the welding process in the factory as well as to check procedures for X-Ray testing of both, the welding and the refractory lining,
 - For pumps, hydrostatic seal testing, as well as pressure head, and vibration testing, amongst others,
 - Control instrumentation, for large paper machines, etc.
- On arrival at the jobsite
 - Check all documentation accompanying equipment at its arrival at the jobsite. Look for full agreement of delivery with the purchase order and for completeness of all required accessories (bolts, seals, gaskets, instruments, etc.), as well as manuals and instructions for assembly, alignment, and special precautions that must be taken for erection and connection with other equipment or piping,
 - Make sure that sensible and especially electric and electronic equipment is stored under roof and on pallets and plastic covered to avoid chances of water damage in case of flooding of the warehouse or roof leakiness,
 - Compare both actual and scheduled dates for delivery,
 - Check for abnormal or damaged packing as well as evidence of blows, dents, water marks and stains, etc.,
 - Same applies for equipment rentals, which must be inspected and anomalies noted before signing the reception,
 - Check, if applicable, for special tools incorporated in the P.O.,
 - In equipment coming from overseas check the name and spec nameplates, by contrasting the ID and numbers in them with the accompanying documentation, especially the voltage and frequency (not all countries use the same voltage nor the same frequency!). Most of the world (practically all Asia, Oceania, Africa and Europe) use 220–240 V/50 Hz, while most of the American countries, except Argentina and Peru use 100–127 V/60 Hz.

- After installation
 - Check for compliance of all working parameters such as pressures, vacuum, temperatures, yields, quality of final product, wear and tear, water and energy consumption, quality of exhaust and wastewater, etc.,
 - Keep records about production, yields, abnormal performance, etc.,

10.5.3 Materials Deliveries for the Project

If some material is produced in the job site such as gravel, concrete, electric energy, etc. keep records of production and quality, and make sure that production matches needs in quantity and in time. Contact the quality department to have some material tested before use, as well as right size and blend for components. For instance, it may be convenient to perform ‘slump tests’ in fresh concrete for workability in each batch delivered observing and recording quality consistency between them. In some cases concrete must be cooled to a certain temperature, and this is another aspect to be considered and checked.

10.6 The Gozinto Diagram for Manufacturing

This is a diagram with a similar format of the WBS. It consists in breaking down a product to analyze the relationships between the final product and its components and establishing an upward hierarchy, starting with parts and raw materials at the lowest level, following with subassemblies at an intermediate level, continuing with assembled sets in a semifinal level, and then to a subsequent level that corresponds to the finished product.

It is useful to determine the amount of each component that intervene, especially when several final products share some of these components as happens in many industrial products such as for instance in a line of different types of bikes. It is also known as ‘*Assembly diagram*’. It can be considered a project management tool, but in reality is a materials management technique used to prepare the ‘*Bill of Materials*’ (BOM).

10.7 CASE STUDY: Contractors Selection for Construction of a Copper Refinery

10.7.1 Background Information – General Objective

The project pertains to the construction of a US \$84 million copper refinery. It is sponsored by NEXXAR Corp. which retained an independent consultant to select a main contractor

responsible for the execution of the whole project, which includes facilities construction and project management for equipment installation (by others). The objective was then to select the best general firm for the job, subject naturally to a series of requirements. After an initial selection of available general firms, five reputable companies were shortlisted and invited to submit their qualifications and credentials for the project according to the Bid Terms and Conditions. Only one main contractor will be selected out of the shortlist, albeit joint ventures between contractors were permitted. The consultant requested referrals from different sources about these five companies, and based on them compiled an evaluation for each one to be used as scores for the objective function ‘*Referrals from industry*’. The selection procedure is based in the methodology exposed in Chap. 8; please refer to it to understand the process followed here.

The five shortlisted firms were:

- RFG Corp.
- United Constructions
- ITO Japan Corp.
- CORD Inc.
- Robert Schmidt GmbH Berlin

10.7.2 Selection Criteria

To evaluate contractors, 15 criteria were chosen as depicted in Table 10.3, all with the same weight.

Table 10.4 depicts the decision matrix in Excel, while Table 10.5 normalized these data. This table shows also the result of selection when only one objective is considered, in this case ‘*Referrals from industry*’. According to this, contractor CORD appears to be the best, since in the ‘*Result using referral from industry*’ row it is the only one with a positive value. However, the PM thinks that there could be some bias in this selection because it is based on subjective appreciations; for that reason he requests a further analysis using a multiobjective appraisal, considering as successive objectives, restrictions 1–5–6–7–8–9–10–14 and 15. (The procedure is explained in Sect. 8.5).

This time, the problem is solved using the complete power of Simus that considers any number of objectives. The result (Table 10.6), shows that again CORD Inc. is by far the best contractor, followed at a distance by Schmidt GmbH.

10.8 Conclusion of This Chapter

This chapter deals with another fundamental aspect in project management, since a thorough, conscious and well done planning and scheduling is of no value if materials, parts, equipment and other inputs are not on the jobsite in the quantities required and at the time when they are needed.

Table 10.3 Criteria to evaluate contractors – Contractors selection for construction of a copper refinery

Criteria I.D.	Criteria
1	Years in business
2	Staff (engineers, draftsmen, etc.)
3	Other specialties (mining, geology, safety, quality, transportation, etc.)
4	Man power assigned to this project
5	Power in MW installed in the last 5 years
6	Number of projects executed related with metallurgical operations
7	What percentage of equipment used for this project is owned by the contractor?
8	Own equipment average age
9	Number of projects finished worth more that US \$25 million
10	Number of projects acting as a main contractor since the establishing of the firm
11	Percentage of projects delayed more that 10% of the initial time
12	Number of times that the same client contracted the firm
13	Number of conflicts with owner that finished in court
14	Working capital during the last five projects
15	Liability insurance in millions of dollars

Table 10.4 Data on five potential contractors – Contractors selection for construction of a copper refinery

Criteria	#	Decision matrix					Sum of rows
1	1	35	48	50	77	57	267
2	2	45	49	62	76	39	271
3	3	11	8	0	7	12	38
4	4	310	294	309	310	290	1513
5	5	137,000	194,200	179,800	204,500	101,000	816,500
6	6	9	12	18	9	13	61
7	7	90	80	91	99	87	447
8	8	5	8	3	5	4	25
9	9	41	54	69	56	45	265
10	10	1.9	1.4	2.3	3.8	2.6	12
11	11	14	21	19	28	12	94
12	12	8	10	19	23	14	74
13	13	5	5	15	12	9	46
14	14	2.6	1.8	2.2	1.9	1.7	10.2
15	15	8.5	13	11.2	14	11.5	58.2

Table 10.5 Normalization of Table 10.4 – Contractors selection for construction of a copper refinery

Criteria	#	Normalization					Results from computation		Threshold required Operator		
							Action				
	1	0.131	0.180	0.187	0.288	0.213	MAX	0.286	≤	0.288	
	2	0.166	0.181	0.229	0.280	0.144	MAX	0.278	≤	0.280	
	3	0.289	0.211	0.000	0.184	0.316	MAX	0.185	≤	0.316	
	4	0.205	0.194	0.204	0.205	0.192	MAX	0.205	≤	0.205	
	5	0.168	0.238	0.220	0.250	0.124	MAX	0.250	≤	0.250	
	6	0.148	0.197	0.295	0.148	0.213	MAX	0.149	≤	0.295	
	7	0.201	0.179	0.204	0.221	0.195	MAX	0.220	≤	0.221	
	8	0.200	0.320	0.120	0.200	0.160	MIN	0.203	≤	0.120	
	9	0.155	0.204	0.260	0.211	0.170	MAX	0.211	≤	0.260	
	10	0.158	0.117	0.192	0.317	0.217	MAX	0.312	≤	0.317	
	11	0.149	0.223	0.202	0.298	0.128	MIN	0.296	≤	0.128	
	12	0.108	0.135	0.257	0.311	0.189	MIN	0.307	≤	0.108	
	13	0.109	0.109	0.326	0.261	0.196	MAX	0.257	≤	0.326	
	14	0.255	0.176	0.216	0.186	0.167	MAX	0.186	≤	0.255	
	15	0.146	0.223	0.192	0.241	0.198	MAX	0.240	≤	0.241	
Projects participation		1	1	1	1	1	EQUAL	1.000	=	1	
Result using 'Referrals from industry'		0	0	0	1	0					
Objective function		0.240									

Table 10.6 Result of selection – Contractors selection for construction of a copper refinery

Objectives	#	RFG Corp	United Const.	ITO Corp.	CORD Inc.	Schmidt GmbH	Action
	1				1		Max
	5				1		Max
	6						Max
	7				1		Max
	8					1	Max
	9				1		Max
	10				1		Max
	14						Max
	15				1		Max
Result using several objectives		0	0	0	6	1	

That is, there are two main aspects to consider: quantity and timing, and of course, with the required and specified quality. The procurement function does cover a wide scope of work commencing with selecting vendors and contractors, tendering, inspection of materials and equipment and finishing with reception.

These aspects have been in general covered here starting with the determination of needs through the Bill of Materials and Bill of Quantities, for both types of projects examined:

- (a) Manufacturing projects where normally there is repetition of inputs and
- (b) Construction projects where in general inputs are punctual and non-repetitive events.

For the first type of projects a method for determining needs is proposed (the Gozinto diagram), while a very well-known formula is described for ordering economic

quantities and frequency of ordering. For the second type of projects a series of considerations are mentioned and illustrated with the construction of the equipment delivery status report.

A case example is also proposed to illustrate a manner to select vendors and contractors.

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Abstract

This chapter analyses the complex relationships between the different departments of an enterprise or a project which more often than not seem to work as if they were separate entities, because of lack of communication or personal problems between members of the staff. The selection and use of specialized software to solve this problem is examined here, aiming at installing a system where all the project or business information is available, without ‘noise’ or transmission errors, and accessible only to people authorized to know it. Besides, this system lets the project manager and the financial department to have a clear picture in real time of what is going on the project, considering any transaction – whatever its nature – related with the project.

Keywords

Enterprise Resource Planning software • Modules • Statistics • Financial indicators • Development indicators

11.1 Reporting Advance and Development of Project

We examine here the different reports that are normally issued in most projects. Figure 11.1 depicts the different graphic and tabular reports usually prepared in a project.

11.1.1 The Weekly Progress Report

The weekly report, a fundamental document used to keep everybody informed about the development of the project during the last week involves three parts (a) Narrative, (b) Tabular, and (c) Graphic

(a) Narrative

- Approval or acceptance by the owner of reports, studies, deliveries, or completion of parts of the work,
- Approval or acceptance by the owner of schedules submitted by a contractor, and previously approved by the entity managing the project,
- Areas that show delay and measures taken to correct it,

- Brief description of the work done during the week,
- Description of milestones met and/or missed,
- Environmental problems encountered and ways adopted to solve them.
- Estimate of completion date and completion costs,
- In case of delays of critical activities report measures taken to correct the problem,
- In remote camps, indicates advance of temporary installations such as personnel accommodation (trailers for dormitories, offices, kitchen, entertainment, etc.) as well as sewage plant, lighting, etc.,
- Latest information about main equipment delivery to the site, when there has been schedule modifications by suppliers,
- Main change orders generated either as a consequence of the development of the work and approved by the owner, or change orders generated by the owner himself,
- Main unforeseen events affecting the work, such as strikes, serious accidents, personnel problems, geological findings, floods, etc,
- Major problems encountered,

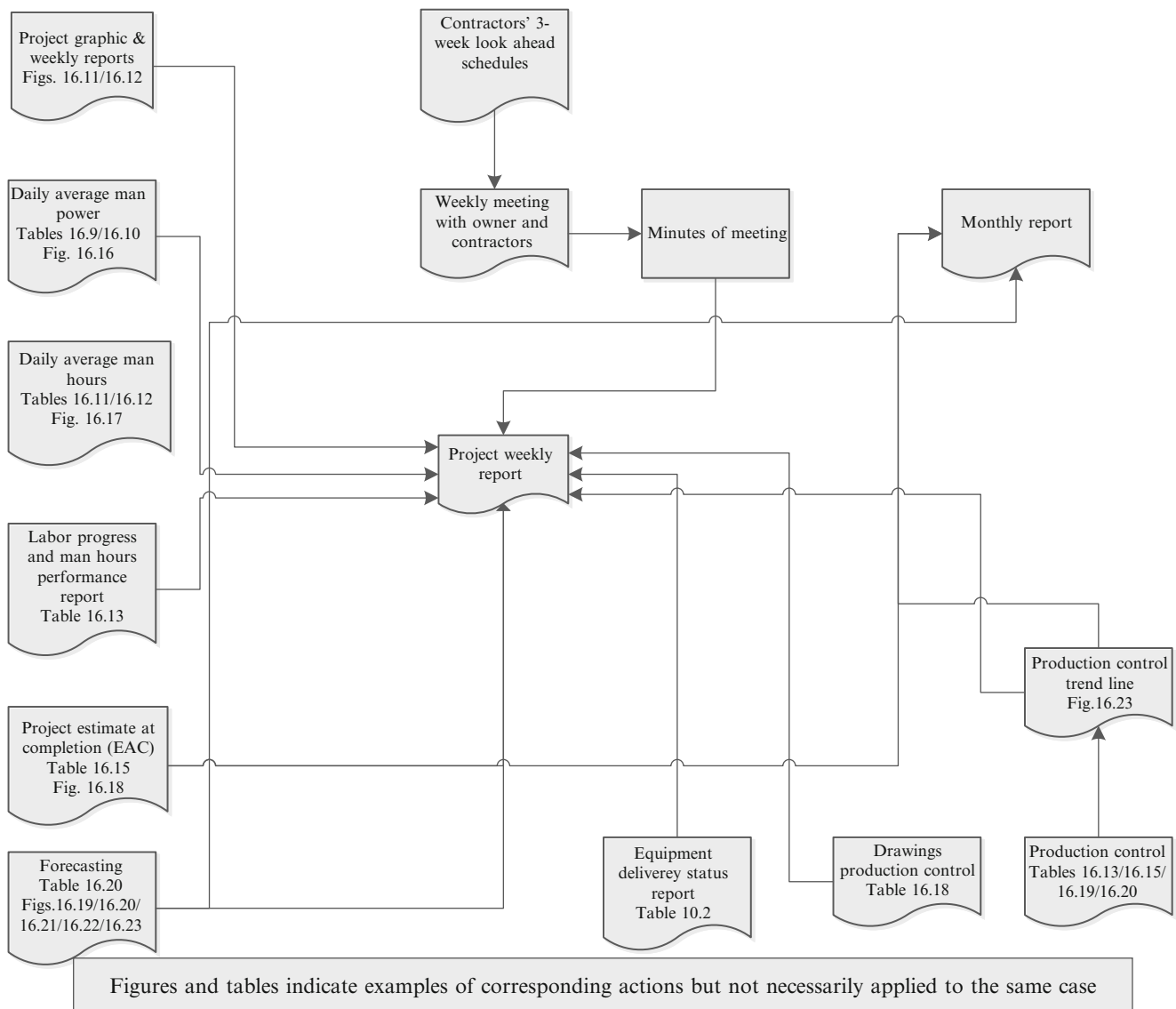


Fig. 11.1 Project graphic and tabular reports

- Overall quantitative comparison in percentage of work advance against scheduled,
- Record on meetings and agreement or disagreement with the owner about main points related with the work, as well as modifications and demands proposed by the owner,
- Report on arrival at the job site of specialized equipment, for instance a Tunnel Boring Machine, (TBM) or large construction crane,
- Report on assembly or erection of large construction equipment such as the TBM or cranes,
- Report on compliance with each contractor's contractual schedule about type and quantity of construction equipment on the jobsite,
- Report on the production of aggregates performed,
- Report work done on ancillary and temporary installations, for instance a refrigeration plant for concrete cooling, a crusher plant for concrete aggregate, the construction of temporary cofferdams for a river deviation, construction roads, etc.
- Results from inspections and tests on equipment at the manufacturer site, and witnessed by entity staff (for instance for large pumps, wind tunnel tests, etc.),
- Safety problems, solutions and measures taken,
- Total manpower by contractor and a brief analysis about compliance with schedule. This count must include the entity's personnel,
- Weather during the past week and related with the development of the project (heavy rain, heavy snow, strong winds, flooding rains, etc.).

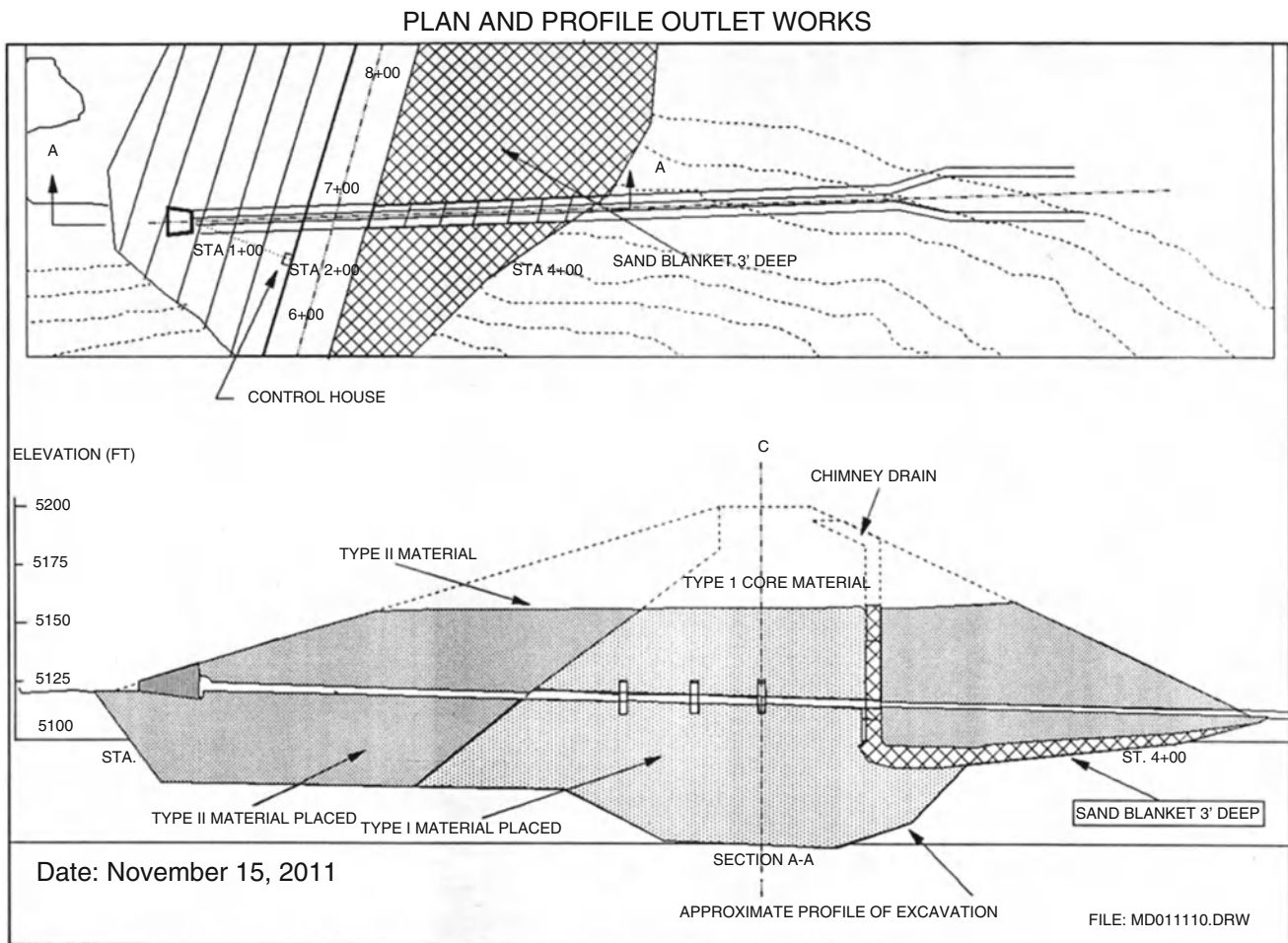


Fig. 11.2 Reporting status of work at November 15, 2011 – Dam construction

It is prepared by the project management people with input from contractor/s as well as from the entity managing the project. The narrative must include the following items:

(b) Tabular reports

- Tabular reports are normally issued to show quantities related with the advance of work,
- 3-week look-ahead schedule which depicts planned advance of work in the following three weeks, and related with main activities in this period.

(c) Graphic reports

A convenient way to transmit information to the owner and stakeholders and in reality to everybody is the preparation of a graphic report showing the advance as a function of time. It is a reproduction of a section of the work, taken from the construction drawings, and using some drawing software for instance FreeLance®, and not necessarily to scale, since it can also be a sketch. There is naturally an initial effort and money spent in drawing the first outline; however it is also possible to get it rapidly considering that drawings are in the data

base. The system consists in showing, through shading, comments, remarks, etc. the status of the work at a certain date, usually on a weekly basis.

Then, for every successive update the same initial sketch is used, and indicating the advance in a certain period. Then the sketch shows two kinds of information (a) The accumulative work done and (b) the work done in the last week or whatever period is considered. This report is an invaluable document which can show in a set of successive updates how the work has been advancing from week to week. It is also an effective document to analyze the development of the project when it is closed out, as well as a source of information for future similar projects.

Figure 11.2 depicts a plant and cross-section views for the construction of a compacted earth embankment dam. Notice its components (up to this status report):

- The cut-off trench filled with impervious material to avoid seepage,
- The water discharge conduit and an outlet gate to control the outflow of water,

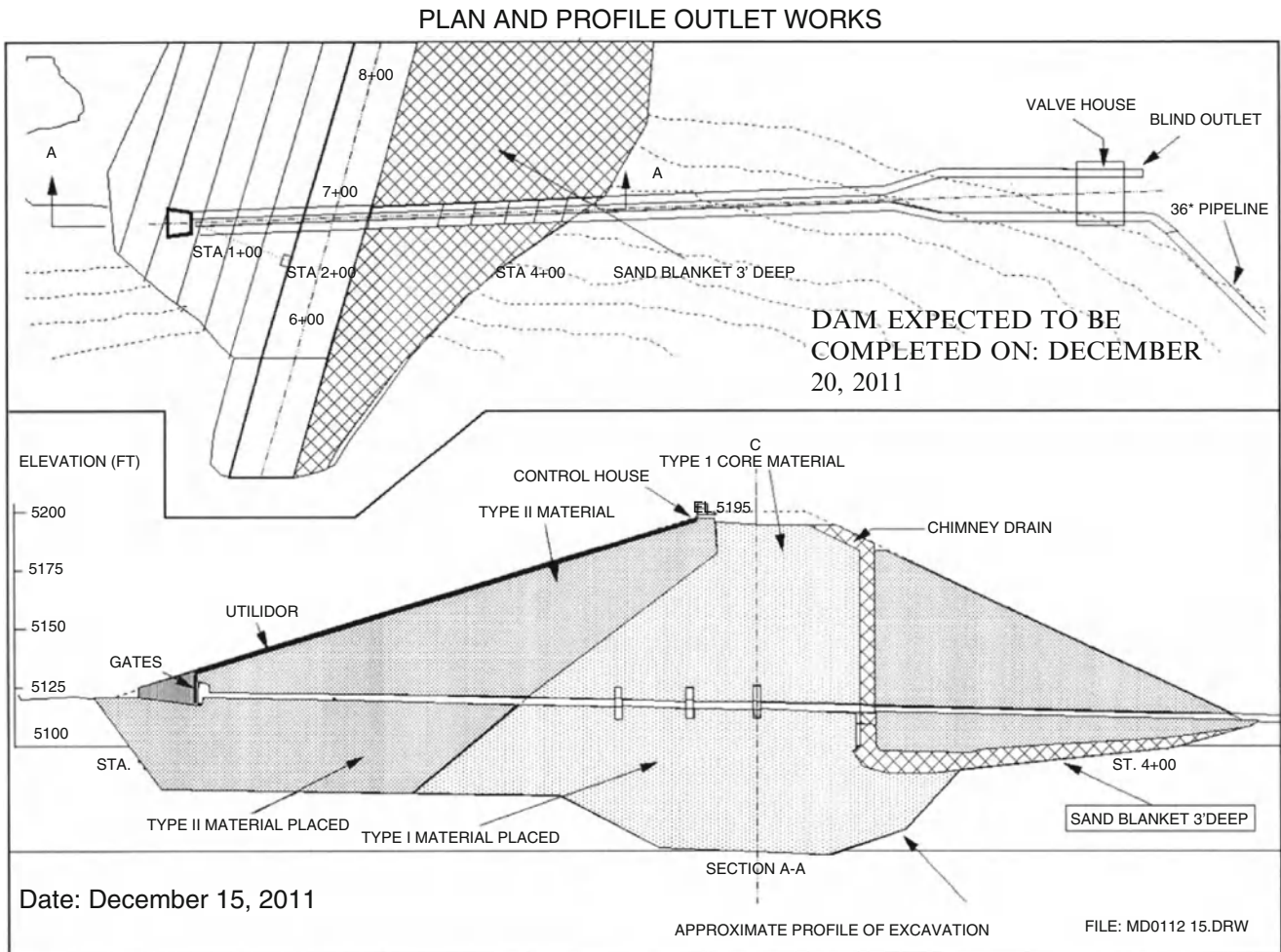


Fig. 11.3 Reporting status of work at December 15, 2011 – Dam construction

- The chimney drain on the down stream slope of the dam, as a drainage system,
- The different types of materials used, identified in different tones of shades and filling.

This report shows the status of the work on November 15.

It informs about:

- The approximate height reached by the core, of about 51.56 ft.
- The placement of the different types of material for the impervious core, rip rap, as well as the sand blanket for the chimney drain.

A month later, on December 15 the sketch is updated (Fig. 11.3). Notice:

- The approximate height reached is now 51.96 ft,
- The construction of the utilidor,¹
- The construction of the valve house,

¹ Tunnel to carry utility lines, in this case electric wire for the outlet gate for the water discharge conduit.

11.2 Meetings

Meetings are events that are almost mandatory in any project, because they allow communication between the different interested parties. Lack of communication is a serious troubling factor in all projects. There are however different kinds of meetings according to their purpose, as follows:

- *'In-house' meetings* that is those attended by the project management staff. They are useful in two counts.
 - (a) There is a vertical communication between the members of a team doing a certain task. In this way the team leader learns about the progress of his/her team and at the same time all members take notice,
 - (b) There is a horizontal communication between the members of different teams pertaining to diverse areas. These meetings facilitate coordination between distinct facets of the work, and at the same time serve to clarify misunderstandings or to reach agreement on a controversial issue. For instance, Project Control, in charge of writing the Weekly Report to the client,

may be reluctant to include in it some remarks furnished by the Safety people because they think that they are irrelevant, which of course is not what the Safety people think. This is the opportunity to air arguments from both parties and to reach an agreement. If not, it will be the Project or the Construction Manager, usually attending the meeting, who will have the last word.

- *Early morning meetings*, usually led by the Construction Manager, with the assistance of leaders from the managing staff, and also by the technical representative of each contractor. In this circumstance, issues related with the general development of the project on each area are briefly analyzed, while work done the day before commented on. This is an opportunity for each contractor representative to explain what has been done or will be done to correct a situation. This is important, not only due to a potential delay but also because all other contractors attending the meeting can take notice about a problem that can affect them in the near future.
- *Weekly meetings* attended by the Construction Manager and the Project Management staff managers, contractor representatives and the owner technical representative. Its main purpose is to keep the owner aware of what is going on and how is the project developing. The owner representative may agree or not with what he/she hear and may propose new measures and changes or request more information. Whatever is discussed a minute of the meeting must be prepared by the managing staff, signed, and sent to every participant in the meeting.
- *Monthly meetings*, attended by the owner and stakeholders, and by the Project Director or the Project Manager on behalf of the managing staff. Naturally, not details are discussed here but crucial aspects that require attention are identified.

The most important singular meetings must comply with a series of conditions to be effective, for instance:

- Establish a meeting etiquette regarding time to expose matters and time for answers,
- Follow an order of matters to be discussed and rank them as per their importance,
- Meetings must be attended only by people who are participating in the project or who have a vested interest in the business under discussion.
- Set up a start and finish time, and reduce a meeting duration to no more than 1 h; after that, besides keeping key people off their daily duties they get tired and their contributions decrease.
- Sometimes there are questions that concern only a few persons, or one contractor, or deal with a particular problem; in that circumstance it is better to prepare a special meeting to tackle the issue instead of considering it in a general working meeting where many other questions are

addressed. It is fundamental to respect other peoples', including a contractor's, time and not to abuse that time with discussion of matters in which they have no interest or participation.

11.3 Additional Communication Means

The above reports and communications are standard documents in any project, however, more elaborate information is usually needed for the stakeholders to take action. This intelligence is more useful when it is on-line, and when authorized people can access files, reports, charts and valuable economic and financial information. It is also possible to learn instantly about the status of materials and equipment, as well as a wealth of information about the project financing, progress in payments to contractors, orders placed to suppliers, relationship with the client, etc. It is also necessary to consider that if there is a large number of stakeholders this communication flow may be very demanding and then the necessity of relying in electronic systems becomes evident.

What was utopian decades ago is now a reality. It is now possible to view and receive this multiple, updated and selected information using a data base accessed through a dedicated software known as '*Enterprise Resource Planning*' (*ERP*). The advantage of the system rests in the fact that all departments in the enterprise are intercommunicated and capable of exchanging information, thus putting an end to the existence of 'secret files or information' that is available only to a certain department or individual of the firm and not shared – as it should be – with other interested departments.

One of the multiple advantages of this system is that it allows any individual to view or receive only the information that he/she needs and with the prescribed frequency. In a project, the level and destination of communications is set by the Project Manager or the Director. In reality the ERP, as its name implies, is an enterprise information system; when it is applied to a project it can be considered a Project Management Information System (PMIS).

Notwithstanding the benefits of ERP in allowing consolidation of all data and information within a company, it does not offer the same advantages for data analysis. For that reason another tool called OLAP (On-Line Analysing Processing) which provides 3-D information from a relational database² can be used.

² In a relational database, information or data is stored in tables with rows (tuple) and with columns (fields) which are independent of the hardware used. These tables are built with relationships between them which permit their navigation.

11.4 CASE STUDY: Diagnosis in an Enterprise and Proposal to Install an ERP System

This case study analyzes how to select an appropriate ERP system for a particular industry, since there are many choices in the market, some oriented to specific activities and some dedicated to a particular industry.

11.4.1 Background Information

The Valencia Cosmetic Company (VCC) is an industrial firm located in the city of Valencia, Spain. Its main business is the manufacturing and distribution of cosmetic products for men and women.

VCC's line of products involves:

- Disposable continuous blade razors for men with soft beards, coded HB,
- Disposable continuous blade razors for men with hard beards, coded HD,
- Disposable continuous blade razor for women, coded HF,
- Pre-shaving lotion for men, coded LAAH,
- After-shaving lotion for men, coded LDAH,
- After-shaving lotion for women, coded LSDM,
- Shaving foam for men, coded ESH,
- Shaving foam for women, coded ESM.

11.4.2 Areas Involved in the Industrial Process

- Human resources,
- There are 87 people working in its two plants (Blades and Cosmetics),
- The Blades Plant, that includes the general manager's office, is located in an industrial park, while the Cosmetic plant is situated in another industrial park about 16 km. away. The Company thinks that this is not the best arrangement since it would be better to have both plants in the same location.

11.4.3 Structural Organization

VCC is a corporation and has a functional structure headed by the Board of Directors and a General Manager for the two plants; in turn each one of them has a Plant Manager. Figure 11.4 shows the VCC structure albeit it is not complete since Accounting and Finance departments are not shown.

11.4.4 Industrial Processes

Their description is necessary to learn about their needs in communication and their interrelationships.

11.4.4.1 Blades Production

- **Materials input**
The raw material is stainless steel 18/8 coming from Sweden. The material is received in coiled sheets about 0.60 m wide and with a weight of about 5 t. It is received by truck at the VCC plant, where weight and thickness are controlled as well as checked for potential damages. A Brinell hardness test is performed in coils selected at random, and if the lot is approved it enters the VCC warehouse.
- **Cutting**
The process is initiated when the width of the steel roll is sliced into several stripes, each about 7 mm wide, and then spooled individually. A coding system is used for all stripes coming from the same roll, with the lot number (given by the steel maker in Sweden), purchase order number, date of arrival in plant and general observations about condition. Then, the material that is not to be used during the same day is stored in the warehouse. Naturally, each time that any material enters or leaves the warehouse it is registered electronically in the warehouse computer.
- **Thermal treatment**
This consists of unwinding each coil and letting it pass between two heated steel plates for tempering, followed by annealing, and then coiled again.
- **Blade sharpening**
A tempered and annealed coil is placed at the head of the sharpening line. This operation is performed by three different pairs of grinders ranging from coarse to fine in order to produce three different cut angles. Finally the strip is cut and stored in a special device called a 'magazine' to preserve its cutting edge. Quality control is exerted using Shewhart³ control charts, throughout the process with automatic stoppage of the sharpening line if quality control standard inspection detects differences to an average beyond $\pm 2\sigma$.

11.4.4.2 Fabrication of Plastic Holders and Blades Insertion

This is simply molding by plastic injection fed with plastic pellets.

³ An American engineer considered 'The father of quality control'. The Shewhart chart, invented by Walter Shewhart in the second decade of the twentieth Century is a graphical plotting of certain characteristics of a product, establishing positive and negative deviations limits regarding an acceptable central value; it is utilized in quality control in manufacturing. Measures taken during manufacturing and plotted in this chart must be as close as possible to the acceptable central value and never surpass both limits. If in a lot there are a large amount of items whose measured characteristics lie consistently beyond the limits, it is considered that the product does not meet the quality standards established by the manufacturer, and then it is destroyed.

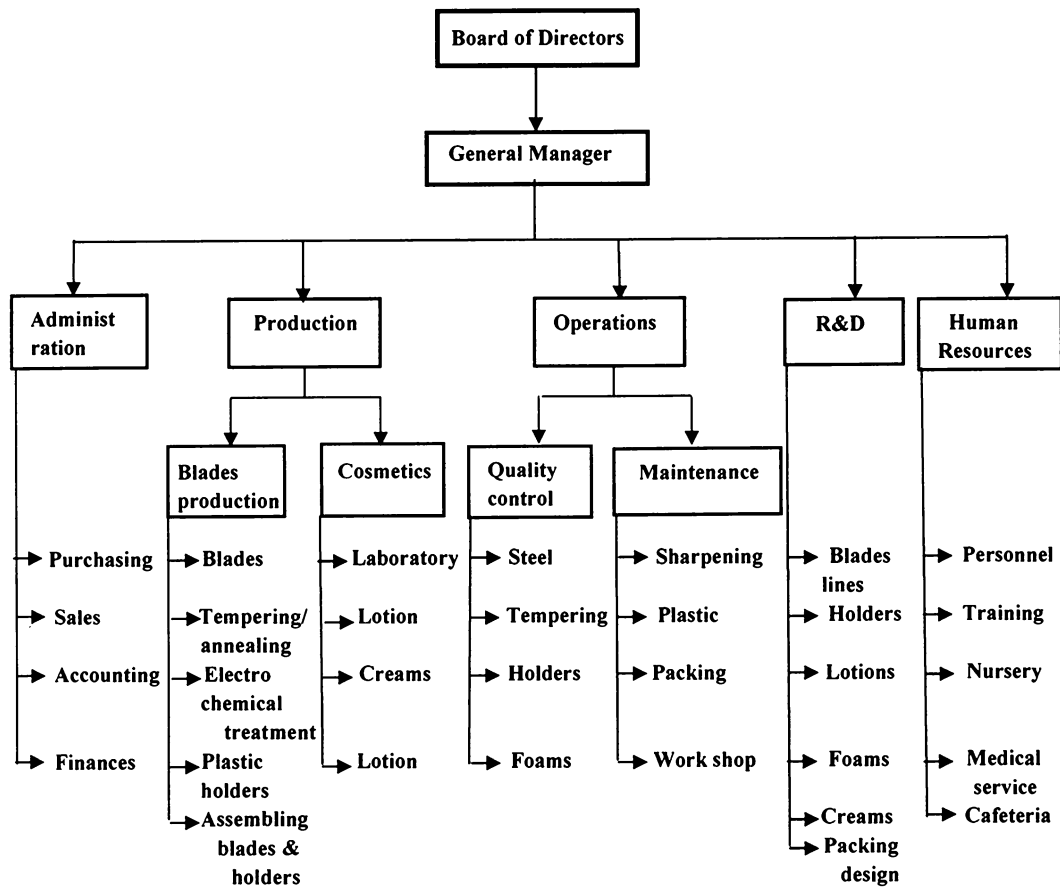


Fig. 11.4 VCC organization structure – Diagnosis in an enterprise and proposal to install an ERP

Assembling blades and holders

An automatic machine takes two blades from the magazine and inserts them into the holder.

Packing

Done by BORA wrappers with a capacity of 100 packages/min. There are also other machines to complete the packing.

11.4.4.3 Cosmetics Plant

Products are:

- Pre and after-shaving lotions
It is a simple process that consists in blending diverse elements such as distilled water, alcohol, oils essences and glycerin.
- Foams
It is in reality a light soap with stearic acid. VCC produces the foam with simple equipment which is similar to that used for bath soap production.
- Creams
This product is created in the plant with neutral soap, distilled water and glycerin. It is packed in aluminum cans and the cream propelled by an inert gas.

11.4.5 Necessary Inputs

There are not a large variety of inputs, however some of them are coming from overseas and prone to delays, and therefore a strict inventory control is necessary.

Other departments indirectly taking part in the manufacturing process are: Administration, Purchasing, Sales, Finance, Accounting, Maintenance, R&D, and Human Resources. The objective of this case is to develop a communications method as well as to facilitate restricted access to production, operations, economic and financial departments with on-line data, involving most of VCC departments.

11.5 Procedure to Install and ERP System

It is necessary to thoroughly study the existent system installed in the company, and detect its weak points related with communications. The following procedure is discussed to analyze relationship between the different departments.

11.5.1 Road Map for a Purchase Order from a Client

1. It is necessary to analyze the standard communications flow between the different departments. As an example we will track the route of a client's purchase order through the different departments until the delivery of the requested good to him, sketched in Fig. 11.5. In this case it will involve the following steps; notice that number references corresponds to numbers between brackets in the cited figure.

1. The client's purchase order (1) (P.O.) arrives to Sales,
2. Sales queries (2) the Warehouse – which is under Operations – regarding finished product availability to comply with the new customer's purchase order, or if the existent stock is already assigned to other clients. If the order can be honored, Warehouse (3) ships the item to the client and reports to Accounting (4) in order for them to deduct that quantity from inventories and credit the amount corresponding to the sale. Naturally, the Warehouse also deducts this quantity from its own inventories registry. The Warehouse also reports to Accounting about items, part or components withdrawn by Production, as well as inputs from Production or production in progress and finished products,
3. If product is not available, Sales informs Production about the need to fabricate the item (5) and also reports about the existence or not of raw materials, parts and components for its manufacturing, information obtained from Warehouse,
4. If necessary, Production requests from Purchasing raw materials, parts and components (6). If it works in batches according to the E.O.Q. policy (see Sect. 10.3), requests that Purchasing issue the corresponding P.O.
5. Purchasing places P.O. to Supplier (7),
6. Supplier ships P.O. order to Warehouse (8),
7. Production manufactures the item and sends it to Warehouse for storage as a finished product (9), and reports to Costs and Analytics about production cost for that batch (10),
8. Warehouse ships the item to Client (11) and returns to Accounting Client's receipt of merchandise (12),
9. Accounting invoices the Client (13) and gets paid (14),
10. Accounting pays Supplier's invoice (15),
11. Accounting informs Finance (16) for them to update the financial statements (see Sect. 7.2),
12. Costs and Analytics reports to Finance (17) about production costs.

This is only an example and of course far from complete, but has been developed to show the complexity of operations. Now think of an actual case with many purchase orders from clients and those placed to suppliers, the hundreds of internal transactions within the company when Production withdraws materials, goods, parts, etc. from the

warehouse and also puts in them as production in progress or finished products, as well as communications with clients and suppliers. There is obviously a need to have all information centralized and that is the purpose of an ERP system.

11.5.2 Symptoms and Problems Detected During the Examination of the Existent System

The decision for the company to consider the installation of an ERP system stems from the following aspects:

- There are constantly differences between quantities specified in purchase orders to suppliers, with those in receipts for materials entering the warehouse and with inventory records on the warehouse shelves. The necessary tracking generates a waste of time, without – most of the times – reaching a satisfactory answer,
- Accounting does not uniformly receive information from Sales regarding account receivables and besides does not know about the economic terms agreed in a transaction,
- There are problems related with devolutions when Accounting does not know about them, consequently affecting the bookkeeping. For the same token there has been opportunities when Production is not informed if devolutions are a consequence of some manufacturing defect or by any other cause,
- One of the reasons of these problems is that apparently Warehouse – that is Operations – fails to inform Accounting about this material reentering, and naturally the balance does not register that movement,
- In turn, there is often disagreement between Production and Quality Control (under Operations), when it is necessary to stop a sharpening line and discard all the material loaded in the line. Apparently the problem lies in the fact that neither of the departments have agreed about who should inform Accounting about this, therefore, sometimes the information is sent twice while in others there is no information at all,
- There are problems between Maintenance (under Operations) and Production regarding the preventive maintenance program that sometimes conflicts with Production programs, because there is a lack of reliable communication, or maybe Maintenance is not aware of Production schedule changes; for instance, there could be an agreement between Production and Sales to satisfy a client's new urgent order. If Maintenance is not informed about this fact, its staff is unaware of the change and tries to proceed with its preventive maintenance schedule, and then a conflict appears,
- R & D is sometimes left out of the information circuit because some people think that certain information does not interest this department. For instance the General

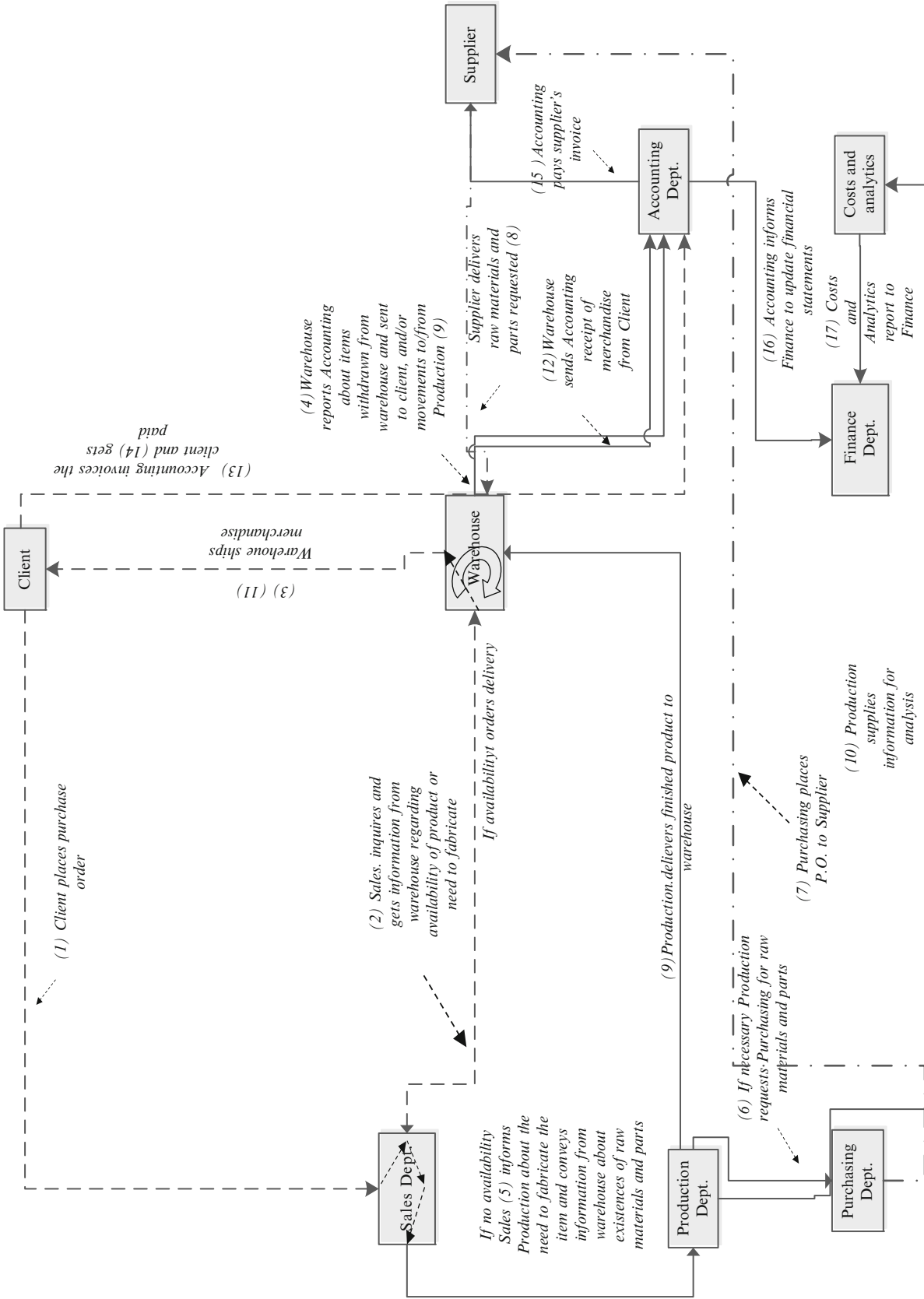


Fig. 11.5 Flow chart for a purchase order from a client – Diagnosis in an enterprise and proposal to install an ERP

Manager has requested from the Sales Department information about the degree of satisfaction from large customers, information that is processed by an outside company not related with VCC. Sales received the report but have not internally distributed it because they want to study it thoroughly (something that in reality is out of its competence). R & D as well as Production argue that they should be informed about that, because if there is a problem, perhaps they can solve it, not the Sales people.

- Sales and Marketing, being in contact with clients and the market sometimes detect new opportunities. In a number of cases they alone screen them and decide if they are worth pursuing. R & D as well as Production complain that they need to have that information before any decision is taken, because they argue that it is their competence to decide if the idea is or not technically feasible, and before its goes to the General Manager, especially because they feel that their appraisal is independent of Sales and Marketing opinions or interests,
- In addition, Production, from both plants, takes an unusual length of time to study ideas and suggestions from employees.

Because of these facts there are frictions and discussions between department managers.

11.5.3 Analysis of the Situation

After an exhaustive analysis of all communications in the company, experts have reached the following conclusion:

1. There are several instances where the information flow is interrupted (willingly or not), which explains why it does not reach all interested parties,
2. There is no consistency or coherence between the numbers corresponding to purchase orders to suppliers, the manufacturing order, the supplier's receipt and the receipt from the client which explains why tracking a problem takes days to be solved,
3. Production does not regularly send actual cost related information to Costs and Analytics (under Finances), which results in Finance not having the right and true values for production costs,
4. Warehouse does not regularly receive information from Sales and/or Production about the necessity of keeping certain materials or finished goods for a particular client, which in the past provoked a serious problem with a large supermarket, and in addition for the company to lose a confidence and prestige gained during several years (This in reality is a problem of external quality, see '*Cost of non-conformance*' in Sect. 15.11),
5. There were some other minor problems as for instance the lack of control in the Cosmetics Plant warehouse because

there was neither an exact idea of where certain raw material is nor their exact quantities, because the absence of labeling or due to lack of space. In that respect it results in purchase orders sometimes being placed to suppliers when there are still exists enough inventory of a product, raw material or part,

6. Another problem related with this plant is that ingredients, being of organic nature, have a limited shelf life; however, a very rudimentary and obsolete control is performed. This caused that in the past, two large glycerin drums had to be discarded because their expiration date had long been passed, since fresher glycerin drums were used and put into production, without taking into account the existence of an older product.

11.5.4 Diagnosis of the Situation

In addition to the circumstances commented on above, there are problems from the fact that whatever the status of a product, that is as raw material, work in process, finished, etc. it has to be registered somewhere, and this obliges staff to make multiple movements from and to the warehouse and the corresponding accounting registration, and this is not done because of 'lack of time' according to the warehouse manager. It is then indispensable that these movements be duly instrumented in order to facilitate their tracking and fundamentally permitting communications between departments.

Because of this a conclusion is reached that the company needs an Enterprise Resource Planning system (ERP). This implementation is neither easy nor does it carry a low cost, but no other solution is envisaged, since continuing with the same policy will lead to a loss of competitiveness and to a decrease in efficiency. From the flow chart depicted in Fig. 11.5 it is seen that there are seven critical areas which are: Warehousing, Accounting, Sales, Purchasing, Production, Clients and Finance. Consequently, it is estimated that an ERP system, in a first stage, which could also be definitive, containing at least the first five modules, is needed. It is obvious that information is centred mainly in Operations (warehousing), Accounting, and Production and in a lesser scale in Sales and Purchasing.

According to this conclusion the procedure consists in performing a study and analysis of the ERP programs existent in the market. Normally each ERP program covers a series of different modules corresponding to different Departments in an organization such as Purchasing, Finance, Production, R & D, Human Resources, etc. and not all of them coincide with the same departments and detail. Consequently VCC must choose a program that includes the most important modules for the company and for that it is necessary to choose those modules as shown in Table 11.1.

Table 11.1 Relationship between number of movements of materials and departments involved – Diagnosis in an enterprise and proposal to install an ERP

Area	Relationships on information entering and leaving the system
Warehouse	12
Accounting	9
Production	7
Sales	3
Purchasing	2
Costs and analytics	2
Finance	1

To determine the modules that the program must contain, Table 11.1 shows the weight assigned to each department. The weights coincide with the number of relationships / information in/off and to/from each department considering not only Fig. 11.5 but the results of a more detailed analysis too; consequentially, the modules for Warehouse, Accounting and Production have the highest values.

11.5.5 Selecting the ERP Program to Implement

The selection was based on information from Table 11.1, and therefore, once the key departments are known the problem consists in selecting the ERP program that better matches VCC's scenario, and naturally considering the least acquisition and implementation costs. Eight informatics ERP programs were examined and related with manufacturing. They correspond to very well-known actual brands (albeit their names have been substituted by letters) and with an ample covering or availability of modules.

Because of the large variety of models and noticing that not all of them offer or have the same modules and considering that some are more powerful than others in certain areas, a Multicriteria Decision Making Analysis has been performed, to determine the most convenient model, and following the procedure explained in Chap. 8.

Notice the number of areas or department that each program covers. This information comes from examining the respective manuals. Thus:

ERP Program	Departments (Modules) covered
A	6
B	6
C	6
D	5
E	4
F	7
G	2
H	3

Table 11.2 shows the analysis of the different programs and the final result reached. In columns are the different models, and immediately below the information shown above about the number of areas or departments that each one covers. In rows are the different departments VCC is interested in. This is the decision matrix (see Sect. 8.1). Its solution by mathematical programming (see Sect. 8.5.2) gives as a result two programs: B and D.

Examining both results it is clear that the best program for VCC is 'D' because:

- It considers the basic modules of Purchasing, Sales, Warehouses and Production in contrast with program 'B' which does not contain modules for Purchasing and Sales, albeit this would have been solved by building programs, but that would be costly because it is not a free program,
- If it is true that program 'B' covers Costs and Analytics, while program 'D' does not, it is relatively simple to insert in it this department, since it comes from two sources: Accounting and Production.
- Since program 'D' is free software, VCC informatics experts can access its source code and adapt special programs that is, to customize the application, at no additional cost.
- From the acquisition point of view program 'D' has a cost sensibly below that program 'B' and also it is less costly to incorporate a module for Costs and Analytical when compared with the programs for Purchasing and Sales necessary for program 'B'.

Table 11.3 shows the program D platform where the following management modules can be appreciated: Supplies, Warehousing, Production, Sales and Accounting, which are key for CVC.

Notwithstanding this information, it is recommended that each module be opened to verify its content and to make sure that they cover VCC needs.

11.6 Conclusions of This Case and Recommendations

As a conclusion, acquisition of program 'D' and contracting for the construction and addition for the Costs and Analytical programs were recommended.

11.7 Conclusion of This Chapter

Communications in a project is a vital issue. The need for sharing intelligence is essential for its healthy development; information about the project must flow in every direction that is, to the upper echelons, in order to maintain

Table 11.2 Selection of ERP programs – Diagnosis in an enterprise and proposal to install the ERP

ERP programs	A	B	C	D	E	F	G	H			
Departments considered in each ERP program (Data from manufacturers)	6	6	6	5	4	7	2	3	Result from computation	Action	Required (from Table 11.1)
Cosmetics industry	1	1				1	1	1	1	≤	1
Purchasing			1	1	1				1	≤	2
Sales				1		1			1	≤	3
Marketing			1						0	≤	1
Warehouses	1	1	1	1					2	≤	12
Production	1	1		1					2	≤	7
Accounting		1	1	1	1	1			1	≤	9
Supply chain	1	1			1	1		1	1	≤	1
Maintenance									0	≤	1
Financing	1		1	1	1	1	1	1	0	≤	1
Costs and analytics		1							1	≤	2
Human resources	1	1	1			1			1	≤	1
Selection:		<input type="checkbox"/>		<input type="checkbox"/>							

Table 11.3 Platform for program 'D' showing the modules that interest VCC – Diagnosis in an enterprise and proposal to install the ERP

Management of	Relationship with suppliers	Supply chain	Warehouses	Production	Sales	Accounting	Relationship with clients

the owner's and stakeholders' awareness of what is going on. It must also flow horizontally between the company departments, as well as to contractors and intermediate staff level, suppliers and clients, and also downwards to keep workers properly informed. Needless to say, not all the information should be available to everybody, since there are data, communications, results, efficiencies, etc. that must reach only certain people.

This chapter tried to emphasise the importance of communications. It proposes a flow chart exemplifying the use of reports such as the weekly progress report with its narrative, tabular reports that allow condensation of information, as well and graphic reports that greatly improve the communication efficiency, and allow estimating progress more accurately than tabular reports. Another very effective form of communications in the form of meetings was also discussed.

However, in certain projects, especially those related with manufacturing, the flow and interrelations of information is so complex that it is difficult to know on a daily basis the status of the work. For that reason the chapter treated in some extension the Enterprise Resources Planning or ERP system, which is the latest advance in entrepreneurial communication. A case study is proposed and analyzed in selected detail to allow the reader to have a fair idea of its possibilities and about how to determine the best program for a particular firm.

Bernroider et al. (2005) proposes a similar use of mathematical programming to select an adequate ERP program.

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Abstract

This chapter deals with the calculation during the planning stage of the ‘costs to develop a project’, which is an essential step to further prepare and maintain the project budget baseline or ‘Budgeting’. These documents are of paramount importance; they summarize project costs in order to determine the necessary investment to be made, while the budgeting process spreads these costs over the construction time. In accordance with these two different concepts, the chapter is clearly divided in these two functions (a) Determination of different costs by type and category and (b) budgeting, which is an aggregate of these different types and categories. This last activity is also crucial to schedule the availability and disbursement of funds needed to pay for work done by contractors.

Keywords

Cost estimates • Different costs • Budgeting • Quantities take off • Budget curve

12.1 Some Definitions

Cost. It is a resource given up to achieve a specific objective and measured in monetary units,

Expense. Disbursement not directly linked with production,
Investment. Disbursement in capital goods which can be amortized,

Logistics. There are many different definitions of this activity mainly related with the management of flows. Here we use the definition given by the Council of Logistics-Management [<http://www.clm1.org/mission.html>, 12 Feb 98]. “It is the process of planning, implementing, and controlling the efficient, effective flow and storage of goods, services, and related information from point of origin to point of consumption for the purpose of conforming to customer requirements.” “Note that this definition includes inbound, outbound, internal, and external movements and return of materials for environmental purposes”, (see also Chap. 11 and the use the ERP system, which can greatly help in this process).

Procurement. Related with the tendering processes to acquire goods, equipment and services. Also involves the

analysis, evaluation, selection and negotiations of proposals (see also Sect. 3.2.2).

12.1.1 The Three Aspects of Cost Management

In the technical literature project costs are frequently treated under ‘Project Cost Management’, and as such all matters related with costs are included here. For this reason, and under this label, there are four different aspects namely: ‘Cost Estimate’, ‘Budgeting’, ‘Monitoring’ and ‘Cost Control’. Let us examine the scope of each one:

Cost Estimate: Consists in determining the amount of necessary money to execute a task or activity. There are several methods to perform this function, as well as different levels, such as, approximation level or Rough Order of Magnitude (ROM), feasibility level (makes it possible to determine economic feasibility), and detailed level (final level, used in budgeting), with increasing reliability, in the same ordering. Cost estimate is possibly the most difficult, time consuming, and costly of the three aspects, and it is normal to recalculate activity costs throughout the project.

An important feature in cost estimate is the consideration of risks in affecting the cost and the duration of projects; because of that, countermeasures or safeguards (see Sect. 6.4.6), have to be taken, costing money, but these steps are many times overlooked, neglected or disregarded.

Budgeting: It shows *expenditures* as a function of *time*, and it is the summation of all cost estimates required by a project during a certain period 'n' (which can be in weeks, months, quarters, etc.). The dates when each task must be executed are extracted from the Gantt chart (see Sect. 9.2); if the amount to be spent on a monthly period 'n' is known, the accumulated value for the subsequent period, i.e. 'n + 1', will be the precedent value found for (n), increased by the partial value for (n + 1), that is, each successive period shows *accumulated expenditures*. If these accumulated expenditures values are plotted in a coordinate plane which has time as abscissa and Dollar or Euros (or any other currency) as ordinates, and if all the corresponding plotted points are linked by a continuous line, the result is a curve, which typically resembles the letter 'S' and for that reason it is known as an 'S-curve'. Its shape can be explained by dividing the whole line into three phases. The first one 'Initiation' involving mobilization, camp preparation, receiving equipment, etc., has a low growth. The second phase, 'Construction' follows almost a straight line with about 30–45° slope from the vertical. The third phase 'Finishing' shows a remarkably decreasing cost growth.

Naturally, there is no rule for the shape since it depends not only on the project but also on the timing of execution of some tasks, that normally can be adjusted depending on the float of non-critical activities (see Sect. 9.1.3.4 for floats). Nives Ostojić and Radujković (2006), have performed a statistical research study comprising 24 high-rise projects; the scatter diagram shows without a doubt that an average S-Curve can be built out of this data, and an important fact is that the deviations between actual cost values and the average S-curve are relatively modest, albeit the degree of deviations increases during the construction phase while deviations are closer in the initiation and finishing phases.

An interesting finding from Ostojić's study is the influence of external and internal risk factors as also mentioned in Risk Analysis (see Sect. 6.4.1). This study considers series of both external and internal risks and their influence in the cost and in the duration of projects. Ostojić's study shows the most important risk factors as percentages of total risks with data obtained from polls. From this study the following information has been extracted:

COST OVERRUN

External factors:

Permissions: 28%,

Consents: 32%

Total: 60%

Internal factors:

Organization: 15%

New technical solutions: 11%

Total: 26%

DURATION OVERRUN

External factors:

Climate: 32%,

Soils: 20%

Total: 52%

Internal factors:

Incompleteness of technical documentation: 17%

New technical solutions: 9%

Total: 26%

The S-curve, which is also known as 'Cost baseline' or 'Project budget', shows the accumulated costs or expenditures time-phased, allowing one to know what funds are committed at a certain date, as well as amount of funds that must be available to pay contractors for work done, suppliers for inputs provided, and manufacturers and installers for equipment delivery and installation. It is also an essential tool for forecasting the final cost to completion. This curve must contemplate all costs in workers, materials and equipment, that is, for all resources, and with regard to their respective calendars (see Sect. 9.4.12).

Monitoring: During the execution of a project this function consists in checking work done not only for quality but also in quantity. Once a quantity is measured it is compared with the corresponding value depicted by the S-curve and deviations reported. If deviations exist, it is necessary to determine their significance, since there must be some sort of tolerance or accepted percentage of variation, for nobody can expect that work done in a certain period exactly corresponds in quantity with work scheduled.

Cost control: If variations are significant they are analyzed using a technique called 'Earned value analysis'; then the Cost Engineer or the PM can apply measures to reduce or eliminate these variations. This action is called 'Project Control'.

In this book the Project Cost Management function is divided into two parts, the first one considers cost estimates and budgeting, which is the object of this chapter. The second part treats project monitoring and control and is explained in Chap. 16. Why two separate chapters? Because the two first aspects are developed in the planning phase of the project, while the third and fourth take place during the execution phase. Therefore, in an attempt to place the whole project management process in an approximate time sequencing (notice the word 'approximate' because there is not really a linear sequence, but a series of feedbacks), it is understood that project monitoring and control develop at a more advanced stage than cost estimate and cost budgeting.

Figure 12.1 depicts the existent relationships between the four elements that have been analysed and their link with the

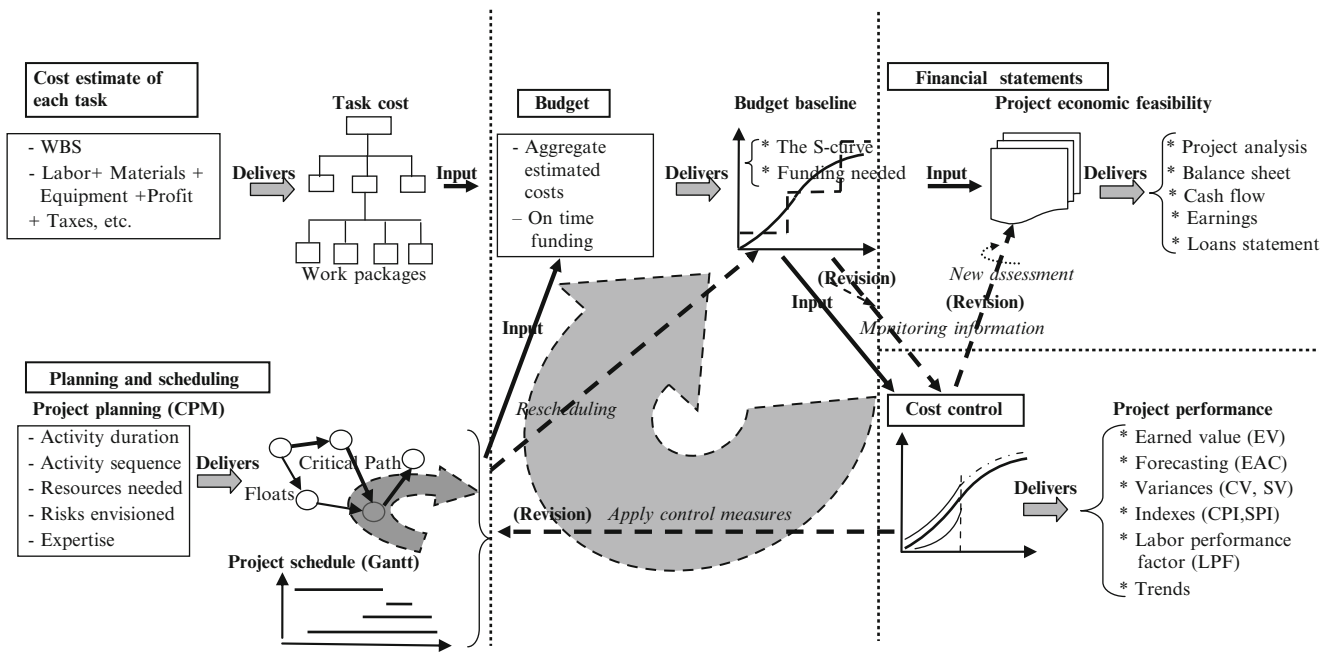


Fig. 12.1 Interrelationship between costs, scheduling, budget, financing, monitoring and cost control

financial statements. Observe that cost estimates generates from the Work Package Structure (WBS) (see Sect. 9.4.5) and using different techniques to cost work packages. Then, the planning action sequences and links tasks and activities according to precedence and thus determines the critical path and floats for non-critical tasks, which makes scheduling possible, generating the Gantt chart.

This joint information provides the ground for budgeting and the drawing of the S-curve or baseline. This information is the base for cost and time monitoring as well as for constructing financial statements and is fundamental. Cost control is derived from the updated S-curve after monitoring detects deviations. Finally project performance is derived from the latter which allows amongst other things to determine expected cost and time at completion.

12.1.1.1 Types of Costs

Costs can be classified as follows:

- Construction coordination: 0.5/1% of construction costs (DOE 2009)
- Direct and indirect

Direct costs are those related with the product to be manufactured or the service to be rendered; for instance, the purchasing of a resin such as high-density polyethylene for blowing moulding plastic bottles. Into this category also enters manpower to operate machines, to pour concrete, to build a wall, etc., as well as the purchasing of electric energy, transportation for the raw material as well as for their distribution, etc. In many construction sites cranes are considered a direct cost, while small tools and pick-up

trucks are indirect costs. For equipment there are many sources from which to obtain these costs, such as from vendor quotations, catalogues, direct consultation, etc.

Indirect costs are those required to pay for labor, materials and equipment that are used to develop the project. A value used in Europe is 3% of the cost of the task For more and comprehensive information about costs in construction see Hendrickson (1998).

- Environmental costs

A project is a human endeavour, and no matter its type or purpose, it always impacts the environment in one way or another. For that reason it is essential in any project to assess its impacts and effects on the environment, and once they are known apply the corresponding mechanisms to eliminate them, usually an impossible task, or at least reduce them – a more achievable goal – and this inevitably has a cost attached, which is the cost of the investment required to remediate that damage. The following comments and examples aim at making the cost estimator aware of the potential effects on the environment of different types of projects, and the necessity to contemplate them.

Consider for instance the construction of a dam on a river to be used for electric generation in a hilly forested area. There are various types of environmental damages here, such as the necessity of logging many trees because they will be covered by the rising waters of the lake formed behind the dam. There will also be erosion in the lake shores, as well as a variation of the ecological conditions of the region. There is a way to remediate these damages, as for instance, replacing those lost trees

in another nearby location and also taking some measures to stop erosion. But those measures have costs attached, which can be then considered as additional costs that must be added to the project in order to 'pay' for the damage to the environment.

In addition, assume that the river is used by salmon swimming upstream for spawning. The construction of the dam will stop that migration, unless a device called a '*fish ladder*' is built to allow the fish to by pass the dam. Therefore, to lessen the damage to the environment caused by blocking the fish from swimming upstream has a cost, materialized in the construction of the fish ladder. Nowadays, because all large projects require an Environmental Impact Assessment (EIA) which could detect that harm, extra investments are required, and consequently their costs must be considered and estimated.

There are many examples of these environmental costs, for instance:

- *Power generation using fossil fuels*: Flue gases from plants burning fossil fuels contain SO₂, NO_x and other contaminants, which react with water contained in the atmosphere to produce weak acids such as H₂SO₄ (sulphuric acid) and HNO₃ (nitric acid). This is called '*acid rain*', which can have serious effects on bodies of water, raising water acidity and damaging aquatic life, as well as killing trees in forests and at the same time dissolving minerals in the soil, affecting tree growth.

It affects buildings, statues, monuments, cars, etc., since the acids formed attack the material they are made of.

Therefore, in a power generation project, costs should be added to capital costs in order to decrease the amount of noxious gases spewed. To that effect several solutions have been devised such as the use of boilers with fluidized beds, more sophisticated measures to eliminate these contaminants from the flue gas, such as scrubbers of different type, or by catalytic reduction of NO_x. There are particles that must be removed, which is done by using cyclones, electrostatic precipitators or filters, all of them expensive devices.

All these cleaning procedures have no relationship with the main object of the facility, that is the generation of electric energy, in the sense that they do not contribute to its production, and rather are a consequence of it, however its importance is so big that their costs have to be carefully considered when costing such an undertaking; they can be a significant part of the total cost of the plant, and in the determination of the production cost of each MW installed, and hence their importance.

- The *depletion of minerals in agriculture*, which can be seen everywhere. Normally this depletion is compensated with the addition of nutrients to the soil, mainly Nitrogen components, which of course must be taken into account when economically assessing the feasibility of an agriculture project. However, there is another cost, and this is environmental, and produced by the percolation of the surplus nitrogen that finds its way to aquifers and rivers. When these sources discharge for instance into a lake the nitrogen is used to feed algae which in turn consume oxygen from the water and producing fish migration. This is another cost that must be considered by preventing the development of these algae.
- The *contamination of aquifers and rivers* by mining operations, through tailings from the tailings pond, such as the Essequibo River disaster in Guyana. There was an unknown human cost here because it is presumed that it killed indigenous people living along the river. The cost that should have been included when designing the mining facility should have been related in increasing safety of the tailings dam.
- The migration of birds and wildlife from their natural breeding areas because of *noise from a nearby airport*, as in many airports around the world and that is an environmental cost. In addition there is usually a cost associated to airlines because aircraft must follow certain norms and air corridors to avoid noise in populated areas for landing and takeoff.
- *Urban highways construction*. In these undertakings there is often need to install highway sound barrier walls for noise reduction, with the corresponding costs. This is a social cost, since devices must be installed to prevent noise reaching and disturbing nearby dwellings.
- The *migration of fish* because of water contamination due to the discharge of industrial effluents, as in the Rhine River. Nowadays, after the river has been cleaned at a huge cost, all industries as well as water treatment plants are required to purify their effluents up to certain standards previous to their discharge into the river. This of course provokes additional cost to a project.

There is no doubt that these costs must be considered in the costs estimation procedure, and for that reason are mentioned here, albeit it is not an easy task. Sometimes their appraisal is straightforward, but usually that is not the case. For instance, it is relatively easy to compute the total cost for planting trees in lieu of those logged because of the formation of a lake behind a dam, or the cost of building a fish ladder, but in general these mitigation measures are difficult

to estimate, for example how to calculate the damage to trees and vegetation because of dust produced by heavy trucks travelling on dirt roads in a mining operation? The dust forms a barrier to the sun rays, therefore the photosynthesis process, and with it the oxygen production is altered. In that case, perhaps the best solution is to decrease dust production by reducing trucks speed, and by doing dirt road dust control, by watering the road or using dust control products, actions that of course, mean additional costs.

- **Escalation costs**
These are the increased costs that must be foreseen due to inflation. In those projects that import material and equipment from other countries, escalation costs calculation must involve both, those in the country of origin, and in the destination country.
- **Externality costs**
These are the costs that do not have a market value. For instance, odours or aromas generated in some industrial installation that may offend, even if they are pleasant (from instance from a chocolate factory), to neighbours who must smell the whiff continuously. Another example is a project to build a domestic waste incinerator, whose fumes may extend for many kilometres away, and perhaps depositing particles. A mitigation measure could perhaps be the installation, at additional costs, of supplementary filtering equipment.
- **Fixed and variables costs**
Fixed costs are those that do not vary with production; for instance, the acquisition of a certain equipment to manufacture a product, or the construction of a building for storage, etc.
- **Health and safety: 0.5/1% of total construction costs (DOE 2009)**
<https://www.directives.doe.gov/directives/current-directives/251.1-BOrder-c>
- **Intangible costs**
These are costs that cannot be measured. For instance the loss of confidence in a product because defects appeared after it is sold, or the decrease in sales because a competitor may release a better or more satisfying product.
- **Locals and non-locals**
It refers to costs incurred locally and from other places, mainly from another country or region. This classification is important because different geographical areas usually have different taxation rates as well as different inflation rates. Therefore, when the Finance Department performs the project's economic and financial evaluation (see Sect. 1.3 and Chap. 7), they will be able to apply the rates corresponding to each origin independently, increasing reliability of the results.
- **Management costs: 5/10% of direct + indirect costs (DOE 2009)**

- **Marginal cost**
It is the incremental cost or benefit due to decrease or increase of a unit of the product manufactured by the project.
- **Operating costs**
These are the costs related to labour, energy, supplies, maintenance and depreciation which are necessary to develop a project or to manufacture something. They are a very important constituent of any project in its operation phase. See in Sect. 7.1.6 an example of their calculation. For restoration and waste management projects, the operating cost over the life of the project can be several order of magnitudes larger than the initial capital costs (DOE 2009).
- **Opportunity costs**
These are the costs for an alternative or option foregone when a resource is applied to another activity. This type of cost is generally used by the Finance Department.
- **Overhead costs**
They are indirect costs or fixed expenses, such as rentals, administration, utilities, and necessary for production, however, there are overhead costs that continue even if production is halted, for instance rentals and insurance. A value used in Europe is 5% of the cost of the task.
- **Potential costs**
Costs that can appear in case something normally unexpected appears, for instance cost inherent with plugging a water leakage in a tunnel.
- **Project management: 2–5% of project cost (DOE 2009)**
- **Sunk costs**
These are the costs that are not considered in the evaluation. A cost of this type is the preparation of a feasibility study prior to the initiation of the project.
- **Training costs**
Costs incurred in instructing people for a certain job.
When a contractor is estimating costs to prepare his proposal, there are sometimes doubts about who is responsible for some of them. For instance, for construction, there are costs associated with certain tasks prior to mobilization and post demobilization. The contractor must clarify this aspect with the owner or promoter or consultant in charge of project management. In turn, for an owner there are costs associated with designing a facility, drawings production, staffing, legal fees, internal administration costs, etc.

12.1.2 Benefits

Most projects aim at achieving an economic benefit, however, usually this economic benefit also brings social benefits. For instance, in the case of an automobile assembly plant, the social benefit is evident in the thousands of direct

and indirect jobs it creates; this benefit can be usually measured by its multiplier effect.¹ Other projects such as the construction of a facility using photovoltaic cells, or a wind farm, to generate electric energy produce a large environmental benefit because they replace power generation plants burning fossil fuels, which spew thousands of metric tons of CO₂ and other noxious gases into the atmosphere. Therefore, using renewable sources for energy generation contributes amongst other benefits, to reducing the global warming effect, the smelting of the poles and the increase of ocean levels.

12.1.3 Sensitivity Analysis for Costs

A mathematical model that yields cost results when certain parameters are introduced is a cost model. Therefore, estimating software can be thought of as cost models, since costs can be obtained as a consequence of varying certain parameters as in a regression model. It is also possible to use a WBS to determine how the intermediate components or the final product are affected when there is a variation of a vital component. For instance, a variation in the price of turbochargers may affect the cost of a diesel engine, which in turn has an effect on the cost of a truck.

12.1.4 Work Breakdown Structure and Dictionary

The WBS has already been defined in Sect. 9.4.5, however, for it to work efficiently each component and deliverable must be clearly described, and this is done through a WBS dictionary, which also considers the whole project scope.

12.1.5 Quantities Takeoff

Given a certain work package, for instance a concrete foundation, it is necessary to identify its components, which are excavation, ready-mix concrete, steel bars and labor. This is called '*Quantities takeoff*'. The identification is not confined to the intervening materials but also contemplates accessories, such as concrete vibrators.

¹ Multiplier effect: A certain project can generate an increase in the spending habits of the population it affects. This spending, in turn, produces more spending, which also creates further expenditures. The relationship between the total spending and the original one is called '*multiplier effect*'. Different multiplier effects can be calculated for such activities as tourism, construction of large industrial complexes, etc.

12.1.6 Aspects to Take into Account When Developing a Cost Estimate

When developing a cost estimate it is necessary to specify:

- Assumptions considered and scope of each estimated activity or task,
 - Contingency values and the basis assumed for their computation,
 - Database employed,
 - Escalation rate if cost data for some task is old, and basis for the corresponding value,
 - Explanation about an uncertain cost (for instance when costing a research study, which duration is in doubt),
 - Identification of direct and indirect costs,
 - In case that estimating software is used specify name, characteristics and what geographical region it belongs to,
 - Method used for costing,
 - Method used for takeoff should be mentioned, i.e. if quantities are taken by hand from paper blueprints or by takeoff software using digitizers from paper blueprints or from digital plans and of course identifying the source by its drawing number. This is absolutely necessary in order to allow for future revisions and information,
 - Scope of each activity,
 - Sometimes, when activities will take place in the future, it will be necessary to consider their timing, by means of the Gantt chart, which indicates when an activity must be performed. In that circumstance, costs are calculated at current values and projected to the future. A similar procedure applies using estimated escalation rates for inflation at the same future. Later, when all pertaining data is that way treated, everything is brought back to present values through the Net Present Value Method, using the corresponding capital recovery factor from tables.
- If in that future there is a choosing of alternatives to select from, involving different acquisition and maintenance costs, using the Net Present Value Method can help in selecting the alternative which offers the least cost. However, it is necessary to take into account that apart from monetary costs it is also required to consider social and environmental costs. In this circumstance the selection procedure is not so simple, and then it is probably wise to use Decision Making Analysis (see Chap. 8), to select that alternative or option that minimizes economical, financial, social and environmental costs.
- The different percentages assigned to taxes, profit and overhead,
 - The WBS and its dictionary on which the costing procedure is based, as well as the codes of accounts,
 - Type of estimate (rough or preliminary stage or feasibility stage).

12.1.7 Methods for Cost Estimating

There are several methods for this function. The next Sections briefly describe them.

12.1.7.1 Rough Estimate

This is also called '*Analogous estimating*'. Considers previous similar activities whose costs are known and tries to get an estimate of a new project based in this similarity. It is a very rough estimate since there could be two similar projects, but not equal, and also because the different parameters are not proportional, and it relies on expert judgment (PMBOK 2008). That is, for instance, a pulp and paper mill project does not double in cost a similar plant half its output. Normally there is a non-linear relationship between plant sizes of the same type as formula 12.1 shows.

$$I_i = I_o \left[\frac{T_o^\alpha}{T_i} \right] \quad (12.1)$$

Where:

I_i : Necessary investment for a size T_i plant

I_o : Necessary investment for a size T_o plant, taken as a reference

α : Scale factor depending of industry type

12.1.7.2 Parametric Estimating

Parametric estimates rely on historical data to determine relationships between variables; essentially they apply regression analysis to determine the existing associations between a variable ' y ' called '*Dependent variable*' and a series of other variables ' x_i ' called '*Independent variables*'. The technique rests in the fact that once we know what relationship existed between variables in the past – analysing similar projects – there is a good chance that said relationship holds at present, and then, knowing or estimating the value of one or more independent variables it is possible to determine with enough approximation the value of the dependent variable, which is usually 'cost' and that can be corrected by inflation, for instance.

As an example, assume that we want to determine the approximate construction cost ' y ' of the pulp and paper mill project, and then relate that cost to items such as '*Production*' (x_1), '*Closeness to logging area*' (x_2), '*Cost for neutralizing the discharge of waste water into the sea*' (x_3), '*Cost of paper machine*' (x_4), '*Cost of necessary buildings construction*' (x_5), etc. This analysis involves examining several pulp and paper mills built in the last years; applying regression a mathematical relationship can be found between all variables. This algebraic expression will probably be represented by a curve whose equation can be found by applying different types of curve fitting.

(Excel offers an easy way to do this). Once the algebraic expression is estimated it is feasible that, giving values to the different variables, the cost of the plant can be estimated. There is a large advantage in using this method because, when this equation is known it is possible not only to obtain a range of cost for different assumptions but also to analyze how a variation in say the cost of the pulping machine, affects the final cost of the plant.

This method is too extensive to be treated here; it is a fundamental part of Statistics and can be found in hundreds of books and papers. Publications that are suggested and that include parametric estimating have been published by the International Society of Parametric Analysis (2008) and Cincotta and Busick (2010).

Thus, parametric estimating follows a series of steps along these lines:

1. Identify which parameters, or independent variables, are more suitable to explain the dependent variable; say for instance that the dependent variable is cost and the independent variable is size.
2. Investigate historical data relating these variables for similar projects, that is, find for a series of projects how much they cost for say 10,000 t of pulp, then for 20,000, 30,000 and so on.
3. A graphic can be built with these values in a cost ' y ' and size ' x ' coordinate system which will show a '*scatter diagram*', that is a collection of dots representing ' y ' values for each ' x ' value. When all dots are drawn corresponding to a range of ' x ' sizes, the complete set of dots follows a certain shape.
4. Just by observing the shape of the set of dots one can imagine how the whole set is behaving and then drawing a line (trend line), that is the loci of the average values, in a form similar to that seen in Fig. 16.23 in Sect. 16.15.2.
5. Inputting all data into a software package allows for drawing this trend line and at the same time obtaining its mathematical equation.
6. The reliability of the mathematical equation can be assessed by computing one of the known historical values; the outcome value will probably not be identical, but close enough to the real value.
7. If satisfied with the approximation (since coincidence cannot be expected for we are working with average values), use the given equation, choose a value for the independent variable ' x ' and find the cost ' y ' for said size.

12.1.7.3 Bottom Up Estimate

As its name implies, this estimate starts by decomposing the task in its constituent components, for instance using the Work Breakdown Structure (WBS) (see Sect. 9.4.5).

As an example consider the task of building a wall with hollow bricks, and assume that for this task the following values are found from the software database which shows

the necessary man-power and materials for 1 m² of wall using hollow bricks:

Total cost for workforce and material (TCWM).

Code		Total: 14.50 €/m ²		
109891	Hollow bricks			
	Quantities	Cost	Total	Accumulative
	per unit	(€/unit)	(€)	(€)
Foreman	0.5 h.	12.42	6.21	6.21
Helper	0.29 h.	10.40	3.02	9.23
Hollow brick	42 units	0.10	4.20	13.43
Mortar	0.02 m ³	53.59	1.07	14.50

Therefore, the total direct cost is 14.50 €/m² naturally, the total cost will be this value times the number of square meters needed for the wall.

Now it is essential to add (please bear in mind that this is only an example and it does not represent the situation in any country; it is only shown as a learning tool. On the other hand it varies from country to country, and this is an example in Europe):

- (b) Direct balancing cost (2% of (a) TCWM).
Execution material budget (EMB) = (a) + (b)
- (c) General expenses: 15% of (b) EMB
- (d) Profit: 6% of (c).
Budget: EMB + (c) + (d)
- (e) Project and work management : 7% of (d)
Total budget: Budget + (e)
- (f) Taxes: 16% of (e)
Total: Total budget + (f)

The total cost for the project will be obtained by adding up values obtained for each task.

The nature of the work has also to do with cost estimate. At present time automation in construction is common; and it can reduce cost significantly. For instance if a large tract of land has to be graded, say for the construction of a large residential housing complex to be built in several stages, the use of a laser controlled scraper can be very convenient and not too expensive, or the use of automated machinery for placing tensioned bolts, as in the example shown in Sect. 16.2.

12.1.7.4 Project Management Estimating Software

There are many construction-estimating software packages in the market. They are databases that contain details for every category in the construction industry, such as carpentry, excavations, concrete, fences, heating and cooling, etc., hundreds of different variations for each one. For each, say excavations, they list in cubic meters for different types of soil, such as sand, clay, rock, etc., the number and qualification of labourers required including perhaps a foreman, as well as the equipment that can be used, and give

the standard cost for each one of them, as well as the man-hours needed.

These databases are grounded on statistical values which are periodically updated, and many of them list information from several regions in a country and even allow applying a coefficient to take into consideration local prices and regulations. Therefore, extracting the characteristics of a job from drawings and specs, it is possible to have immediate information about the cost per unit. Another advantage is that they list everything needed for doing a certain job, and then, it is difficult to overlook or forget something. Most of this software also considers taxes, overheads and profits when the user inputs the applicable percentage for each case. In addition because all data is in the data base it can be shown in several different ways.

12.1.7.5 Analysing Vendor Bids

In response to calling for bids there are normally several contractors, vendors or sellers offers. These people are specialized in their line of work and their quotations for different parts of the project, although different in amount, surely keep a certain homogeneity which guarantees that most important items are carefully considered and other estimated.

12.1.7.6 Costs Considering Risks

There are no projects without risk, an eventuality that can be present in many different forms such as risks in delays, in cost overruns, in suppliers failure to provide items in time, etc. There are costs related with risks that appear when it is convenient to develop measures to avoid or decrease potential risks. Assume for instance a project to manage 60 ha of fruit trees in appropriate land, with enough rain, good soil and weather. However, the region is also prone to strong winds which can break the young trees. Therefore, there is a risk which perhaps can be prevented by reinforcing the trees through adequate support. Whatever the measure taken to mitigate or reduce the risk, it has a cost, and this cost has also to be considered.

12.1.7.7 Productivity

Whatever the process used for estimating, there is an aspect that should not be ignored, and it is *productivity*. Either if a contractor is preparing a proposal, or if the project management team is examining one from a contractor, productivity must be considered; for instance, when using equipment for a certain type of job, certain conditions need to be taken into account. In an excavation for example, productivity depends on several factors such as quality, type of soil, and water content, amongst others; therefore, when using data given by tables or from software it is convenient to check that said data addresses the kind of existent soil. It is not a difficult question, and it is useful to make a simple verification just to be on the safe side, because tables and

Table 12.1 Information provided by a typical construction estimating software – Budget determination for construction of a dwellings complex

Work package account code	Description	Qty (#)	Characteristics	Material	Unit	Labor (€)	Crew	Man hours	Total labor cost /h (€)	Total cost direct (€)
2890	Rectangular wall	1	Thickness of concrete: 0.10 m. Height: 1.22 m. Long: 2.44 m.	Concrete at 86 €/m ³	m ³	0.56	One carpenter Two laborers	0.025	22.33	26.16
	Concrete reinforcing steel		Pump steel 16" diameter, with 6 # 6 bars	Steel welded wire mesh 29.84	Vertical linear feet	1.42	One iron worker	0.050	31.20	37.83
	Concrete form work		Standard block	3.74	m ²		One carpenter Two labourers	0.10	22.33	24.50
									Total cost	88.49

software do not consider all types of soils and their combinations. For good examples see Chap. 4, Inventory Control in Hendrickson (2008).

12.2 CASE STUDY: Estimating Costs for a Retaining Wall

As an example, say that a work package consists in building a retaining wall in a dwellings complex. We are using a software package which provides the information depicted in Table 12.1. These prices are per unit, therefore, when the takeoff data produces the total measure of the retaining wall and its inputs, it is easy to compute the total cost. Thus, for work package 2890:

$$\text{Materials cost} : 0.10 \times 1.22 \times 2.44 \times 86 = 25.60$$

$$\text{Labor} : 22.33 \times 0.025 = 0.56$$

$$\text{Total direct cost} : 25.60 + 0.56 = 26.16$$

12.2.1 Examination of Cost Estimates

Cost estimating is a delicate matter, it has to deal with different data bases, make assumptions, estimate cost of uncertain activities, and in a field which is constantly changing because prices are not usually fixed and depend on political situations, weather variations and actions that are external to the project, such as for instance an increase in oil prices because there is war in a rich oil producing country. In addition, as in any other activity, there is the human factor, the estimator, who can make bona-fide mistakes by working with wrong or doubtful assumptions.

For this reason it is sometimes convenient to have the costs estimates audited by an independent party, who must not be related whatsoever with the project or with the

contractor if he is examining his proposal. The reviewer should:

1. Analyze the project and get familiar with its scope, establish his/her own assumptions and compare them with those taken by the estimator. Of course, it could very well be that there are discrepancies, but those can be discussed with the estimator, and maybe they differ because one or the other did not consider certain facts. For instance, it could be that the estimator assumed that in a section of a tunnel being excavated by a tunnel boring machine, there is different kind of rock from milestone 122.3 to milestone 341.8. His opinion is substantiated with discussions with the chief geologist and with the construction manager, and because of that he thinks that it will be necessary to change the cutting wheels when starting milestone 122.3.

This fact will require more manpower than expected, because that circumstance had not been considered, in the belief that the same set of cutting wheels could be used. In reality, this is true, but the estimator also learned that the installed cutting wheels will not last long if used with the new type of considerably harder rock. Perhaps the reviewer did not know this circumstance, and hence the reason for his disagreement. Naturally, the opposite can be also true.

2. The reviewer must also check if the estimator has considered the whole scope of the project.
3. Also must examine the methods used by the estimator.
4. There are some uncertainties in this project because of its nature. The reviewer must analyze them and check if the assumptions made by the cost estimator agree with his own appraisal.
5. Possibly the reviewer could select a couple of activities at random and redo the cost estimates, comparing results with those of the estimator.
6. If the estimator used the relationships method, the reviewer must analyze under what conditions and assumptions they were used to verify that they indeed apply to

this project activity, because there could be hidden factors special to another project and that perhaps are not applicable to this one.

7. The reviewer must also verify when it corresponds if the estimator has considered social and environmental costs, and how have been both evaluated.

This brief description of course, does not cover all the validations that the reviewer needs to make; its only purpose is to give a glimpse of his action.

12.3 Budgeting

As defined before budgeting is the distribution of expenses throughout the life of the project. It allows for the construction of the budget or S-curve that is the original document that forms part of the contract. The mechanics of its construction has already been commented on in Sect. 9.2.1. In this section it is applied to a more complex case, and its use as a monitoring and control tool is described in Chap. 16.

12.4 CASE STUDY: Budget Determination for Construction of a Dwellings Complex

This case refers to the construction of a dwellings complex of 278 houses with three different sizes in floor plans as well as different plot surfaces, and construction time is estimated to be 29 months. Cost calculation is assumed done, and it is fairly simple since there are repeated tasks, based on the developer's experience and using computer software. There are 26 activities which are used to determine the budget and they correspond to excavations, civil works, wood, basement concrete, aluminium and wood carpentry with double glass, insulation, roofing, gas, sewage, water, electricity, roads, landscaping, kitchen furniture, bathrooms appliances, finishing, flooring, painting, etc., as well as provision for construction services. The whole job is divided into months. Table 12.2 shows this cost data, but limited only to the first 9 months of the project, from November 2011 to July 2012.

To illustrate the method assume that task number 3 has a total duration of 23 months to complete and a total cost of 777,000 Euros. Prorating this total amount in 23 equal installments it is then possibly to get for this activity the amount invested (33,783 Euros), which is then assigned to each month. Once each activity expenditures are scheduled and placed in the corresponding month, add up all the values found in each column, provided of course, that all are expressed in the same units such as Euros, man-hours, percentages, etc. The bottom rows of Table 12.2 depict for

each month the partial values for said month as well as the accumulated amount.

In reality this prorating in a continuous task is only an approximation since at its beginning the expenditures are smaller and increasing from month to month, then leveling, and with a further decrease in the last periods. This reasoning can be applied to other tasks, and the resulting curve for partial expenses in a project is somehow as sketched in Fig. 12.2 for a whole project.

This information allows drawing of Fig. 12.3 whose vertical bars represent the partial or monthly expenditures (Remember that this represents only the first 9 months, not the whole project). Figure 12.4 shows a solid line that indicates the accumulated expenditures, that is the budget line or S-curve. This is the curve that is used to monitor the progress of the work as explained in Chap. 16.

12.4.1 The Two Extreme Budget Curves

Information about the period when each activity will be performed comes from the logic diagram and the Gantt chart, both examined in detail in Chap. 9. The duration of each task has already been defined and it is known that the commencement of a non-critical task depends in a great measure on the resource availability, and that it can start anytime between its early start and late start dates. Therefore, if all non-critical tasks are scheduled to start at their early dates, an early S-curve will be generated, while if at the other extreme, they all start at late dates, then the S-curve will be displaced to the right and will have another format. Figure 12.5 shows both curves computing early and late dates respectively for the first 9 months.

The difference between the two curves indicates that many activities can start either in their early dates, or at their late dates, or in between. This is important from the point of view of cash flow, that is, the Finance Department can use it to forecast the availability of funds, or ask for delaying the commencement of some non-critical tasks (or may be reception on equipment), until funds are on hand. As seen the accumulated disbursement up to the ninth month for late starts amounts to 217,547 Euros, compared with 326,762 Euros if non-critical tasks start early. Naturally, at the end of the project and assuming that there will be no price increases, the total amount will be same, however with a sharp increase of disbursements in the last months. Why is then the reason that in general, tasks are scheduled to start early or at intermediate dates?

The answer is: The delay risk, since then all tasks become critical and therefore a delay in any of them translates into a corresponding delay for the whole project.

Table 12.2 Expenditures during the first 9 months – Budget determination for construction of a dwellings complex

Task #	Year Month	2011			2012			June	July	
		November	December	January	February	March	April			May
	Task									
	Cost (€)									
1	5,760	5,760								
2	2,560	2,560								
3	777,000				33,783	33,783	33,783	33,783	33,783	
4	3,780			3,780						
5	336			336						
6	336			336						
7	3,500		1,750	1,750						
8	7,640		7,640							
9	1,176				1,176					
10	5,360				5,360					
11	210				210					
12	18,720					6,420	6,420	6,420		
13	140					140				
14	11,000					2,200	2,200	2,200	2,200	
15	72,000								6,545	
16	18,000								3,600	
17	24,000								1,846	
18	38,000								3,800	
19	9,600								2,400	
20	57,600								7,200	
21	9,900								2,475	
22	12,000								4,000	
23	31,680	5,280	5,280	5,280	5,280	5,280	5,280			
24	9,000									
25	6,000									
26	21,420									
	Partial	13,600	7,030	19,122	45,809	47,643	47,503	42,223	35,983	67,849
	Cumm.	13,600	20,630	39,752	85,561	133,203	180,706	222,928	258,911	326,760

Fig. 12.2 Approximate format of partial expenses in a project as function of time

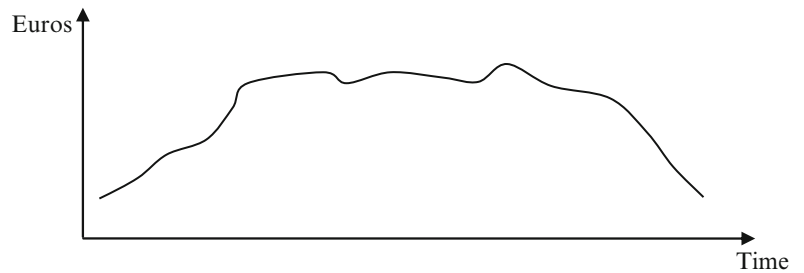


Fig. 12.3 Monthly expenditures for the first 9 months – Budget determination for construction of a dwellings complex

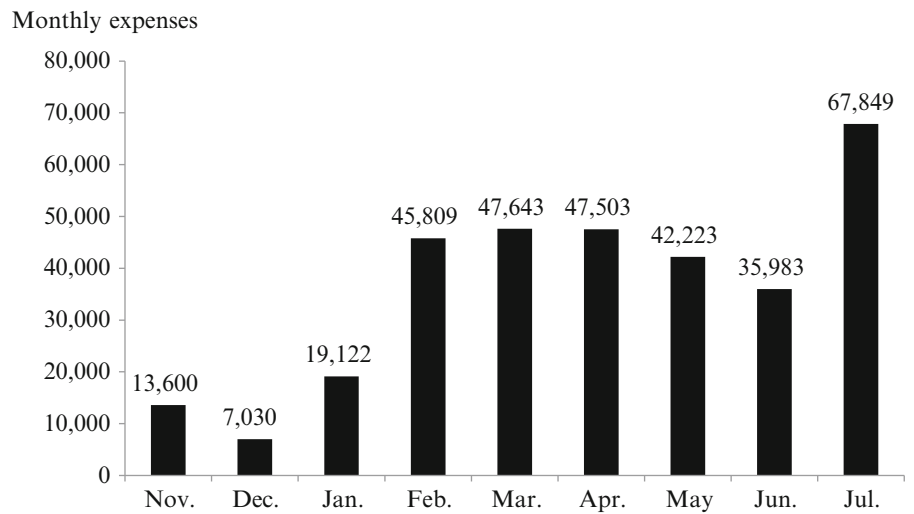


Fig. 12.4 The budget curve or S-curve with accumulated values for the first 9 months – Budget determination for construction of a dwellings complex

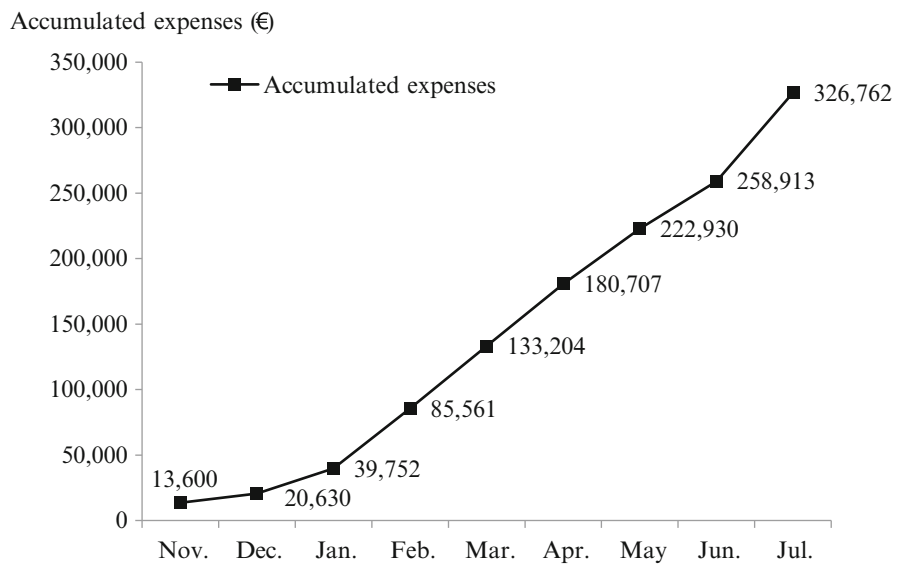
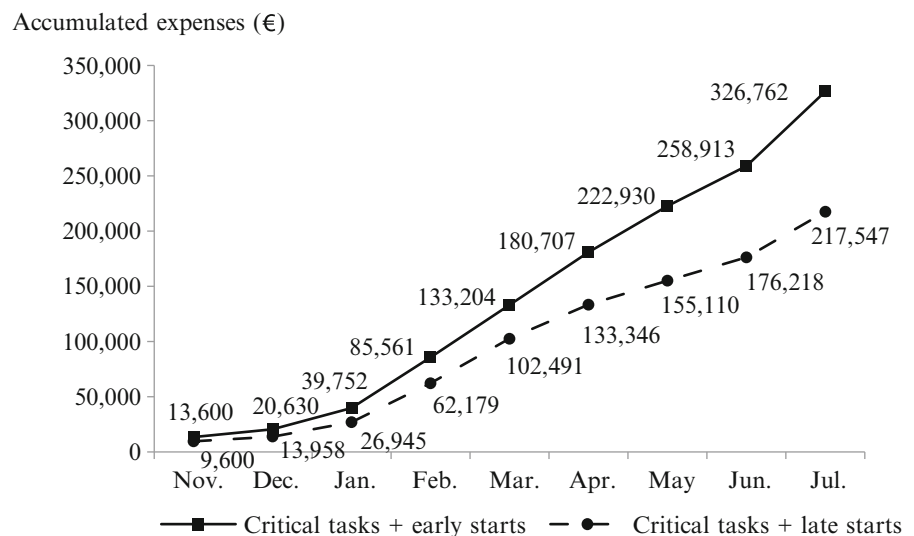


Fig. 12.5 Comparison between early and late starts for the first 9 months – Budget determination for construction of a dwellings complex



12.5 Conclusion of This Chapter

This chapter dealt with the very important function of determining costs and then spreading them throughout the life of the project. It is needless to point out its importance since practically the whole project is based on these costs, from the very beginning, to determine the feasibility of the venture, to its development and conclusion. These costs are the grounds for developing the budget baseline or S-curve which facilitates the control. Figure 12.1 depicts the interrelationship between these functions. The chapter identifies the different costs usually found in projects, exemplifies them and emphasizes the importance of environmental costs. Further it analyzes the different methods to cost a project starting with the takeoff and finishing with project estimating software.

Entering in the budgeting phase, a case is proposed where the construction of the baseline is demonstrated, and is followed with an analysis of the convenience of starting non-critical tasks early or late.

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Abstract

The essential role played by human resources is briefly analyzed here in relationship with projects with different characteristics, and thus emphasizing that each project establishes its own conditions, requirements and demands. The purpose of this chapter is to stress the fact that a very careful selection is needed for filling positions, at any level, and not only from the technical expertise point of view, but also about how a worker may or may not fit in a certain project, since not everybody is suitable for everything and everywhere. There are excellent professionals who will not accept a position, even with larger benefits than usual, if it does not match his or her requirements, which may be personal, physical or others. As an example of the importance of human resources, a more common case, regarding a manufacturing company with an ongoing production, is analyzed to illustrate how a wrong human resources policy can deteriorate and endanger a project, whatever it might be.

Keywords

Worker integration • Job location • Diagnosis • Productivity • Quality • Health and safety • Accident prevention

13.1 Introduction

According to Heathfield (2010), “*Human Resource Management is the organizational function that deals with issues related to people such as compensation, hiring, performance management, organization development, safety, wellness, benefits, employee motivation, communication, administration, and training*”.

The managing of human resources is one of the most important as well as one of the most difficult tasks in any project. Machines and equipment can be programmed; supply deliveries can be scheduled and negotiated; technical problems can in most cases be solved, but human nature cannot be modelled, and if it is true that a set of similar machines have a established and expected production rate, that one can anticipate a fairly stable concrete production, or that flights will take place according to established time tables, this assumption usually does not apply to a group of people working and doing even repeated tasks in a project.

However, we are not considering here this function in its whole concept, for it is a matter for Human Resources specialists, but in analyzing how it relates with the project management activity.

13.2 Working with People

Two aspects must be considered when working with people in a project, (a) The worker as an individual human being, and (b) A worker integrated in a team, which groups individuals with different, varied, and sometimes controversial characteristics.

13.2.1 The Worker as an Individual Human Being

If a position calls for a sole individual when selecting personnel for a certain job a few circumstances have to be considered, such as:

13.2.1.1 Adequacy

Vacant positions have to be filled with people that can work or feel comfortable in that type of physical environment. A person can be very good working alone and not so good teaming with others, and then, the selection has to consider this circumstance, taking into account that usually there are many activities that pertain to these different conditions in projects. Developing a computer code may be one of the activities which demands concentration and adequacy for a lone programmer, while cost control may need the efforts of several people, albeit each one with a specific function, such as one person in charge of manpower control, other with the advance of work, another with work certificates, and so on, and all of them related.

13.2.1.2 Capability

Naturally, it refers to the attributes and academic background that a person must have to be considered for a certain activity, that is, his/her expertise and knowledge of the work ahead; however, sometimes this requisite is not enough if the position demands sound knowledge of some specific feature. For instance, hiring a scheduler with experience does not mean that this person will be the most adequate, because the position may require using a certain planning and scheduling computer program which the candidate is not familiar with, albeit highly proficient in another program.

This aspect is sometimes used as a screening device for choosing between two people both high qualified for the job.

13.2.1.3 Human Aspects

On top of the technical ability, dexterity, speed and efficiency of each person, a human being is not a machine – fortunately – cannot be treated as that, and then it is necessary to take into account that the behaviour of a person can change, due to a series of circumstances distinct to the individual himself and also to external causes. These circumstances can be temporary ailments, money or emotional problems or/and family troubles, worries with financial aspects, unhappiness with the job, and many others that can produce lack of concentration, boredom, negligence, carelessness – which statistics show are the major cause for accidents in the job – and that besides, alter a person efficiency.

It is of course very difficult to assess these special circumstances; however they must be considered according to the type of job. Take the case of a company that needed to hire an accounting clerk for an accounts payable position. Two candidates were short listed, Amy (34), and Edward (59), both with ample experience and with excellent references. Edward had initially some disadvantage due to his age compared with Amy, and also because Amy was a little ahead regarding experience in more recent jobs, as Edward quit 3 years ago to start his own business and now wanted to take up again with his line of work. However, after the Accounting Manager talked with both of them, he inclined for Edward, because

Amy had hinted that in the future there could be some problems; she was taking care of her mother and was not very happy in staying the whole day far away from her. The manager thought that this fact could be a potential source of problems, since Amy demonstrated great concern about her mother, and there could be the possibility of quitting the job and/or being distracted in her work.

13.2.1.4 Ability to Manage Alone

Another fact that must be considered when building a roster for a job, besides the technical capability and background, is the fact that in many cases a person will be on his/her own, most especially for high and senior management positions, for instance cost control manager, project scheduler, safety, etc. This is especially relevant when the jobsite is in a remote location, for usually there are no opportunities for somebody to analyze and interchange information and ideas with a colleague about a difficult issue, or for going to the company library for technical references. In that circumstance, a person must be capable of managing difficulties based on his/her sole criterion, and if it is true that this is also applicable to a city position, in the former it is far more difficult.

13.2.2 Worker Integration in a Team

Regarding this aspect, there exist many circumstances that might block a harmonious and balanced work in a team, such as resistance to accepting directions, envy, jealousy, lack of integration, belief of technical superiority over his or her colleagues or mates, gender discrimination, political opinions, cultural customs, ethnic discrimination, and many others.

Usually, a project is a team effort, and there must be coordination between the team members, otherwise it becomes chaos. A team must comply with directives as in some sort of lineal organization where instructions, orders and procedures flow from top to bottom, establishing a discipline, a chain of command, to borrow a military expression. Then a person doing a certain job receives instructions from a foreperson, who in turn follows directives from another person, and so on, with the project manager at its top. This scheme usually works well, provided that all people involved in the chain of command have clear instructions and that their work is periodically verified by a supervisor. This is one of the reasons that justify the need for a function manual and definition of responsibility. See Sect. 9.4.10 about the team responsibility matrix in a project.

13.2.3 Job Location

When starting a new project, selecting a project manager or choosing/contracting people for a certain job, whatsoever its nature and scope, special care has to be taken in considering

the circumstances above mentioned, which is still more relevant depending on the location of the project. One thing is to work in an in-house project, or in the client's offices or factory, in modern, comfortable and well equipped premises in a city, where after 8 h work, no matter how intense or demanding it may be, people go home, stay with family or take pleasure chatting with friends, or going to a movie theatre or enjoying a good meal, and, besides having the benefit of weekends.

Another completely different scenario is when the project is located in the middle of nowhere, usually with harsh weather and climate conditions, as it very often happens with projects related with construction of highways, hydroelectric dams, mining and metal refining, oil pipelines, offshore platforms, forestry logging, etc. In these circumstances people live in camps, which are usually comfortable, with catering services and some amenities, but that require a whole week's work, running continuously during perhaps 6 or 7 weeks, and then having 1 week R&R (Rest & Recreation).

Of course, the paycheque is big, and since there is nowhere to spend the money it accumulates in the bank account, but people live together 24 h a day, enjoy little privacy, see each other daily for maybe more than 15 h, cannot communicate by phone very often with their families, and it is then only natural that pressure from the job as well as family remoteness takes its toll, which becomes reflected in different types of conflicts. This is another aspect in large projects that has to be carefully considered and made known to the candidate.

It is then evident that in recruiting personnel for a job, besides being a delicate affair for both parties involved, the interviewer must consider not only the applicant's qualifications, but also the project's characteristics, and in the case of a job in a remote place, each individual's ability to behave and produce according to his/her capabilities, and of course willingness to work in that remote area. Naturally, this also puts an extra burden on the project manager's shoulders, who, on top of his/her technical and managerial capabilities must have a good command of personnel management, and be able to solve personal conflicts which, perhaps minimized in a town environment, are dramatized and maximized in a camp.

13.2.4 Summary

Considering all the above it is understood that selecting people for a project is a little different from the procedure followed for filling positions for other more common assignments, and it is the purpose of this chapter to emphasize that difference and to point out some particular facets. Every project is different and consequently it is impossible

to establish guidelines applying to them all. For that reason the above sections consider only some features that are often ignored, just to call them to the attention of a prospective evaluator.

Until now, this chapter dealt with a *first stage* – hiring people for a new project – trying to *match an individual potential with project needs*. Expertise, knowledge and competence were assessed by an evaluator – usually the project manager for upper level managerial responsibilities – on the grounds of information provided verbally and in writing by the candidate; from here, and studying responses and reactions a personal evaluation is done. Note that in this stage, the candidate is assessed according to his/her qualities and attributes as an individual, however, it is also probably necessary to have a hint of his/her reactions when working in a team and in relationship with other workers.

When the project has started, there is also a *second stage* – evaluation performance – which commands a different kind of analysis since it is concerned with *relationships involving management and workers*. Then, during the on-going project other features are considered such as reliability, efficiency, leadership, etc., on the grounds of daily observation of the work done. In this stage a worker's output is most probably the input for others, and since the quality of his work and behaviour may affect the efforts of the latter, he cannot be analyzed in isolation, but also as a member of team aiming for the same target.

Projects commented on until now were mainly of the construction type, which are undertakings with a clear start and defined finish (large buildings and high-rises, industrial plant construction, chemical plant erection, road construction, etc.), but there are also projects that involve continuous activities, such as those found in production (food industry, Portland cement production, fish processing, etc), and that can also be located in cities or in remote places. According to these two types of projects another difference can be observed, in the sense that in the continuous type there is not generally a project manager but a line structure, where the process is managed by a series of lower or upper level individuals.

These production structures in a remote place can be found for instance in mining and metallurgical operations, such as a gold metal production and refinery built very close to the mine. The continuous process involves mining, ore transportation, crushing and grinding, floatation, refining, with a manager for each one of these activities.

In this type of continuous production there are of course problems related with workers, and management, but however they possibly belong to another kind because the repetitive nature of the job, many times with a high degree of automation. Human Resources management in this case is perhaps different than in the mentioned cases.

Section 13.4 proposes an example of this type of continuous operation in a city in order to analyze the type of problems generated.

13.3 Diagnosing Existing Problems

It is often seen that in an ongoing project things are not developing as they should; the symptoms are usually clear enough and translates into lower productivity, or quality worsening, or increase in rejects, or in the demeanour of employees. There are thousands of causes for this deterioration and in this circumstance it is imperative to read the symptoms and most important, to analyze the causes that originate them. Next section example portrays such a situation and its analysis.

A very useful publication (© Peopleinaid 2007) provides a listing of 25 points as a check list and questions that “...can be used as a diagnostic tool when reviewing and planning the basic element of a Human Resources System”, as follows (only titles are reproduced here).

1. Organizational structure,
2. Job design,
3. Job descriptions,
4. Recruitment policy,
5. Recruitment procedures,
6. Staff induction to the organization,
7. Staff induction to the job,
8. Staff review,
9. Career path planning,
10. Training and staff development,
11. Management development,
12. Reward,
13. Human Resources function and budget,
14. Human Resources Planning,
15. Staff personal records,
16. Organisational culture,
17. Planning and managing change,
18. Job satisfaction and employee engagement,
19. Information sharing and communication,
20. Staff relations,
21. Staff health,
22. Staff safety and security,
23. Metrics gathered,
24. Retrenchment practices,
25. Social interaction.

As can be appreciated this listing, when completed with the corresponding questions relative to each issue (not reproduced here because it is a copyright material), can help a lot as a guide for a Human Resources system in a company. Its reading is highly recommended.

13.4 CASE STUDY: Analyzing Existent Personnel Problems in an Organization

13.4.1 Background Information

This case applies to an industrial firm manufacturing cosmetic products for men (disposable razors, shaving foam, after shave lotion), and for women (disposable razors, feminine shaving gel, and after shave cream). The company is a branch of a multinational and is located in a developing country, and even when working with imported technology, there is an R&D department to adapt its products to local needs and tastes.

13.4.2 Process Sectors

13.4.2.1 Main Activities in Manufacturing and Assembling

Manufacturing and packing area

- Consist in cutting a stainless steel sheet coil into narrow strips, followed by quenching, tempering, annealing and sharpening the strip with rotating grindstones,
- Plastic melting of razor blades holders in their different models,
- Mounting blade cartridge in the razor,
- Packing.

Chemical area

- Foam and lotions preparation,
- Canning and bottling different products,
- Packing.

R&D area

- Research to improve products.

Personnel area

General Manager. Supervises high level staff in the following sectors:

Production, Quality Control, Maintenance, Human Resources, Marketing, Accounting and Financing, Sales and Purchasing.

Production Manager. Responsible for medium management positions and 35 qualified workers.

Quality Control Manager: Two qualified employees.

Maintenance Manager: Two technicians and five workers.

Human Resources Manager: Three assistants, a nurse with full presence in the plant, and a physician available to come to the plant when required.

Marketing Manager: Two assistants.

Accounting and Financing Manager: Five clerks.

Sales and Purchasing Manager: Two clerks.

Type of structure: Functional

First Level: General Manager.

Table 13.1 Symptoms and perception – Analyzing existent personnel problems in an organization

Symptoms	Perceived as:
Low level moral	It is 'felt' in the plant. People work in a too serious mode. There are few salutations between staff and workers and clerks. Answers are correct, even polite, but neuter
Decreasing productivity	Detected from production statistics
Increase in rejects	There is a substantial rise in the quantity of blades rejected by quality control
Production targets are not met	It is the main complaint from marketing and sales. Established delivery dates are not honoured, which provokes that assumed compromises with clients are not met. There even exists a warning from a large supermarket chain to rescind signed purchasing contract, if this continues.
Increase in raw material wastes	There are always wastes, but these have been continuously increasing. Part of it is attributed to frequent interruption of electric energy which causes that all the in-process blades production must be removed from machinery, destroyed because there are not appropriate for sale and then going to production waste.
Quality is at its low limit	Quality Control (QC) reports that the plant is producing just in the fringe of the Shewhart quality control charts (see Sect. 11.3.4.1). QC has tried to identify the reason, but this is a difficult task since it can take place at any time along the process.
Absenteeism	According to human resources this has increased 5% in the last 3 months.
Staying in the job	Human Resources reports that the number of workers and clerks that have sent a letter of resignation has increased in the last 6 months. When asked why, a large percentage manifest that they are not happy with the existent working conditions; they feel 'used'. There is no complaint about wages, albeit this is the minimum by law, but the grievance refers to the lack of company concern for its personnel. The work is also monotonous, boring and there are not incentives.
There is not a friendly environment	Area managers coincide in this aspect. In other times there was an easier atmosphere, smiles, salutations and jokes, and that no longer exists. A bad mood in the environment is clearly.
Labor accidents	It is not a serious issue, albeit the number of accidents as a consequence of negligence and carelessness (such as falls and fractures, cuts, inhalation of chemical products such as ethylene chloride, burns, etc.), has increased, which of course reduce production time

Second Level: Production – Production and support areas

Third Level: Production – Workers and clerks.

The plant possesses a cafeteria where staff and personnel can have lunch at cost price, which is automatically discounted from the pay cheque (except during vacation time). There is also a little nursery for mother employees to leave their kids during their working time.

13.4.2.2 Diagnosis of the Problem

Some symptoms have been detected and detailed in Table 13.1.

Consequently, the existing problem is that the plant is working under undesirable conditions due to a series of factors. An analysis of these symptoms carried out by area managers, foremen and with the attendance of worker's delegate, shows the following results as per data from statistics, suggestions, formal and informal talks, anonymous notes placed in the suggestion box, etc.

Low Moral

There are possibly several intervening causes, such as:

- If it is true that the company cares for its personnel, apparently it does not pay attention to them. For instance, there are departments, especially Production, where its manager very seldom delegates, which is seen as a lack of confidence to his subordinates, and consequently destroy any intent of initiative. The production manager holds that this is only partially true, and that he does not

delegate because he feels that his personnel is not competent enough to work without strict supervision. The Human Resources manager asks then when was he informed about this circumstance in order for him to take measures to train people. The Production manager leaves the question without answer for suddenly he rises from the meeting and runs to his office because he had forgotten a very important telephone call. . . .

- The plant personnel think that management does not listen to their suggestions which are placed with name and surname in the suggestion box. They add that it very seldom that somebody is called by management to explain his/her suggestion. There is without a doubt a serious fault attributable to Human Resources and also to every area managers.

Decreasing Productivity

- The worker's delegate recognizes the truth of that, but he says it is due to constant changes in production orders for the different models they manufacture. That implies halting machines, removing steel spools, loading new ones because the new order belongs to a different quality product, set up the whole system, and start production with the corresponding waste of material. Marketing and Sales do agree that they frequently change the production orders, but contend that they do that as per client's requests. All of this, of course, alters productivity.

Increase in Rejects

- Production acknowledges this fact but contends that each time the production is changed, new quality norms are in force, which implies a continuous change in the productive scheme and also that it originates confusion in workers, who because of that make mistakes.

Production Targets Are Not Met

- It was already commented on about time and raw material wasted. Nevertheless the workers' delegate mentions that sometimes there is not enough raw material (mainly imported steel in spools). Purchasing confirms this fact and mentions that lately this is due to a halt of shipping from the supplier, a Swedish firm, because of a personnel strike. Since this has also happened in the past they suggest accumulating stock to guaranty production continuity. Financing then says that they already suggested said procedure to the General Manager, but she rejected the suggestion on the grounds that it would involve tying up capital which will undoubtedly influence the company's cash flow, which was not showing at its best lately, and also reflecting in the company balance.

It shows that the general manager values an equilibrated balance sheet over the necessity of complying with production targets. This does not sound logical, since even when the company has material in stock, and if it is true that liabilities will increase, it is also the same for assets, especially if this is an in-process production. It looks necessary perhaps to have the stakeholders decide about the policy to apply.

Increase in Wastes from Raw Material

An investigation has determined that part of that waste responds to no scheduled changes in production and the stopping of quenching lines due to faulty thermal sensors. However, there are also other causes, as for example:

- Stopping sharpening machines. This is due because they are obsolete equipment, discarded from a similar plant in their country of origin. Naturally they do have neither the speed, nor the precision of the new models and besides, they fail with alarming frequency. The general manager is personally involved in this aspect either by telephone, documents or by personal meetings with her equals at headquarters. The central office has promised to send new equipment but until this date has steadily refused to specify a date for that.
- The sharpening line work is monotonous and despite that the operator at the end of the line must verify at least every minute, through a visual inspection – which is reliable – of the cutting edge; often this is not done either because of fatigue or lack of interest. As a consequence, when Quality Control inspects at random each batch of blades it could reject the whole batch which goes as production waste and is destroyed. We are talking

here of thousands of strips, which are near the end of the production process, and thus carrying a high added value. The sharpening area foreman proposed some weeks ago a way to avoid that waste, but this suggestion was not even answered.

Blade Quality at Its Lowest Limit

This is a topic that reveals that relationships between managers of the different areas are not at their best. Production argues that poor quality is due in part to a low quenching temperature and blames Maintenance for that. Maintenance counterattacks stating that temperature sensors fail and blames Purchasing by not purchasing the brand they recommend.

Absenteeism

Production department does not have any contingency plan when a line operator does not show up for work. In that circumstance there are two procedures, (a) to stop the line or (b) make other co-worker work simultaneously with two lines. Naturally, this procedure cannot be maintained every time somebody does not show up for work; resentment on the part of a worker charged with a double task is not conducive to quality output.

Staying in the Job

Human Resources manager expresses his worry because of the exodus of qualified workers, and then the worker's delegate jumps to the opportunity and says that he can explain in a few words why it is happening. The reasons are:

- The company does not offer any future, and if there is any, it is unknown to the workers, since even considering that there is an ambiguous promotions plan, it has never materialized. A clear recent example was that a senior vacancy occurred due to a retirement; everybody expected that one of the senior workers, with 11 years in the company, and highly qualified, would be chosen to fill the position. Instead the company hired a young engineer, just graduated and without experience,
- The workers requested that norms and procedures, be provided in written form, but they only got promises,
- There is no communication between levels, that is, informal meetings where workers and staff can freely and amiably discuss areas of interest regarding the process problems, workers', needs, prospective new products, etc.,
- There are some examples where the company showed very little empathy to some personal problems of its workers,
- The workers received only a basic training 4 years ago when a new product was introduced,
- The company provides safety devices such as gloves and safety goggles, albeit these do not comply with safety standards because they lack side protection. However, it does not provide masks for working with slightly toxic gases such as ethylene chloride,

- There is a production bonus and it works, however, when the production falls due to various causes such as breakdowns, failure of electric power or lack of raw materials, this bonus decreases. The workers maintain that they are not to be blamed for something for which they do not have any participation.

13.4.2.3 Conclusion

Nearly each analyzed problem is related with people since:

- Production department, the heart of the company, does not delegate, so people feel that they are not sufficiently prepared (when they know that they are), and are just considered as pieces of machinery,
- Even if people collaborate with suggestions, those are not taken into account,
- There is no future in the company since no plans have been published and no record of upward mobility has been established,
- The personnel have received no technical instructions whatsoever in the last 5 years,
- Quality is decreasing as a consequence of an understandable bad feeling among the machine operators,
- People do not complain about wages, even considering that they are the minimum by law; they complain about the way they are treated.

13.4.3 Comments on This Case

This is a fictitious case; however it is based in actual facts and evidently can be replicated in different types of projects. It was developed with a certain detail to illustrate common problems in many companies and projects. There is no doubt that the symptoms show two main aspects:

- There is an absence of internal documented communication, evidenced by the mutual blaming between managers, regarding who is responsible for something. This subject is treated in Chap. 11,
- There is a manifest lack of interest in the most valuable asset the company has: Its workers. There is no doubt that a change of attitude towards them is urgently needed regarding several aspects such as:
 - Listening to what people have to say and suggest,
 - Developing a working policy that makes people feel proud of the company they work for, which is achieved when different measures are implemented such as:
 - Allowing them to participate in the whole process,
 - Develop stricter quality norms but that can be followed by workers. If quality, as expressed, is many times affected by actions that are out of the control of workers, it is not expected that they can improve it.

- In reality it appears that there are failures at the manager level regarding the performing of their managerial duties. When the Production manager says that he does not delegate, it implies that he believes that his people are not prepared; obviously he is doing himself a disfavor, for it is he who is responsible for their training, and he apparently has done nothing to ameliorate that situation,
- There are obviously no incentives for workers, again evidenced by lack of promotions when vacancies occur.

There are more conclusions that can be extracted from this case, whose only purpose was to make the PM aware and interpret the symptoms that she receives and make efforts not only addressing sales efforts but also her company working conditions. The company may be a leader in its field because of its research and innovation, but it also evident that its Human Resources policy needs a change.

13.5 Conclusion of This Chapter

This chapter is about people and aims at two different aspects (a) Hiring people and (b) Maintaining a healthy and good relation with workers, which in turn translates into benefits for a company or for any project.

Regarding the first aspect, the chapter suggests some attributes that must be considered when hiring for a job, not only from the traditional technical point of view, not only to verify proficiency or competence for a position, but also considering the aptitude of a person for that job, especially, when in the case of some projects they are in the middle of nowhere, where perhaps an individual must take decisions based only on his/her judgement. Another situation develops when the position requires a team effort; many people do not feel comfortable working with others, they prefer to work on their own and this circumstance needs to be examined when interviewing a potential candidate.

With respect to the second aspect the chapter proposes a case that intends to shed some light on the complicated aspect of human interrelations and especially when this relation, as in the case of any company or project, is only one way — down from managers to workers. Its purpose is to extract conclusions and especially to pinpoint a situation which unfortunately is present in some companies and projects.

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Abstract

This chapter involves examination of a project with respect to potentially dangerous hazards, their evaluations, and recommendations in the form of a set of instructions that will help all managers and staff members in complying with a requirement to guarantee the safety of the working personnel, adoption of necessary prevention measures, and signalling of evacuation routes. In addition to prevention measures, some actions are suggested whose intention is to emphasize the necessity of assuring their compliance.

Keywords

Accidents prevention • Health and safety • Accidents prevention • Risk hazards • Identification • Control

14.1 Safety in Projects

Even though there are many different kinds of projects with multiple opportunities for accidents to happen, in reality there are a limited number of common types of accidents. Most of them are in the form of falling from heights, being struck by something, electrocution, being run over by vehicles, getting burnt from fire or by chemicals, wearing inadequate protective equipment, etc. Unless an accident is caused by unforeseen circumstances, such as being struck by lightning during a storm, falling into a hidden cave, or suffering heart attacks and other ailments, all accidents are predictable and can be avoided. Avoidance is the main objective of safety in projects. Like some other aspects in project management, safety can be divided into two phases, namely *prevention* and *control*.

14.2 Accidents Prevention

Naturally, each type of project has its own kind of type of accident risks. For instance:

Road projects

The main problem might possibly be traffic related, because of the large quantity of trucks and heavy equipment working simultaneously in a relatively confined space.

Buildings construction

In a tall building construction project the risks are probably linked with falls from heights and with the operation of hand tools.

Refinery construction projects

In a refinery construction there is probably a large incidence of accidents related with loading equipment such as fork lift trucks, cranes and crane booms, welding, as well as falls.

Tunnelling projects

In tunnelling there are personnel risks associated with heavy traffic, the use of explosives, tunnel collapsing, flooding, etc.

Trenching

The typical accident is by trench walls collapsing.

Sewage work

The most usual is perhaps asphyxiation due to personnel working without protective equipment and with no fellow worker as backup.

For a particular project it is necessary to perform an analysis of the project from the safety point of view, and to detect the possible hazardous areas to prevent accidents happening during construction. Table 14.1 depicts as a guide a series of hazards in different projects.

14.3 Hazards Identification

Probably the first thing to do when detecting personnel hazards in a project is the identification of potential risks. It is suggested to break down the project into segments and examine each one for potential hazards risks. Consider for instance a large industrial project; hazards in areas can be examined as suggested in Table 14.2 (it only illustrates one work station). The last column proposes measures that can be taken to ameliorate or eliminate the risk of accident.

Each of these hazards must be analyzed in detail. For instance, for any type of scaffolding, inspect the machinery and the documentation that certifies it as safe; in addition make a plan to periodically check its elements, for instance to inspect the strapping and the eyes in a two-point suspension scaffold.

14.4 Evaluate Safety Risks

Once the existence of any safety risk has been detected it is necessary to evaluate it, that is to estimate its probability and potential degree of severity. To do this it is convenient to start working with each working position. Assume that we consider a working position with six workers preparing a 3/8 in. diameter steel bar/wire mesh for reinforcing concrete in columns, or floors in a building.

14.5 Safety Control

It is necessary to establish a plan or routine for inspections to verify that established regulations are abided by. Amongst other things the plan should check periodically:

- *Accident records*: Must be included in the weekly progress report (see Sect. 11.1),
- *Blasting operations*: Establish safety norms for blasting operations, aided by audible signals,
- *Chemicals*: Keep chemicals in appropriate containers and clearly labelled, and accessed only by authorized people,
- *Cleanliness*: Make sure that the construction area is kept clean, permitting the free pass of people and equipment. For instance verify that when there is material on the floor

such as bricks, they do not impede the pass of a forklift or other equipment,

- *Excavations*:
 - Check that trenches are dug and protected with adequate shoring and of the appropriate type (hydraulic, pneumatic, etc.). See OSHA Technical Manual (1999),
 - In an excavation make sure that protection is in place to avoid falling in it,
- *Equipment*: Control that maintenance plans for equipment are kept as well as records,
- *Fire*: Establish escape routes in buildings under construction in cases of fire. Verify date of charge of fire extinguishers,
- Make sure that workers know the type of fire extinguisher to use in case of electric fire,
- *First aid*: The site must have a first aid centre equipped and served as established by regulations, for instance 'Health and Safety (First Aid) Regulations (1981) in the UK (see HSE 1981), with an skilled appointed person every 50 workers,
- *Fuel*: Verify that fuel of any kind as well as highly volatile chemicals are not close to welding work, or near hand tools producing sparks such as grinders, oxygen/acetylene cutting, etc.,
- *Heavy machinery operators documentation*: Check documentation from heavy equipment operators (cranes, trucks, forklift, etc.), to make sure that they possess the corresponding updated permit,
- *Ladders*:
 - Check the different types of ladders utilized in the site. There are several different types, but a worker must use the appropriate ladder for each specific application,
 - Verify that ladders have the corresponding anti-slip rung cover, as well as no-slip safety feet,
 - Make sure that a worker uses a ladder that supports his weight and the weight of something that he is to install,
- *Machinery*: Verify that machinery is in good working order through the updated certificate issued by the corresponding governmental office; check for leaks from shock absorbers, and look for leak signals under the vehicle. If it is true that this inspection pertains to environmental protection it also affects safety; as an example consider a leak in the brake system of a heavy truck, that sooner or later will lead to the loss of braking power.
- *Mobile equipment*: Verify that all vehicles have their lights in good condition and that they carry the pair of reflective triangles for stopping in a highway, as well as a reflective waistcoat for the driver,

Table 14.1 Most common hazards associated with different types of projects

<i>Project areas or operation</i>	Bridges	Buildings	Confined spaces	Construction camps	Hand tools	Mechanical construction and erection	Mining lines	Overhead power lines	Roads and mountain roads	Trenching and excavation	Tunnels	Working area
<i>Potential associated personnel hazards</i>												
Avalanches, flooding		X	X				X		X		X	X
Blasting	X						X		X		X	X
Construction vehicles traffic and accidents. Personnel hit by load or by equipment becoming unstable (for instance a skip steer loader rolling over when working on a slope), or workers caught in between equipment and other objects, etc.	X			X								
Dust in suspension in air		X					X			X		X
Electrocution		X	X	X	X	X						
Exposure to chemicals			X			X						X
Exposure to fumes			X			X						X
Exposure to particles					X	X			X	X		X
Falls from heights	X	X						X		X		X
Fire		X	X		X	X						X
Mechanical accidents		X			X	X			X	X	X	X
Sandblasting		X			X	X						X
Slides and collapses									X	X	X	X
Water			X				X			X	X	X
Welding	X	X	X			X		X				X

Table 14.2 Analysis of a work station preparing steel/wire mesh for concrete columns

Work station: Production of steel bar/wire mesh for concrete columns				
Risk identification	Probability of occurrence	Potential damage to personnel	Risk value	Measures taken to address each risk
Steel bars getting loose and dropping from the crane	Low	Very serious	Medium	Double check the steel bars bundle before hoisting Make sure that the bundle is tight packed to avoid some steel bars getting loose during hoisting Establish a circular safety area with enough diameter and with centre in the vertical of the load when hoisting, for workers to stay outside the area. The diameter should be as a minimum equal the length of the rods plus a 10%
When wiring steel bars to form mesh	Medium	Falls	Low	Wear steel toe boots and work gloves When wiring use a wooden platform to avoid feet being trapped between bars which can produce ankle sprain
Buns from welding	Low	Medium	Low	Wear aprons, gloves and electric welding helmets for head and face protection
Swing of the mesh when hanging from the crane prior to placing in column	High	Very serious	High	Use the same safety circular area as above Utilize a sling attached to the load to direct it to position. Verify that sling is strong enough and in good condition
Cuts and bruises when placing hooks on stirrups	Low	Low	Low	Wear steel toe boots and heavy working gloves as well as the appropriate hand tool

- *Mobile equipment*: Verify that construction mobile equipment is equipped with an acoustic alarm when the reverse gear is engaged,
- *Physical barriers*: Check that there are physical barriers activated while stationary machines are in operation to ban access to their moving parts, i.e. those parts must only be accessed when the machines are not working, switched off or unplugged and without possibility of a sudden unexpected start,
- *Power lines*:
 - Electric cables for machinery must be hanging from appropriate poles at sufficient so as to not interfere with passing vehicles,
 - Instruct personnel not to touch – under any circumstance – downed power lines, even if they seem to be without power,
- *Protections*: Check that protections against falls are placed and clearly visible on every floor,
- *Slings, straps*: Make sure that wires, cables, slings and straps are adequate for their function in quantity, quality, diameter and kind of material,
- *Standard equipment working order*: Such as fire extinguishers of different types,
- *Stationary equipment*: Make sure that equipment protecting devices are in place, working and activated, such as screens in grinders, protection from rotating parts, etc.,
- *Tunnelling*: In projects involving tunnelling make sure that there is a log at the entrance with the name of each person normally authorized for working inside. A simple board with the corresponding names and with two holes for each name (worker IN or worker OUT), where pins can be inserted, will do the job,
- *Vehicle traffic*: Enforce maximum speed limits for construction equipment as well as cars in camps and working areas,
- *Workers*:
 - Keep a registry of people who must attend safety courses from OSHA¹ or from the European Agency for Safety and Health at Work, and confirm that they have the corresponding certificate. Do not allow people to work without it,
 - Control must be exerted on all workers and it is irrelevant if they work for the owner, for an A/E consulting firm or for a contractor,
 - Make sure that people handling and firing explosives have the corresponding licence,
 - Verify and act with all rigor with personnel not complying with safety regulations in their working attire such as hard hats, working gloves, steel toe work boots (if necessary), reflective waistcoat, harness and lifelines, protective goggles, etc.,
 - Verify that people entering a confined space are authorized, well equipped, with a lifeline, supported by a fellow worker in the surface, and with wire or radio communications,
- *Working area*: Keep the working area as dry as possible; many accidents are caused by water on slippery floors,

¹Occupational Safety & Health Organization – United States Department of Labor.

Table 14.3 Form for reporting accident

Form for reporting accident

Job #	Contractor	Subcontractor	Work area	
Workers involved	Craft	Category	Position	Equipment involved
Accident description				
Describe personnel injuries				
Seriousness of injuries	<input type="checkbox"/> Death	<input type="checkbox"/> Serious Future consequences? Yes No Unknown	<input type="checkbox"/> Mild Future consequences? Yes No Unknown	
Accident's cause				
Were safety measures in place? If not, explain why				
Is this the first time for this type of accident? If not, explain similar cases and circumstances				
Are there possibilities for a replication? Yes /Not Explain in each case				
What measures are being taken to avoid repetition?				
What is the impact on the project?	Time-wise	Cost-wise	Legal-wise	Workers moral-wise
Investigated by	Date of accident	Date of this report		

- Make sure that when people are working below moving parts of equipment, this part is secured for moving down; that is, they must be properly supported. For instance inspect the lower part of forks in a forklift truck on a hydraulic car lift,

It follows an example of risk evaluation for a work station. The important function of safety control is commented on and suggests checking procedures. Finally a form for reporting accidents is proposed.

14.6 Reporting Accidents

For each accident an accident report must be written. Table 14.3 suggests a form.

14.7 Conclusion for This Chapter

As a quick reference the chapter starts by commenting on typical accidents for different projects, and then presents a listing of project areas and potential associated hazards.

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Abstract

After defining quality, its relationship with projects is examined mainly regarding clients and/or stakeholders satisfaction. International and world-wide applied norms are also commented on, and an example of quality control posted. Typical and widely used models are also commented on and exemplified, such as the Kano model and Total Quality Management.

Keywords

Quality • PMBOK • ISO • Quality controls • Quality cost • Total quality • Kano • QFD

15.1 What Is Quality?

There are several definitions for quality such as '*Quality is a way to do things*', or '*Quality is the difference between a work well done and a poor one*', or '*The set of attributes of a project, product, or service to satisfy expressed or implicit needs*'. This book defines quality as the actions and procedures that lead to the production of something (a project or a product), using the best possible techniques and materials, in such a way that the product matches or even surpasses expectations, and aiming at a client's complete satisfaction.

Quality in a project begins with its inception (involving data reliability, drawings exactness and accuracy, and with the appointing of a good Project Manager), continues with a conscious and down-to-earth budget and subject to a realistic financing. Quality means a project built or developed with the best efforts of contractors and suppliers, which selection has been made not only considering the cost of their proposals but performance and experience too. There is quality when the project grows under the direction of a good project management team, with a sound, realistic and accurate monitoring time and cost control, and finishes when the job is handed over to its owner on time and on budget.

15.2 Goal for Quality and Its Relationship with Diverse Areas of the Project

Quality has an ultimate goal which is to develop something that wholly satisfies stakeholders in addressing their needs and wishes, with an outcome showing a faultless finish and with the evidence that the highest standard techniques were used for construction or development as well as for materials selection and testing.

Quality is '*produced*', it is a continuous effort, and thus it cannot be obtained through inspections (this is too expensive), but in preventing failures.

Quality in a project is also related with workers, the most important component, when there is concern about their safety and determination to finish the assignment with a record of zero accidents. It is associated with having a friendly and harmonious work environment, with workers knowing what they are doing, and using the right tools and equipment, feeling that they have proper supervisors, and with a fair recompense for their work.

Quality is tightly bound up with the environment. There must be a constant concern and associated respect for the milieu in which a project is undertaken, with the goal of

disturbing it as little as possible. When there are disturbances, the damage done must be somehow ‘compensated’ by the execution of additional work, possibly not related whatsoever with the project. Examples could be replanting trees to make up for destroyed foliage, or creating areas to attract wildlife when their habitats have been encroached upon by noise or air contamination, or constructing facilities to restore initial conditions such as building a fish ladder in a dam.

However, this is not enough; every project should also be considered as a contribution to improvement of the environment, through many different measures such as reducing erosion, facilitating percolation in the soil, diminishing previous chemical consumption as in the case of fertilizers, making a more rational use of water, preventing unnecessary evaporation, etc.

Quality is also related with communications in the project; poor quality in this aspect can lead to serious problems and increasing costs. It also relates to a good strategic planning, since its absence will probably lead to economic disaster, when the quality of data is weak, nonexistent or assumed without too much regards for reliability.

Quality also means the execution of a rational analysis to decrease or eliminate risks not only for workers but too in defence of the stakeholders’ interests.

Finally, a project must have a *quality* closing, meaning that complete documentation and history about its development must be furnished to the client; there is quality when the memoirs include lessons learnt, main problems encountered and how they were solved, change orders and causes, a complete set of as-built drawings, and enough information to allow for the possible recreation in the future of any aspect, calculation, study or situation that arose during construction or project development. Considering that preparing this document is usually mandatory, the client will appreciate its completeness and quality because it can also help him as a data bank for future projects.

It sounds too ambitious? It is, but also real and necessary.

Is it unfeasible? No, but it is difficult.

Does quality produce an increase in cost?

In most cases, affirmative, and a cost that has to be added to the budget.

But quality seems to be a very general concept, without a clear definition out of context. Not really. There are international norms and procedures, many of which have been inherited from early norms derived from best practices used in engineering for working with metals and other materials and for their testing and treatment.

As a matter of fact there are several international institutions that have been studying for many years the means to do work in the best possible manner, and then issuing norms

and procedures for use throughout industry. An example is ISO (International Standardization Organization), founded in 1947, an international body with links in more than 100 countries. In the USA is the American National Standard Institute (ANSI); in the U.K. the PROjects IN Control Environments (PRINCE2), on the continent the European Foundation for Quality Management (EFQM), and others in different countries. In our specific field of project management the world leader is the Project Management Institute (PMI) that prepared the PMBOK that is, the Project Management Body of Knowledge. This book is taken as a guide in project management processes in explaining what things are to be done to follow best practices.

What has been said regarding quality must be realized in every aspect of a project if it to match recent advances in this area which postulates the concept of ‘*Total quality*’, meaning that every department in the consulting or construction firm in charge of the project management or in the owner’s company, must adhere to quality principles and norms. Many companies have aimed at getting a ‘*Quality Certificate*’ granted by government agencies following ISO directives. A firm is certified when an auditing report confirms the excellence of its quality system.

15.3 Quality Assurance

It is performed by a continuous and repetitive monitoring and appraisal of various facets of the project. Its purpose is to make sure that the work is made with at least the minimum acceptable levels of quality.

15.4 Something About the Norms

Norms do not address specific activities; they apply to any field. However, in some cases, there exist norms that are particularly relevant to a specific area as for instance the project management practiced by PMBOK (Project Management Institute 2008). The ISO also has norm ISO 10006 that addresses project management; are they in conflict?, No, they are not, although they treat the same subject from a different point of view. Stanleigh (2004) points out their differences very well as:

The ISO 10006 guideline outlines quality management principles and practices as they relate to the management of projects. It provides the guidance on quality issues that impact projects. It is applicable to projects of varying complexity, size and length. The guidelines can be applied to projects managed by an individual or by a team or for a program (large project comprised of smaller but interrelated projects) or for a portfolio of projects.

PMBOK is PMI's Project Management Body of Knowledge. It describes the sum of knowledge generally accepted within the profession of project management.

References of the main standard families applied to project management are faithfully reproduced from their sources (when in *italic*) (see ISO 9000).

ISO 9000 (2008) – Quality management.

It is what the organization does to fulfill:

- *The customers quality requirements, and*
- *Applicable regulatory requirements while aiming to*
- *Enhance customer satisfaction, and*
- *Achieve continual improvement of its performance in pursuit of these objectives.*

ISO 31000 (2009) – Risk management

It sets out principles, a framework and a process for the management of risk that are applicable to any type of organization in public or private sector. It does not mandate a "one size fits all" approach, but rather emphasizes the fact that the management of risk must be tailored to the specific needs and structure of the particular organization.

ISO 13824: 2009 – General principles on risk assessment on systems involving structures.

ISO 14000 – Environmental management. It is what the organization does to:

- *Minimize harmful effects on the environment caused by its activities, and*
- *Achieve continual improvement of its environmental performance*

- Risks identification (Sect. 6.5.2)
- Risks analysis (Sect. 6.5.3)
- Risk responses (Sect. 6.5.6)
- Risk communications (Chap. 11)
- Risk procurement
- Project organization (Sect. 9.4.3)
- Changes (Sect. 16.2.1)
- Project plan
- Quality assurance (Sect. 15.3)
- Information distribution (Chap. 11)
- Request seller responses
- Sellers selection (Chap. 8)
- Establishing project team (Sect. 9.4)
- Developing project team (Sect. 9.4.9)
- Project execution (Sect. 1.6.3)
- Scope control (Chap. 16)
- Scheduling control (Chap. 16)
- Costs control (Chap. 16)
- Quality control (Chap. 15)
- Risks control (Chap. 6)
- Information distribution control
- Project work control (Chap. 16)
- Contracts administration (Chap. 3)
- Project team managing (Chap. 3)
- Managing stakeholders (Chaps. 11 and 16)
- Changes control (Sect. 16.2.1)
- Resources control (Chap. 16)
- Lessons learnt communication (Sect. 17.1)
- Project close (Chap. 17)

The norm is still in the preparation stage and will probably be ready at the end of 2011 or early 2012.

15.5 The ISO/DIS 21500 – Guidance on Project Management

It is dedicated to good practices in project management. This family of norms includes 43 sections, each one devoted to a specific area of project management as follows (Numbers in brackets indicate Chapters or Sections of this book where the corresponding aspect is treated):

- Project charter (Sect. 1.7)
- Preliminary scope (Sect. 9.4.4)
- Stakeholders identification (Sect. 1.7)
- Scope definition (Sect. 9.4.4)
- WBS construction (Sect. 9.4.5)
- Tasks definition (Sect. 1.6.2, Table 1.2, # 3)
- Resources (Sect. 1.6.2, Table 1.2, # 6)
- Durations (Sect. 1.6.2, Table 1.2, # 5)
- Sequencing (Sect. 1.6.2, Table 1.2, # 4)
- Scheduling (Sect. 1.6.2, Table 1.2, # 9)
- Costs estimation (Sect. 12.1)
- Budget developing (Sect. 12.3)
- Plan quality (Sect. 15.10)
- Risk management (Chap. 6)

15.6 Example of Quality Controls for a Construction/Consulting Company

This listing, admittedly forcefully incomplete, only intends to give an idea of what quality involves in a construction company or in a consulting firm managing the construction.

- Are contractors ISO certified?
- Are suppliers ISO certified?
- How are accounting procedures evaluated?
- How are budgets verified?
- How are computations checked?
- How are drawings checked and what concepts are considered?
- How are fire and safety systems evaluated?
- How are reimbursable expenses evaluated?
- How are risks evaluated?
- How are suppliers selected?
- How are the different steps for construction drawings edition?

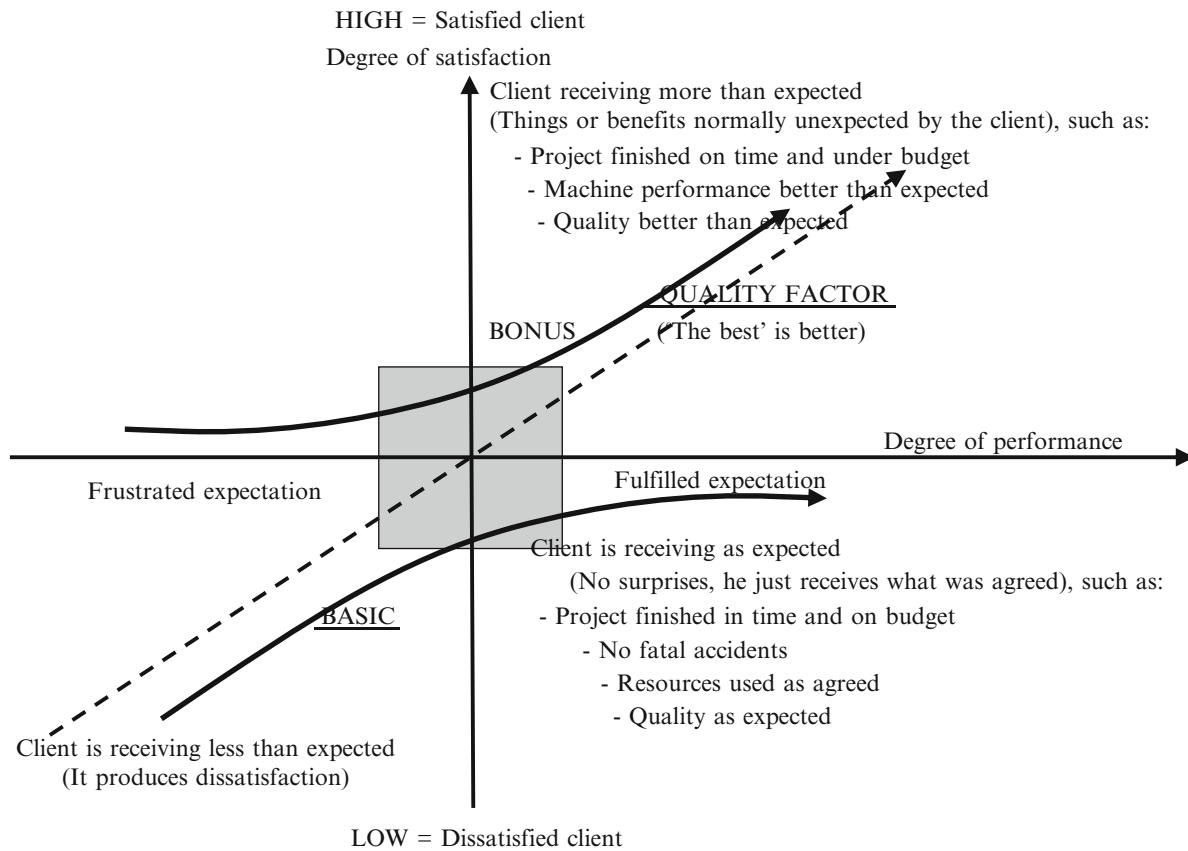


Fig. 15.1 The Kano model

- How are work certificates checked?
- How fast are in average contractors' progress payments cancelled?
- How is a Project Manager selected?
- How is cost control performed?
- How is monitoring performed?
- How is new personnel hired?
- How is relationship with client evaluated?
- How is the internal communications system in the firm evaluated?
- Is concrete temperature controlled if necessary?
- Are the personnel attending regular courses about safety?
- Is there any auditing about quality of reports to client?
- Is there any training for personnel?
- What are the procedures followed to check materials and equipment arriving to the jobsite?
- What are the procedures to check concrete quality?
- What aspects are considered in verifying the quality of work?
- What aspects are considered relevant for contractors and suppliers selection?
- What is done to approve and register changes?
- What is the procedure and norms followed for contractors' selection?

- What is the procedure followed to identify risks?
- Which ISO norms are followed?

15.7 Quality in Manufacturing

One capital concept in quality, especially in manufacturing, is that errors must be detected before the process, *not during or after it* as the old quality control (QC) promoted. In manufacturing projects there are two tools than can be used, both aiming at client's satisfaction: The Kano Model, and The Quality Function Deployment Model (QFD).

15.8 The Kano Model

It is a quality model whose objective is to find and analyze customer requirements; it was developed by Dr. Noriaki Kano (Akao 1997). For a simple and very illustrative explanation of the philosophy of the Kano Model see Parker (2006). Figure 15.1 depicts the Kano model. In a coordinate axis system formed by degree of performance in abscissas and degree of satisfaction in ordinates, three lines can be drawn. The first one, a straight line, is the 'Quality factor'.

It shows that the better the performance (first quadrant), the more satisfaction for the client. When performance decreases (third quadrant), there is less satisfaction (or dissatisfaction), of the client.

A second line, which is a curve, is the *'Basic'* line. It depicts (fourth quadrant), just what the client expects as long as his expectations are fulfilled. As the opposite, if his expectations are not even fulfilled (third quadrant) he becomes frustrated and dissatisfied. The third line, another curve, is the *'Bonus or surprise'* line. In the first quadrant the client gets more than expected, he is agreeably surprised, and consequently his degree of satisfaction increases. In the second quadrant the client is slightly surprised, which perhaps can compensate for a poor performance. The square shaded area is called *'The indifference zone'*, which needs no explanation.

There is obviously no need to stress which is the best policy. Whatever the business you are in, and if your service or products are in the first quadrant, the client will probably be the best fan you have; he will most probably rehire you and will recommend your services or products.

15.9 The Quality Factor Deployment Model (QFD)

Developed by Dr. Yoji Akao its function is to consider client's needs, wishes and necessities (or *'listening to the client's voice'*), and *transforming these demands into an engineering design*. The capital concept is that those aspects that are significant in the quality of a product must be considered in its design stage. Toyota, for instance, applied QFD in 1977 enlisting its utilization by all of its suppliers, thus and getting a considerable reduction in costs. Usually reengineering is applied here aiming at *'what to change?'* in lieu of *'what and how to improve?'*

15.10 CASE STUDY: Launching a New Portable Music Player

An electronic manufacturing company intends to launch a new portable music player, which will be in open competition with other brands already in the marketplace.

The company decides to use a Quality Function Deployment (QFD) tool, also called the *'House of Quality'* to analyze their position in the field. Figure 15.2 depicts this analysis. (Please consider that the given values are meaningless since this is not a real example; its only purpose is to illustrate the method).

It consists of six different matrices which work interrelated. Reading from the left they are:

(Matrix 1) Client's requirements.

This is also called *'Plan Quality'* because, in accordance with PMBOK (2008) definition, *"It is the process of identifying quality requirements and/or standards of the project and product"*.

People requirements are obtained through surveys, and with the corresponding weights. These weights can be estimated, or by using some decision making tools (see Sect. 8.2).

(Matrix 2) Market information. This matrix is divided into two parts. This first part (on the left), compares our product (★) with those from the competition *from the user point of view*. The competition products have other icons. Thus, from *'low weight'* for instance, our product gets a '2' mark, behind two products of the competition that get '3' and '4' respectively. Our product is also weaker in *'Vision'*, however it has the strongest marks for *'Game centre size'*, *'Large songs capacity'* and *'Camera'* and an intermediate value for *'Low cost'*.

The second part, on the right, considers for each requirement the increase/improvement or the drop/decline in values between the company's device and the competition (first column) and a relationship found (second column). These values are multiplied by the weights from matrix (1) (column *'Importance'*). Finally the relative weight of each requirement is found (column 4). In this way *customer's demands and other products are expressed by a single number*.

(Matrix 3) This matrix depicted in black describes the product from the *manufacturer's point of view* with information provided by the QFD team.

(Matrix 4) This matrix establishes *the relationships between customers' requirements* (Matrix 1) with the technical attributes of the company product (Matrix 3). Here values are assigned as follows: L (Low) = 3; M (Medium) = 6, and H, (High) = 9. These values are placed at the left in each box row. Thus, it is assumed that requirement *'Low weight'* is related with *'Total volume'* from a technical parameter; this relationship is evaluated as (M) Medium equivalent to a value for 6.

(Matrix 5) This matrix, also called *'The correlation matrix'*, allows one to investigate the *relationships or correlation between technical parameters*. For example, determining that *'Game centre size'* is related with *'Icons size'*. How does it influence other technical parameters? Follow the latter column and you will see that it has medium influence (○) on *'Screen size'* and on *'Glossy glass covered LED'*. Also see for instance that *'Screen size'* has a strong influence (●) on *'64 GB storage'*, which is negative, as indicated by the downwards arrow. The coding is:

- Strong influence
- Medium influence
- ▲ Strong influence

Coming back to Matrix 4 we use the values previously determined (left small column in each column). Each figure is then multiplied by the amount (in decimals) from the last column in Matrix 2. For instance, for 'Vision' and 'Screen size' it will be $3 \text{ (that is L)} \times 0.08 = 0.24$.

(Matrix 6) This is the technical evaluation of the most important aspect in the company's product. It has the sum for each column of the respective values. Their sum is 69. Finally the relative weight for each technical parameter is found, indicating that the parameter '64 GB storage' is the most important, considering customer's requirements, the advantage or disadvantage of our product related with the competition and the technical parameters, and most significant, considering the customer. From here the company can establish targets to satisfy its customers.

15.11 Cost of Quality (COQ)

It is the cost incurred when a product or projects do not have the expected quality, or as Sharma (2009) defines it, "quality costs are the costs of no creating a quality product".

The different costs of quality can be summarized as follows:

Cost of conformance (To conform or comply with client expectations)	}	<i>Prevention costs</i> : Those incurred to prevent a project or product showing poor quality, for instance in finishing aspects
		<i>Costs of appraisal</i> : Those incurred as a consequence of adopting measures to evaluate the project or product during execution, and also after completion.

Prevention costs:

These are costs incurred during the production stage, fixing defects discovered before the product is launched or the service performed. Its purpose is to avoid poor quality and involves:

- Destructive tests,
- Inspectors,
- Material lost because of the test or because of the result of an inspection,
- Personnel salaries to look for these defects,
- Purchase of specialized equipment, etc.

Costs of appraisal:

In this category are costs associated with evaluations at various intervals or stages during the process.

Cost of non - conformance (Those to correct failures)	}	<i>Internal</i> , that is during fabrication, production or construction.
		<i>External</i> , that is after the product is delivered or the project finished.

Internal costs

- Equipment in bad repair,
- Failure in checking the arrival of raw materials,

- Idle time,
- Lack of technical support to activities in the field.
- Lost time and accidents due to lack of safety measures,
- Poor or deficient communications,
- Poor resource utilization,
- Rejection of work in progress,
- Untrained workers,

External costs of failure

These are the costs once the product or service has reached the consumer or are in the hands of the owner of a facility. To this category belong:

- Actualizations from some software companies, to ameliorate, to fix software loopholes or a security flaw,
- Costs to fix problems. There are of course many costs associated to this category, probably the most known is manufacturers recalling thousands of cars to fix something,
- Loss of clients,
- Loss of confidence from clients,
- Loss of prestige,
- Loss of revenue when a client rejects a product or stops buying it,
- Risk of legal actions by clients and suppliers,
- Support costs,
- Warranty costs,
- Costs derived of replacing poor packaged products, etc.

15.12 Total Quality Management (TQM)

Many people see quality as an improvement of the product, manifested by fewer rejects, satisfactory performance, better design, ease of use, etc. However, a philosophy branded as 'Total Quality Management' sees it from a different point of view. It essentially maintains that a company and everyone within it must aim at reaching total quality, which means that all departments and individuals in the firm are committed to quality, even if they are not directly related with the product.

TQM aims at 100% staff commitment – from top management to workers and including suppliers – to *continuously* improve quality in such a way as to meet, and still better, surpass customer expectations. Even the customer is required to participate when he/she is requested to detail and make known what his/her expectations are in a product. In addition, TQM provides a linkage between productivity and quality (Scribd 2009).

15.13 Conclusion of This Chapter

This chapter focused on 'quality', which is considered by many a rather elusive concept that however is very tangible. Consequently, it starts by defining it and determining its

relationship with the project or product goal, workers, and the environment, and of course with the firm as a whole. It continues with the norms that regulate the concept, emphasizing the norm ISO /DIS 21500 related with good practices in project management, and proposes as a guide a series of questions that the Project Manager should formulate himself to assure quality in the project. Two practical models are discussed, the Kano model and the House of Quality since these two illustrate very well indeed what 'practical quality' means, the first one as a way to find out what the client expects and how to satisfy this expectation or even enhance it. The second model translates people's or client's demand into an engineering design, and an example is proposed to illustrate this method.

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Abstract

This chapter covers all areas that need monitoring and control during the execution of the project; this is done by using specific tools, methods and procedures; every tool is explained, templates suggested and examples developed. For the most important aspects, i.e. monitoring and cost control, actual cases are proposed using ‘hand solving’ as well as dedicated software. Different tools are used such as the Earned Value Analysis to check progress in both time and costs, to compute variances, to evaluate contractor’s performance regarding manpower and man-hours, and to also check contractor’s appreciation about estimate at completion and final costs. In addition, different exercises provide practical information about how to compute costs at completion, as well as labor performance factors, and how to develop and use information provided by learning curves.

The chapter provides samples and comments on different reports from the point of view of contractors, suppliers, drawings production, equipment, strategic planning, etc. Sections are devoted to forecasting advance on work and to factors affecting production. The control process also involves quality as well as environmental protection.

Keywords

Project monitoring • Project control • Earned value • Variances • Estimate at completion • Learning curve • Man-hours and manpower • Uncertainty • Forecasting

16.1 Monitoring the Work – Time, Costs and Performance

Monitoring and controlling the work performed is one of the most important activities in project management because it must make sure that the work is executed with quality, following established norms and providing a safe working environment for workers. Its goal is to make every effort for the project to be done and finished as scheduled, respecting the original budget, and to the entire satisfaction of the client. Albeit special emphasis is placed in construction, there are many other activities to monitor and control such as risks of every type, or to ensure that material and equipment is delivered on time, or that there is a fluent communication between all interested parties, and of course, to certify the work done by a contractor in such a manner that he can be paid for his work. Practically all components of

monitoring and control were briefly analyzed in Chap. 1 and in Table 1.4, with the main purpose to let the reader know about what is included in this group and also to give a road map of its contents, actions to be taken and activities to be considered. In this section a deeper analysis is done and applied to concrete cases using a methodology called ‘*Earned Value Analysis*’.

This analysis is based in evaluating at a certain date, that is, at the ‘*status date*’ the relationship between the following concepts:

- Amount of work scheduled,
- Cost of work scheduled,
- Amount of work performed,
- Cost of work performed.

Consider a coordinate system with time in abscissa and dollars or whatever other currency in ordinates. When budgeting a project – as explained in Sect. 12.3 – for each

period, say for each month, a value is obtained which is the product of units of work to be done in that period multiplied by its cost. This value is added to the amount found for the previous month, obtaining then a cumulative figure for work scheduled. Each of these monthly values can be plotted in a cost/time coordinate system; when all of these successive cumulative figures are linked by a line, the result is what is called an 'S-curve'. Therefore this curve represents cumulative costs spread along the project life.

The S-curve is then the baseline or budget cost for the project and is known as '**BCWS**' (**Budget Cost of Work Scheduled**). As explained, this curve is built from the Gantt chart, which in turn derives from the CPM analysis, and it links the advance of work as per schedule and the corresponding cost per budget. It is normally attached to the contractual documents once it has been agreed and approved by the client, and expresses that at a *specified date* or in a stipulated period there must be an established percentage of the work done and a fixed amount of money spent.

After a project starts, at each revision period, say each month, the work done is appraised in the same manner, that is, quantities are multiplied by the respective budget costs and a similar S-curve is obtained. This curve is called '**BCWP**' (**Budget Cost of Work Performed**). Ideally, this curve should coincide with BCWS, but it rarely happens, because there are normally a series of circumstances in both durations and costs that make them different.

In addition, we are assuming here that actual costs are coincident to those estimated, which is not normally the case even with costs agreed and approved. There are many reasons for this discrepancy, for instance inflation (producing the increment of cost of inputs such as bricks, Portland cement, or whatever other input), or maybe the contractor experienced unexpected difficulties due to unforeseen events (such as finding unexpected underground utilities, archaeological ruins, poor soil, etc., during the excavation for the foundations of a building). Consequently, there is usually an actual cost that is higher (or lower), than the scheduled cost for a specific task. This cost is called '**ACWP**' (**Actual Cost of Work Performed**), and if plotted monthly will generate another S-curve. It represents the total actual cost incurred in a work considering all type of costs (direct and indirect labor, materials and equipment, direct and indirect costs, etc.), and related with the quantity of work actually done.

Plotting the three curves together produces a graph as depicted in Fig. 16.1.

16.1.1 Comparison of Curves

When at status date the advance of work is checked for quality, measures taken and data gathered, several scenarios are possible considering these three curves.

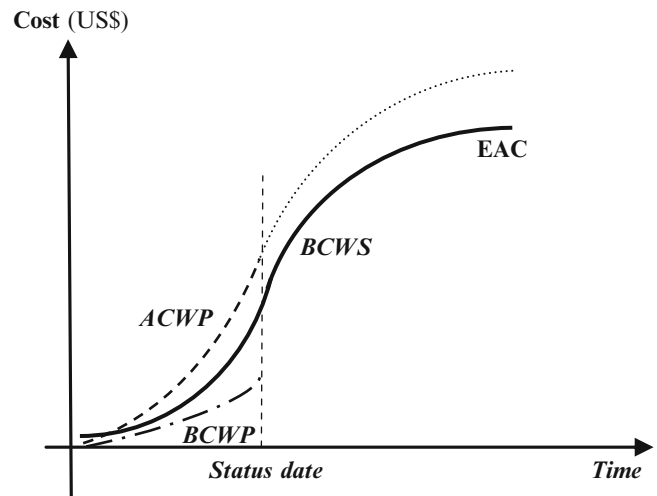


Fig. 16.1 The three curves in the earned value analysis

Some of these scenarios are:

Measuring work performed $\left\{ \begin{array}{l} \text{Actual quantity (m}^3\text{)} = \text{Scheduled quantity (m}^3\text{)} \\ \text{Actual cost (dollars)} = \text{Scheduled cost (dollars)} \end{array} \right.$

In this case $BCWP = BCWS = EAC$ and the three S-curves coincide.

That is: Quantities *installed* and quantities *scheduled* do coincide, as well as *actual* and *scheduled* costs. However, this is indeed very atypical.

Measuring work performed $\left\{ \begin{array}{l} \text{Actual quantity (m}^3\text{)} = \text{Scheduled quantity (m}^3\text{)} \\ \text{Actual cost (dollars)} \neq \text{Scheduled cost (dollars)} \end{array} \right.$

In this case $ACWP \neq BCWS \neq BCWP$ and the three S-curves do not coincide.

That is: Quantities *installed* and quantities *scheduled* do coincide, however, *actual* costs and *scheduled* costs do not. The non-coincidence in costs can be due to different reasons, for instance a low estimate of labour, and then requiring the utilization of more resources than expected, or maybe shorter or larger durations for some tasks than those assumed during costing, lower than expected productivity, technical problems, increase in labour wages, changes in design, etc.; but whatever the cause, there is a cost overrun if for the same quantities scheduled and installed there are higher costs. The reverse could also happen, and in this case there is a cost underrun.

Measuring work performed $\left\{ \begin{array}{l} \text{Actual quantity (m}^3\text{)} \neq \text{Quantity scheduled (m}^3\text{)} \\ \text{Actual cost (dollars)} = \text{Scheduled cost (dollars)} \end{array} \right.$

In this case $ACWP \neq BCWS \neq BCWP$ and the three S-curves do not coincide.

Urban underpass construction									
Main activities	Cost (€)	Duration (Days)							
			May	June	July	August	September	October	November
Trench excavation, walls, roofing and access Percentage of work scheduled	525,249	150	10	22	36	58	80	100	
Relocation of existing piping Percentage of work scheduled	308,901	95		20	41	92	100		
Electrical and mechanical systems Percentage of work scheduled	117,411	80			50	84	100		
Paving and landscaping Percentage of work scheduled	90,428	70					80	90	100
Total investment			1,041,989						

Horizontal bars represent duration of the activity while numbers indicate accumulative percentages of completion of each activity

Fig. 16.2 The Gantt chart – Planning, scheduling and control for an underpass construction project

That is, Quantities *installed* and quantities scheduled do not *coincide*, and *actual* costs and *scheduled* costs do coincide. This could mean that albeit costs coincide, and if quantities installed are fewer than expected, there is a cost overrun, because the same money gets less work done.

As seen, the monitoring action compares these three curves at certain dates, and hence valuable information can be obtained. According to the relationship between the three costs, there will be three different curves as sketched, but of course the order in which they are drawn may change as the curves combine differently. In this case it is assumed that actual costs (ACWP) are higher than estimated costs (BCWS). By the same token it is assumed that actual costs are higher than the same amount of work valued at budget cost (BCWP). Figure 16.1 shows the three curves. As seen, the BCWS extends up to the final steps of the project, while ACWP and BCWP extend up to the status date.

It is of great interest to estimate the final cost, that is, at the completion of the project. This estimate is known as '*EAC*' (*Estimate at completion*). The ACWP can be projected up to the end of the project in order to have an idea of how much this cost could be, and this has been indicated by a dashed and dotted line. This is not an easy prediction, because there is no guaranty that everything will replicate onwards the status date, nor is it an extrapolation by hand from the status date. There are formulas that are more convenient to use and that also take into account the contractor's efficiency, which, needless to say, can increase, decrease or stay constant. From this point of view it is usual, and depending the task, to use the learning curve for repetitive work, as mentioned in Sect. 16.3.2.

Let's see an example for using this technique.

16.1.2 CASE STUDY: Planning, Scheduling and Control for an Underpass Construction Project

This case refers to the construction of an underpass in a busy urban intersection of two important avenues. The project contemplates an 83 m long, two-way tunnel under one of the avenues, and will be built using the cut and fill method that is, excavating a trench, constructing the concrete walls and roof, and using reinforced concrete for the tunnel road. Assume that the work was planned according to the procedure explained in Chap. 9 and that a construction schedule materialized in a Gantt chart as depicted in Fig. 16.2, using percentages of completion, with the work commencing in May and finishing at the end of October.

Based on this chart the BCWS can be constructed as follows (Table 16.1).

The value for each task is calculated based on the estimated accumulated percentage of completion in each month, multiplied by the budget cost of each task. Thus, starting in May, only task '*Trench excavation*' is to be performed up to 10%.

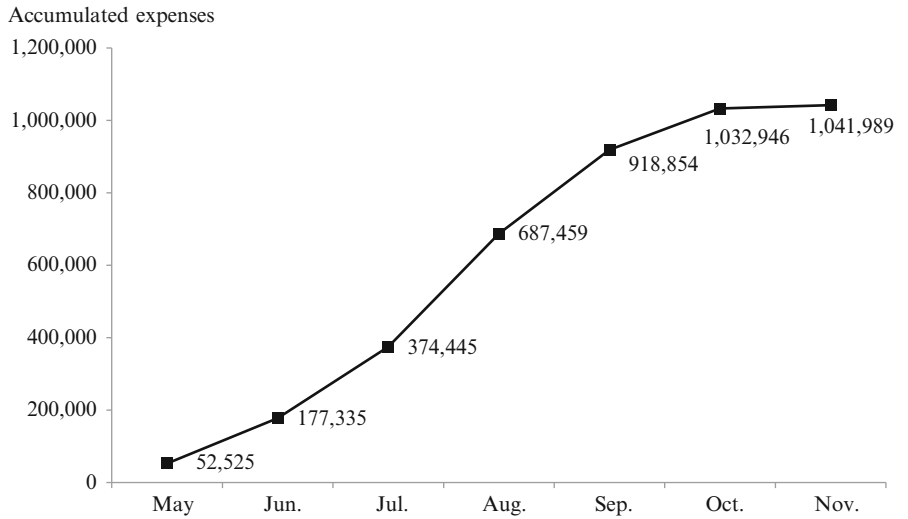
Therefore at the end of that first month the value of work scheduled is $0.10 \times 525,249 = 52,525$ Euros, which is shown at the bottom of said table. For June it will be $0.22 \times 525,249 + 0.20 \times 308,901 = 177,335$ Euros; for July $0.36 \times 525,249 + 0.41 \times 308,901 + 0.50 \times 117,411 = 374,445$ Euros, and so on. Total amount of the project is 1,041,989 Euros, which is also called '*Budget at completion*' (BAC).

Data from Table 16.1 permits drawing the BCWS curve (Fig. 16.3), that is, the base line, budget curve, or S-curve.

Table 16.1 Calculation of BCWS – Planning, scheduling and control for an underpass construction project

Main activities	May	June	July	August	September	October	November
Trench excavation, walls, roofing and access	52,525	115,555	189,090	304,644	420,199	525,249	525,249
Relocation of existing piping		61,780	126,649	284,189	308,901	308,901	308,901
Electrical and mechanical systems			58,706	98,625	117,411	117,411	117,411
Paving and landscaping					72,342	81,385	90,428
Total per month	52,525	177,335	374,445	687,459	918,854	1,032,946	1,041,989

Fig. 16.3 Procedure to build the BCWS or S-curve – Planning, scheduling and control for an underpass construction project



This is a contractual document and shows the accumulated disbursements, as computed in Table 16.1.

16.1.2.1 Units of Measure

In this example notice that all activities or tasks are expressed in monetary units, and for that reason it is possible to add them up. However, this is not normally the case since for a certain month there will be activities of very diverse nature and units, such as m² for installing curtain walls in a building, or m³ for concrete pavement, or lineal metres for piping, man-hours for labor to lay the piping, etc., and the progress will be reported in those same units. It is then customary to express all activities in monetary values or in man-hours. This also allows for the computation of a weight for each task by finding a ratio between the value of each activity and the total budget. When this is done for each month the value to consider for building the S-curve is equal to:

$$\sum (\text{activity or percentage to be performed}) \times (\text{total amount}) \times (\text{weight}). \tag{16.1}$$

Ideally, as already commented, the work should develop according to this schedule, completing activities in the specified time and within the established costs, but in general in most projects this is rarely the case. Many circumstances attempt against this ideal scenario such as for instance, more difficulties than expected in performing some tasks which

means increased duration and higher costs; delays in the arrival of equipment to be installed; labor efficiency lower than assumed; the emergence of unexpected problems, such as finding more water than anticipated from underground sources; poor weather, etc.

Therefore, it is necessary to monitor, that is to assess the advance of the work and evaluate its cost, and, in case of deviations from the planned schedule, establish control actions to correct them. Regarding deviations it is necessary to define when a deviation is important, because it is useless to consider that a deviation exists if for instance control measures show that there are 478 m³ of concrete poured when in reality there should have been 480 m³, and also because there are measuring errors. Consequently, a tolerance in percentage should be allowed and only consider that there is a deviation in quantities installed (in plus or minus), when that percentage is surpassed.

16.1.2.2 Checking the Work Done – Updating the Schedule

The Gantt chart in Fig. 16.4 reproduces the original schedule, but now with an additional double line bar drawn for each task, which indicates for every one of them when it started, and how much of it was done, in percentage.

It is seen that execution of the first task (*Trench excavation, walls, roofing and access*), should have commenced in May, but it did not, for it started in June, (therefore the onset

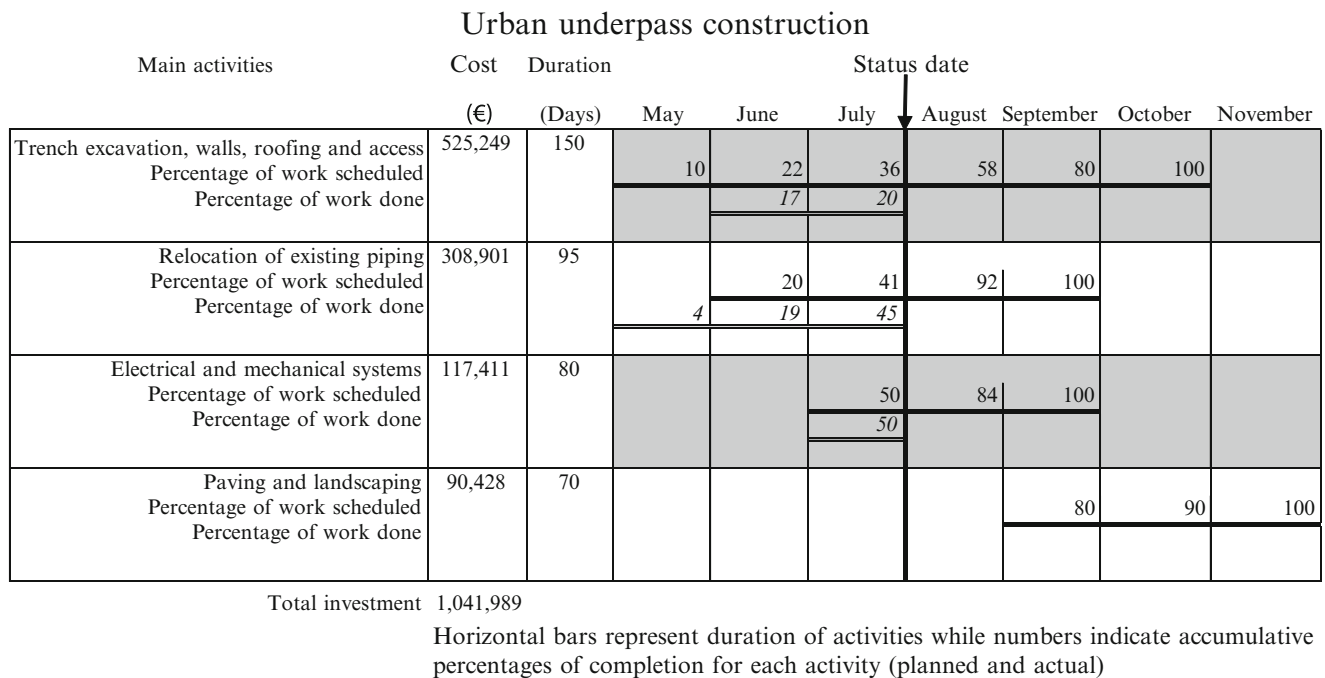


Fig. 16.4 Monitoring work at status date – Planning, scheduling and control for an underpass construction project

Table 16.2 Calculation of BCWP – Planning, scheduling and control for an underpass construction project

Main activities	May	June	July
Trench excavation, walls, roofing and access		89,292	105,050
Relocation of existing piping	12,356	58,691	139,005
Electrical and mechanical systems			58,706
Paving and landscaping			
Total per month	12,356	147,984	302,761

was behind schedule); at the end of July it accumulated an advance of 20% which is lower than the percentage scheduled (36%), that is, the task is behind schedule. The second task (*Relocation of existing piping*), commenced in May, when it should have started in June, i.e. its onset was ahead of schedule; in that said first month it reached a 4% advance, and showed a total advance of 45% at the end of July, that is ahead of schedule (that was 41%). Remember that these are accumulated percentages.

The same examination can be done for the third task (*Electrical and mechanical systems*), but we can not perform it for the fourth task (*Paving and landscaping*) because it was not scheduled to commence until September. However, if for whatever reasons it actually started, say in July, the Gantt chart should take into account that action and register that circumstance and advance, if any.

With this information it is now possible to compute the amount of work actually performed in Euros (*Earned values*) or BCWP (*Budget Cost of Work Performed*) (Table 16.2). Since '*Relocation of exiting piping*' reached an advance of 4%, its valuation, at budget cost, is $0.04 \times 308,901 = 12,356$ Euros, which is also written at the bottom of the table.

For June, trench excavation actually started and reached an accumulated percentage of completion of 17% (Fig. 16.4), which translated into budget costs amounts to $0.17 \times 525,249 = 89,292$ Euros. Similar calculation for relocation of existing piping yields a value of 58,691 Euros. Consequently, for June the total value of work done is $89,292 + 58,691 = 147,984$ Euros, the value shown at the bottom of the BCWP Table 16.2. Similar analysis produces the total value for July, which is 302,761 Euros.

However, remember that these costs, even when they are based on work actually done, were computed using estimated cost figures from the budget, which may not coincide with actual costs. The actual expenditures for the 3 months are shown for the ACWP (Table 16.3). This data is obtained considering work done at actual costs incurred.

Notice that the ACWP exceeds the estimated budget at this time. Why?

The reasons for this increase could be efficiency, that is, more time was used than estimated for executing a certain task (because perhaps it was assumed a higher efficiency, or due to change orders, or to additional tasks, or simply because a wrong estimate, etc.).

Table 16.3 Values for ACWP – Planning, scheduling and control for an underpass construction project

Main activities	May	June	July
Trench excavation, walls, roofing and access		140,713	209,765
Relocation of existing piping	18,736	30,740	145,987
Electrical and mechanical systems			89,958
Paving and landscaping			
Total per month	18,736	171,453	445,710

Fig. 16.5 Combining the three curves – Planning, scheduling and control for an underpass construction project

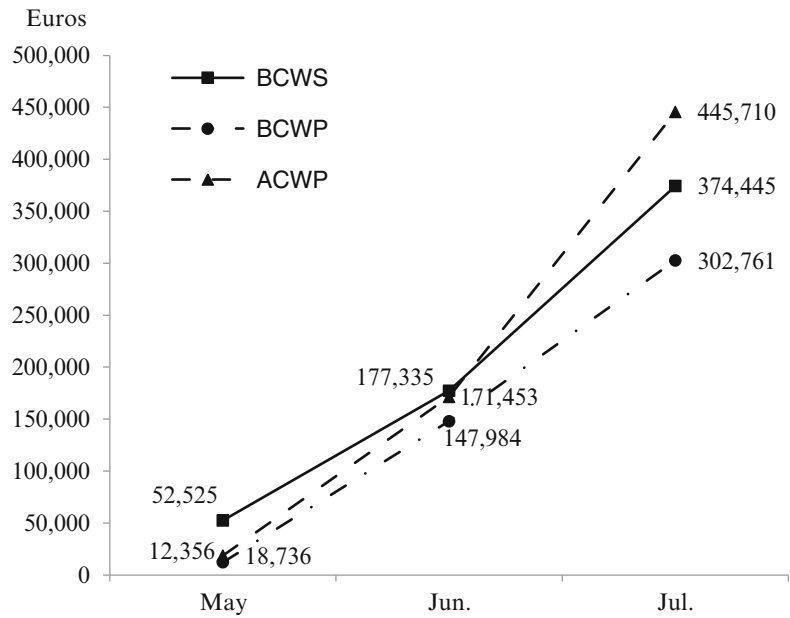


Figure 16.5 displays the BCWS, BCWP and ACWP curves in the same diagram and scale. Their values have been obtained from the corresponding bottom values for each curve from the above mentioned tables. There could be different combinations of how these curves show. In this example and at the July check, the ACWP has the largest value (445,710 €), followed by the BCWS (374,445 €), and the BCWP (302,761 €) values. The analysis consists in examining these different amounts in order to extract conclusions. In this case it can be checked that at the end of July, there are not only higher expenditures but a delay as well, since the estimated amount of work performed at the end of July – that is the earned value (BCWP) is 302,761 €, but it should have been reached at about 2 weeks earlier, as indicated by the vertical dot line.

16.1.2.3 Variances

Comparing the three values a series of variances can be obtained, as follows (Fig. 16.6):

$$\begin{aligned}
 \text{Costvariance}(CV) &= \text{BCWP} - \text{ACWP} = 302,761 - 445,710 = \\
 &= -142,949.
 \end{aligned}
 \tag{16.2}$$

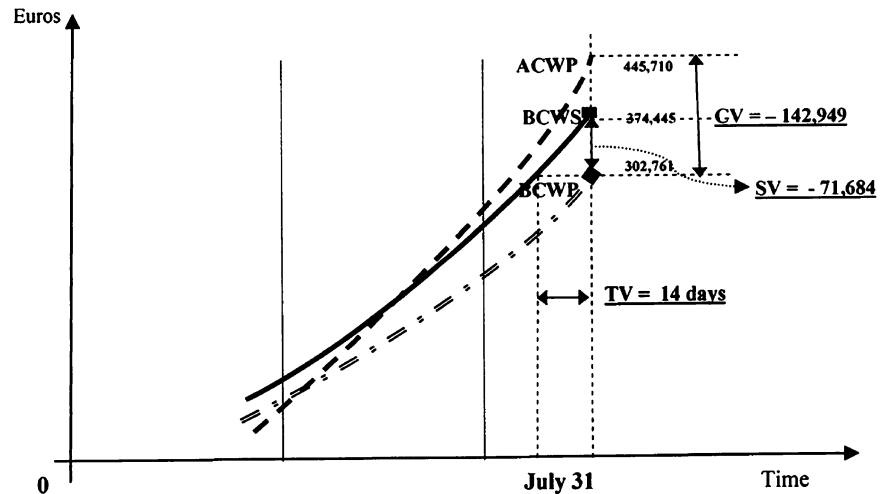
That is, cost variance is the difference between two values: The BCWP that expresses the worth of the work done

appraised at *budget values*, and the ACWP that expresses the worth of work done considering *actual expenses*. If this difference is negative, as in this case, it indicates that the project has ‘*cost overrun*’, since the actual amount spent is greater than the same amount of work valued at budget costs. Conversely, if the metric is positive, it will indicate that the project is ‘*under budget*’.

Consider now the difference between BCWP and BCWS, the *schedule variance (SV)*. If this difference is negative, as in this case, it indicates that the project is ‘*behind schedule*’; since at this date the work is valued lower than it should be. Conversely, if the $SV > 0$, most probably the work is ‘*ahead of schedule*’.

It was said that in this case the project is behind schedule; however, task ‘*Relocation of existing pipe*’ is ahead of schedule because its percentage of completion is higher than estimated (45% > 41%), and at the same time task ‘*Electrical and mechanical systems*’ in right on schedule (50% = 50%). However, observe that for the first task ‘*Trench excavation*’, which is the task with the higher weight, the difference in percentage of completion is considerable (20% < 36%). It is convenient to find the reasons for this difference, and perhaps it can be corrected or decreased. It is also fitting to check if this task is or not on the critical path. In the first case perhaps increasing the speed of trenching with another machine can help. In the second

Fig. 16.6 Variances – Planning, scheduling and control for an underpass construction project



case possibly there is no necessity to do anything because the task has enough float to absorb the difference.

* *Time variance (TV)* = It is the difference between dates of execution. That is, the amount of 302,761 Euros should have been reached about 14 days ago.

16.1.2.4 Performance Indexes

These values can also be used to build indexes. Thus, the '*Cost Performance Index*' (CPI) relates work performed at *budget* values with work performed at *actual* values. Then:

$$* \text{CPI} = \frac{\text{BCWP}}{\text{ACWP}} = \frac{302,761}{445,710} = 0.68. \quad (16.3)$$

When, as in this case $\text{CPI} < 1$, it means that the work actually performed when valued at budget costs, was only 68% of the actual cost of the work on July 31; i.e., there is a cost overrun. As commented above there are many reasons that can produce this metric, to which we can add that it can also signify that the budget estimate was unrealistic.

If in another case the $\text{CPI} > 1$, it means that the completion cost is lower than estimated. This apparently is good news; however, in this case it could also signify that the original estimate was not down-to earth because costs were computed above standards in the industry. If it really happened, maybe it can be considered that those increased costs were some sort of a preventive measure to avoid overruns; if this is the case it could also mean that the owner or promoter had to compromise a larger than needed amount of capital, which probably increased the needs for bank loans and caused the paying of additional interest for the unused capital.

Another index is the '*Schedule Performance Index*' (SPI) that relates work performed and work scheduled *both valued at budget costs*. Then:

$$* \text{SPI} = \frac{\text{BCWP}}{\text{BPWS}} = \frac{302,761}{374,445} = 0.81. \quad (16.4)$$

When, as in this case $\text{SPI} < 1$, it means that the work actually performed when valued at budget cost, was only 81% of the cost scheduled at July 31; i.e. the project is '*behind schedule*'. When the $\text{SPI} > 1$, then the project is '*ahead of schedule*'.

As mentioned, the 302,761 Euros expenditure should have been reached about 14 days ago, which in consequence indicates how much is the project is behind schedule.

In another words, up to this day the project is spending more than expected and is also behind schedule.

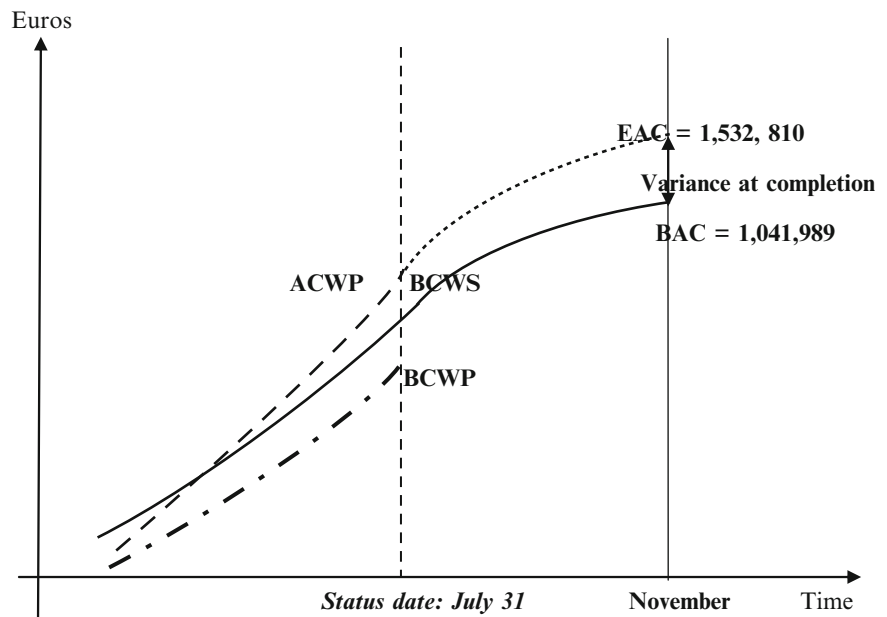
A reflection:

In reality, SV and TV are different views of the same issue, the advance of the schedule, and then both represent schedule variance. However there is a difference, and it lies in the fact that SV measures delays or advances in monetary values (Euros), while TV measures delays or advances employing time as a unit of measure; nonetheless, using SV can be misleading. For instance, at the completion of the work, the SV should equal 0 since the $\text{BCWP} = \text{BCWS}$; as well, the SPI should be 1, for the same reason. However, these metrics do not register if the project was indeed finished at the scheduled date; if it did not finish, then there is a schedule variance accounting for the difference between the actual finishing date and the planned one, and this is indicated by TV.

16.1.2.5 Estimate at Completion (EAC)

We already know that the *Budget at Completion* (BAC), will be 1,041,989 Euros (from Table 16.1). It is also known that the BCWP on July 31 is 302,761 Euros (from Table 16.2). Consequently, the amount of money necessary to complete the work would be: $1,041,989 - 302,761 = 739,228$ Euros. Since until July 31 an actual amount of 445,710 Euros have actually been spent (ACWP) (from Table 16.3), at its completion the project will have a total cost of $445,710 + 739,228 = 1,184,938$ Euros. However, this holds true only if the CPI is equal to 1, i.e. a perfect compliance to the schedule. The calculation of the CPI shows that on July 31, this efficiency was only 0.68;

Fig. 16.7 Cost estimate at completion (not to scale) – Planning, scheduling and control for an underpass construction project



consequently the amount of 1,184,938 Euros must be affected by this CPI. Then, the formula to apply to compute the EAC value is (Fig. 16.7):

$$EAC = ACWP + \frac{(BAC - BCWP)}{CPI} =$$

$$EAC = 445,710 + \frac{1,041,989 - 302,761}{0.68} = 1,532,810 \text{ Euros.} \quad (16.5)$$

And the variance at completion will be:
 $1,532,810 - 1,041,989 = 490,821$ Euros.

16.1.2.6 The 3-Week Ahead Schedule

This report is simply a forecast done by a contractor detailing which activities or tasks will be performed in the next 3 weeks. It usually refers to important and potentially problematic activities on the critical path. It is used by contractors in weekly meetings with the client and project management to inform them of how they plan to address conflicting issues and how they will solve incoming problems (for instance working an extra shift, adding more equipment, modifying the construction process, etc.). Information from a contractor is also useful to other contractors who cannot start their own activities until tasks by others are finished, for instance painters, who need the electrical wiring completed, embedded into a wall, and plaster finished, in order for them to start painting. If there is a delay from the electricians for instance, the painters perhaps can alter their own schedule by shifting their people to other tasks, or other areas of a building. That is, the 3-week look ahead schedule is a tool for short term planning and adjustments, and, compared with last week's status, allows one to learn how a contractor solved prior problems and to what

extent. This can be a valuable document in case of prospective future claims (see Sect. 16.2.1 and for more information it is suggested to consult Max's 1990).

16.1.3 CASE STUDY: Contractor's Cost Report in an Underground Stormwater Storage Project

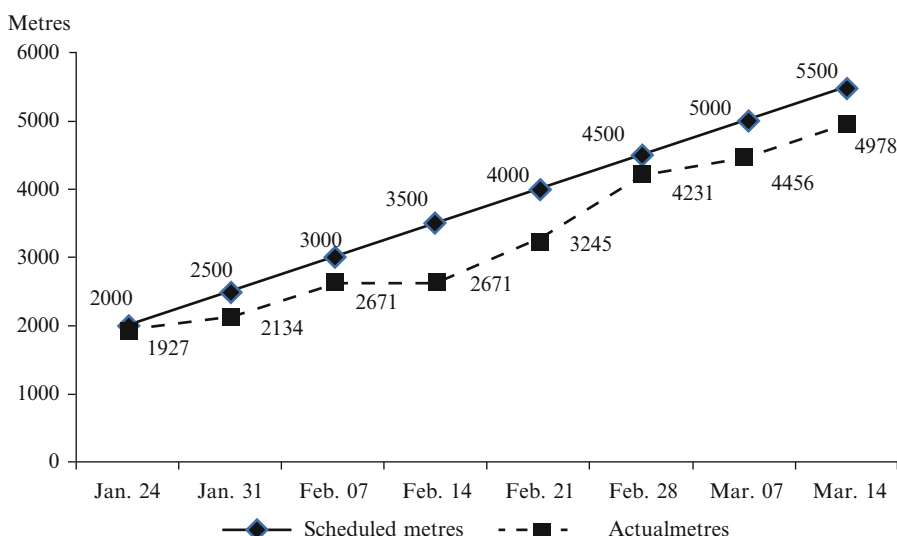
This case refers to a city where a whole district is subject to flooding from severe rains; damages are considerable, affecting dwellings, closing many streets to vehicular traffic and destroying valuable property. One solution to this problem is a common feature in many cities and provides satisfactory results; it consists of collecting water from the streets in an underground reservoir that is generally built under an avenue. The reservoir works as a stormwater detention basin, since later, after the storm, water is released to a river passing through the city, or else can be saved for city park irrigation.

In this case the City Hall has decided to build a reservoir under West Avenue. Structurally it consists of a box formed by 33 modules of precast concrete; water comes into the reservoir through two main trunks and leaves it by another trunk that discharges into the river. We analyze here the contractor's documentation on which his offer for doing the work is grounded.

16.1.3.1 Contractor's Cost Report

This report, also called '*Schedule of Quantities and Prices*', in addition to representing the formal contractor's offer is a useful document since it permits further control of the contractor's performance. The control is based on the WBS as depicted in Fig. 16.9 which provides the cost codes for

Fig. 16.8 Scheduled and actual non-tensioned anchor bolts installed



identification. Table 16.4 shows a sample of such a report as of January 07, 2012. The main areas are shown in Table 16.4:

The first area contains information from the *schedule of prices* submitted by the contractor and approved, where for each item, whatever its nature, there is the quantity, the unit of measure (also in Lump Sum (LS)), the unit price in US\$ and the total amount. This is the BCWS (*Budget Cost of Work Scheduled*). The second area pertains to the values collected from the field regarding the work already done, or earned value at budget cost, i.e. the BWCP (*Budget Cost of Work Performed*).

The third area corresponds to cost forecast at completion. Notice that for task (03) ‘*Demolition of existing construction*’, the second area of the report shows that only 1.3 ha out of the 2 ha, are complete, therefore the work done is linearly computed as US\$ (1.3 × 18,000 = 23,400 €) (Earned value), and the remaining cost is equal to the difference between this and the original total value (36,000 – 23,400 = 12,600 €). However, this is not the case with task (07) ‘*Temporary bypass road construction*’; since the length has been increased from 435 to 563 m, therefore, the cost will be 4,442 Euros instead of the original 3,432. Notice that task (14) ‘*Pump system*’ whose original cost was US \$374,516 increased to US \$395,434 because it was necessary to look for another supplier of pumps which resulted in higher prices for similar equipment.

Nothing has been done regarding (11) ‘*Electrical wiring*’; therefore there is nothing to report in the second and third areas. Regarding task (10) ‘*Excavation for access trench*’, it is expected to be completed on time and under budget.

Task (09) ‘*Excavation for reservoir*’ has increased from 732 to 900 m³ with the corresponding increase in cost and is complete.

The original estimate for the work is given in the schedule of prices sector in US \$5,231,161. Since in the

‘*Earned to date*’ column there is a value of US \$3,268,759 earned, and considering that the balance of the job amounts to 2,366,180 Euros, the total estimated cost will be 3,268,759 + 2,366,180 = US \$5,634,939. This amount exceeds the original estimate in 5,231,161 – 5,634,939 = US \$ –403,778 which is the cost overrun.

16.1.4 Computer Updating

Figure 16.10 shows the updating at status date (December 31, 2012) of the project described in Sect. 9.4, which refers to the development and the basic engineering for a light truck and then for the management of civil construction and acquisition and installation of equipment. However, now we assume that the basic engineering is complete and that the construction phase is underway.

At the left the different contractors and manufacturers that have been selected for this undertaking are listed. Duration in months of each activity as well as start and finish dates were calculated by the software and reproduced here, as well as the precedence that was used to build the logic diagram. The last column identifies the different contractors.

At the right is displayed the bar chart in solid bars. The status day, that is the date when the advance of work is checked is shown by a vertical dotted line that corresponds to December 31, 2012. Notice that there are solid lines within the bars; they represent the advance of work at status day.

For instance, check that the task (1) ‘*Civil works*’ is complete, i.e. 100% done. Task (2) ‘*Electrophoresis cell*’ shows a delay since it has not reached the expected degree of advance at that status date. Task (7) ‘*Industrial transformers*’ is ahead of schedule, since it has started even when it was not scheduled to do so, while (8) ‘*Electrical network*’ is on schedule. The second column at the left

Table 16.4 Work breakdown structure for an underground water storm storage system. Contractor's cost report – Schedule of quantities and prices

		Contract # 19 – 117 - 098 Contractor: Hydraulic Projects Corp.					Week ending: January 07, 2012				
			Schedule of prices (BCWS) (Budget)				Earned to date (BCWP)			Forecast to spend at completion	
Bid item	WBS Cost code	Description	Qty	Unit	Unit price (US\$)	Amount (US\$)	Qty	Amount (US\$)	%	Qty	Amount (US\$)
01	1.1.1.1	Mobilization		LS		975,341		975,341	100		
02	1.1.1.2	Demobilization		LS		127,000					127,820
03	1.1.2.1	Demolition of existing constructions	2	Ha	18,000	36,000	1.3	23,400	65	0.7	12,600
04	1.2.1.1	Removal of U/G utilities	1,600	Metre	50.9	81,440	1,000	50,900	62.5	600	30,540
05	1.2.1.2	Relocation of U/G utilities	1,875	Metre	65.20	122,250	347	22,624	18.5	1,528	99,626
06	1.2.2.1	Fabrication of precast concrete boxes	33	Ea	4,641	153,153	11	31,220	33	22	102,102
07	1.1.1	Temporary bypass road construction	435	M	7.89	3,432	563	4,442	100		
08	1.1.2	Paving temporary bypass road	5,830	M ²	4.52	26,352	2,915	13,176	50	2,915	13,176
09	1.2.1	Excavation for reservoir	732	M ³	2,273	1,663,836	900	2,045,700	100		
10	1.2.2	Excavation for trash rack and concrete work	11.25	LS		7,756					7,756
11	1.3.1	Electrical wiring ducts and fixtures	4,200	M	1.44	6,048					6,048
12	1.1	Excavation of access trench	90	M ³	1,095	98,550	75	82,125	83	15	16,425
13	1.2	Placement of precast concrete boxes	6,280	M ³	219	1,375,320					1,375,320
14	1.3	Pump piping	21,500	M	17.42	374,530				21,500	395,434
15	1.4	Main rain water trunk to reservoir		LS	56,923	56,923					56,923
16	1.5	Main rain water trunk from reservoir		LS	78,504	78,504					78,504
17	1.6	Reservoir control centre	1	LS		43,906					43,906
		Underground stormwater storage system				5,231,161		3,268,759			2,366,180

provides different information via icons. For instance the '√' informs that the respective task has been 100% completed; another icon can explain why a start or finish date is not honoured, due for instance to the existence of a '*Start no Earlier than*' constraint. Consider that this is only an example of the information given by these computer programs; obviously this is not the place to discuss them in detail, but certainly there are many more columns that can be added regarding resources, actual dates, WBS, floats, percentage of completion, remaining duration, etc. as well as plenty of different reports.

16.2 Monitoring Installations

In certain construction projects there is a need to install not only equipment but also different components that intervene in the structure, such as rebar for foundations, columns, floors, etc. Therefore, the supply in quantity and in time of these elements is as important as the work itself and must also be controlled. An example is a mountain road project requiring anchoring bolts to reinforce slopes, done with non-tensioned bolts. Installation takes place along with the road construction and it can be controlled as depicted in Fig. 16.8.

16.2.1 Change Orders and Claims

Changing some items from the original plan is a common feature in most projects and it is more the rule than the exception; as a consequence they must be contemplated in our process, and usually they are processed as '*claims*'. Changes may be due to many different reasons, such as amendments, additional requirements, or because, very often the promoter or owner decides to change it, or because something has not been foreseen. As an example, we continue with the stormwater reservoir commented on in Sect. 16.1.3. The City Hall has decided that the system must be able to exchange water with other reservoirs, and then requests the installation of additional pumping equipment and the construction of a transfer duct, which will be built by another contractor. In addition, City Hall Engineering Department, makes a more careful study and decides that 11.25 m² is too much for a trash rack, and then reduces the work to 8.7 m².

There are three change orders to Hydraulic Projects Corp. to be added to its contract number 19 -117 - 098.

Change order 01: Supply two centrifugal pumps (characteristics are detailed in the change order),

Change order 01/02: Install and connect them,

Change order 03: Reduction in the quantity of m³ to excavate for the trash rack.

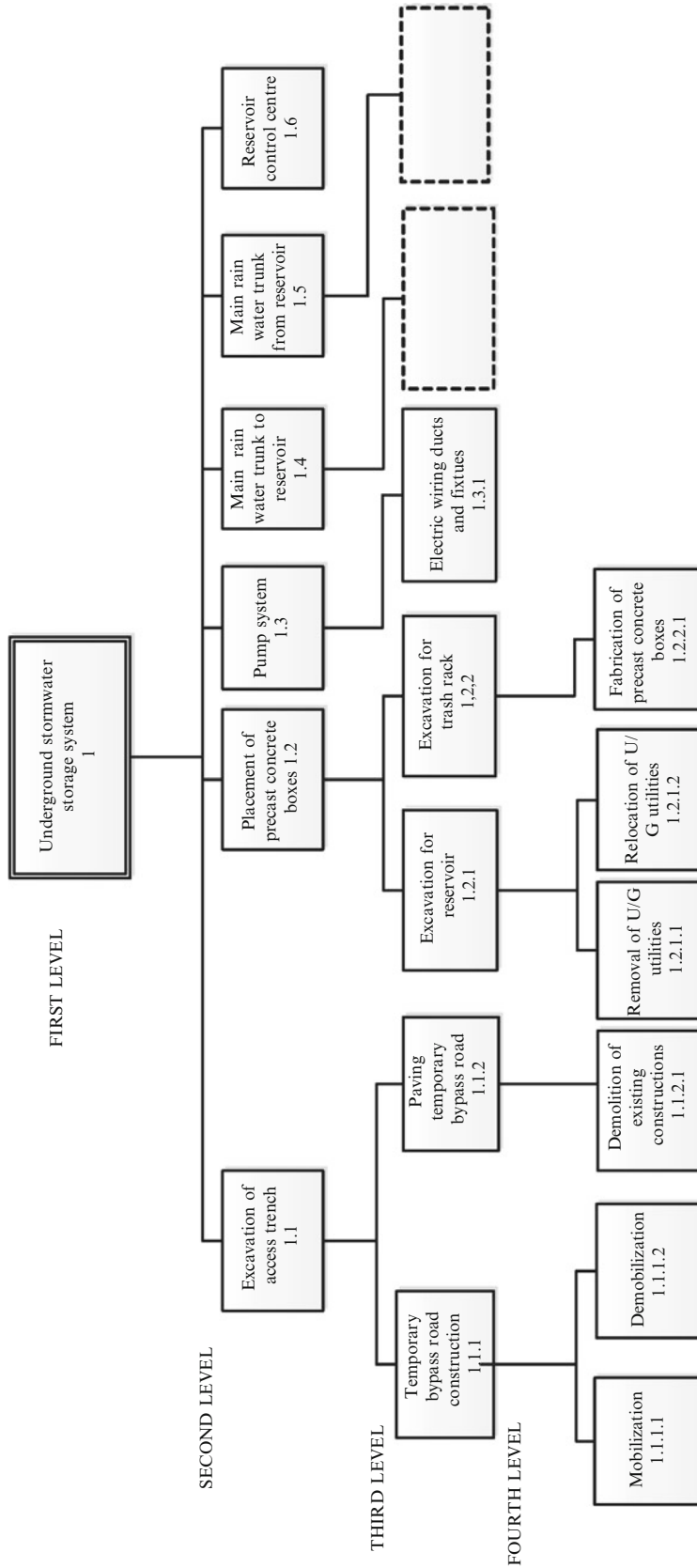


Fig. 16.9 Work Breakdown Structure – Contractor’s cost report in an underground stormwater storage project

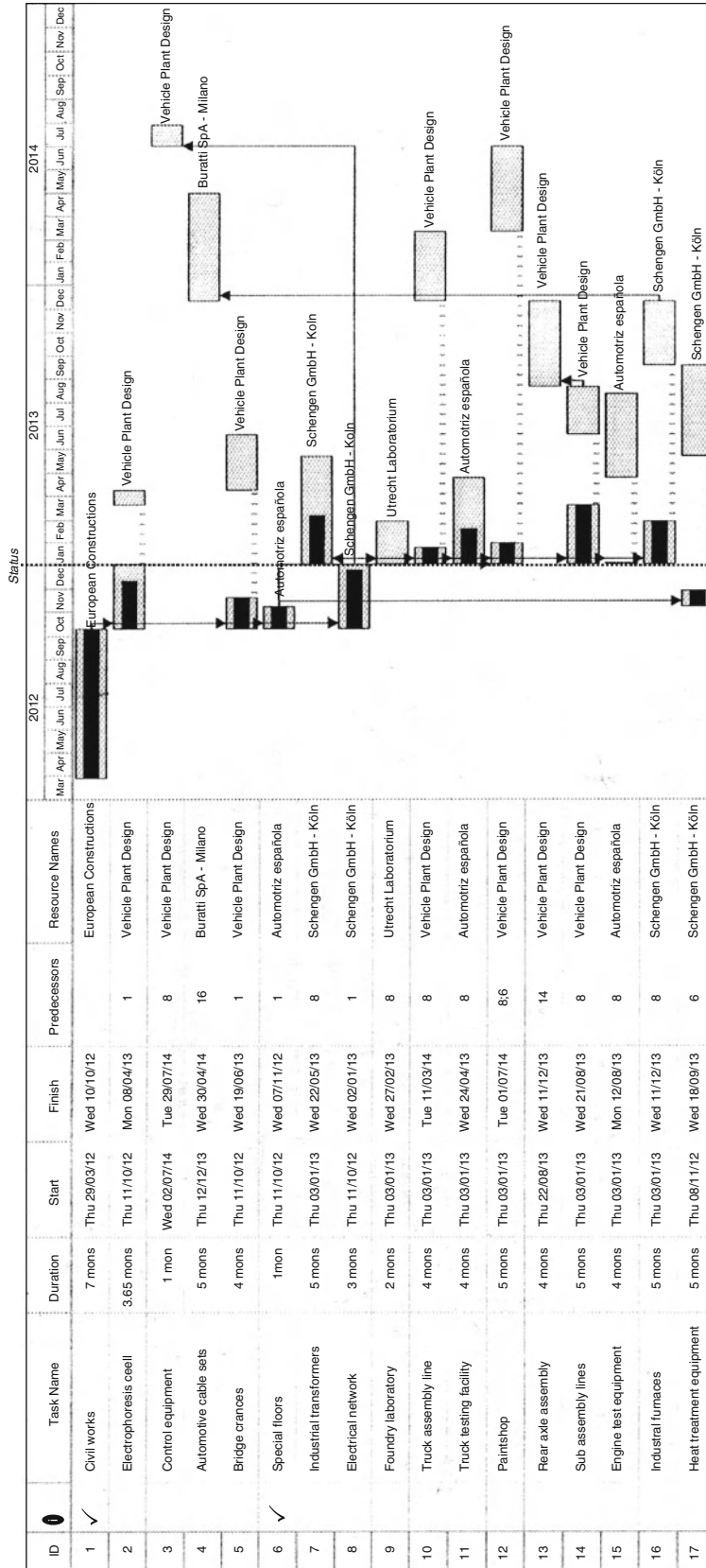


Fig. 16.10 Updating the schedule – Construction of an automobile plant

Table 16.5 Incorporating change orders

Contract # 19 -117 - 098 Contractor: Hydraulic Projects Corp.							Week ending: July 04, 2012				
			Schedule of Prices (BCWS) (Budget)				Earned to date (BCWP)		Forecast at completion		
Bid item	WBS cost code	Description	Qty	Unit	Unit price (US\$)	Amount (US\$)	Qty	Amount (US\$)	Qty	Amount (US\$)	
		Revision of contract price									
		Change order number 01									
		Supply 2 centrifugal type water pumps with: Flow: 12m ³ /h Head: 45 metre Power: 1.5 HP 230 volts	2	Ea.	105.80	211.60			2	211.60	
		Change order number 01/02									
		Install two water pumps and piping connection	2	LS	524	1,048			2	1,048	
		Change order number 03									
		Excavation for trash rack and concrete work	11.25	M ²	LS	3,825				3,825	
						Total	5,188,301	Total	3,268,759	Total	2,298,697

Consequently, in the first case new expenses are introduced and added to the original budget. In the third change order, there will be a reduction in the number of m³ excavated with the corresponding reduction in the total cost. These changes have to be registered, and the same form as depicted in Table 16.4 'Contractor's cost report' can be used (see Table 16.5). Therefore the costs and particulars of the additional work have to be included and added to the original budget, and the old one deleted, although keeping data if some work has been performed. It can be seen that the cost at completion has increased by change order 1 and 2 but decreased by change order 3.

The final cost, considering these change orders, amounts to 5,628,337 that is, with an overrun of 397,176.

16.3 Controlling Time and Costs – Finding Possible Causes for Deviations and Proposing Solutions

There are of course thousands of causes for delays and cost overruns, and it is also true that the nature of the project has a direct incidence, consequently it would be naive to think of writing a 'prescription' to remediate, ameliorate or reduce these variations. However, there are some procedures than can be followed, such as:

1. Find out if one of the delayed activities is in the critical path. If one of them is, then the mentioned delay is already affecting the whole project completion date. If it is not, observe the floats and see if they permit an extension of the task duration or for the start date without compromising the final date.
2. Look for the reasons for this cost overrun and delay. Most probably its source can be identified, and in this case, check if the same situation may occur in another task even if it is of different nature, that is, not necessarily repetitive. For instance, it could be that unusual weather, much colder than expected, is delaying the hardening of concrete, and in that case consider that most probably this phenomenon will also affect tasks ahead, therefore, make provisions to deal with this problem.
3. It could very well be that greater costs are associated with additional work that was unforeseen. An example would be, during an excavation, damage to a water trunk that nobody knew existed; and if it is in service, has to be repaired, usually very urgently. The problem could be complex, because it could mean that for a while a part of the population of the district will be deprived of potable water, which most probably will call for a temporary duct to be installed while the permanent one is prepared and connected to the water network.

4. In an actual project for widening an avenue there were delays from the very beginning because neighbours, especially those with commercial business on the avenue, tried to block the project, contending that it would hurt sales, due to a stop in traffic of cars and people. The solution in this case consisted in assuring merchants and other interested parties that the disruption will be greatly reduced as a result of modifying the construction method, by working on one side of the avenue at a time, instead of on both simultaneously as originally planned; also City Hall proposed to compensate merchants for potential losses by reducing property taxes in affected properties during 1 year.
5. In another project a potential delay was foreseen because large equipment had to be transported from another country along 1,700 km of roads, some of them in hilly country. The solution was to modify the transportation task by shipping the equipment to a port near the job site and then trucking it.
6. Sometimes unforeseen delays and increased costs are due to changes in the project either by technical reasons or, as often happen, because the promoter, owner or client wants something else that was not originally considered. In this case the additional task must be added to the project schedule and a new calculation done, which most probably will generate new dates and new critical activities, perhaps converting some critical activities to non-critical and vice versa.

There is hardly a project without changes during its execution, and as mentioned, most probably all of them will alter the schedule; therefore a tight control is paramount.

16.3.1 Graphical Information of Work Done

Figure 16.11 depicts the cross-section of the construction of a hydro electrical facility, in this case the foundations for turbines and a turbine hall. The light shaded sections correspond to walls to be built according to the approved drawings. The darker shaded sections identify those built (concrete poured), with their corresponding drawing identification code (which can be WBS coding).

In the upper right-hand side information is given regarding how much concrete was poured last week, how much the present week, and total to date, as well as percentage of completion. This type of report is very helpful, since documenting work done week by week, or in some other interval, constitutes a graphical history of the project which is useful at present and invaluable in the future, and can also be used advantageously in the weekly meetings with the contractor and owner. It does need to be at scale, is just a sketch, and, can be easily done once using drawing software, and then updated every week. In this case the software used was Freelance®. Once the initial drawing is made it takes a few minutes to update.

Figure 16.12 depicts another graphic report for the construction of a roasting and quenching area for a metallurgical project. Notice the differences in the two parallel constructions regarding the work performed during the week the report refers to. In this case drawing numbers and darker shades illustrate the work done.

16.3.2 Learning Curve

The learning curve is a plot that shows how productivity rises as a consequence of a task or series of tasks many times repeated. In general, it measures production against man-hours, or, like in manufacturing, it can compare units produced against cost.

The learning curve does not measure the skills of people, since it is assumed that the personnel working on a certain task has the necessary experience for the job, i.e. this curve does not indicate or measure expertise; it reflects productivity derived by learning and improving the execution of a repeated task, which could imply less waste, better finishing, higher speed, etc. Therefore, if a Tunnel Boring Machine (TBM) is boring a subway tunnel, the learning curve measures the gained experience related with the operation of the equipment in this environment, which translates not only in the necessary skills to operate such a complex equipment, but also in the appropriate selection of the cutting heads (according to the type of rock, the removal of material from the excavation, the disposal of this material, the supply of electric energy, etc.). Consequently, there is a relationship or ratio between man-hours used and amount in cubic meters of rock removed, say per day, although this is not a direct or linear relationship but a power curve. Experience shows that each time the accumulative time for doing a task doubles, the output regarding the last value decreases in a constant percentage.

Table 16.6 reports the number of man-hours/m³, of rock removed in boring this tunnel. Observe that when the number of weeks doubles, that is 1, 2, 4, 8, 16, the quantity of man-hours/m³ decreases.

From this data Fig. 16.13 can be built, which is the learning curve. The ratio '*man-hours/m³*' in ordinates and '*time in weeks*' in abscissas is used. Values for the construction of this curve have been obtained from the contractor's weekly reports. Successively doubling the number of weeks it can be observed that:

In the **first** week ending September 27 this ratio is 34. By the end of the **second** week it is 21, for the **third** it is 17, and so. Therefore the reduction between the first and second week is $21/34 = 0.62$.

For the **fourth** week it is 14.5, as a result its relationship with the **second** week is $14.5/21 = 0.69$.

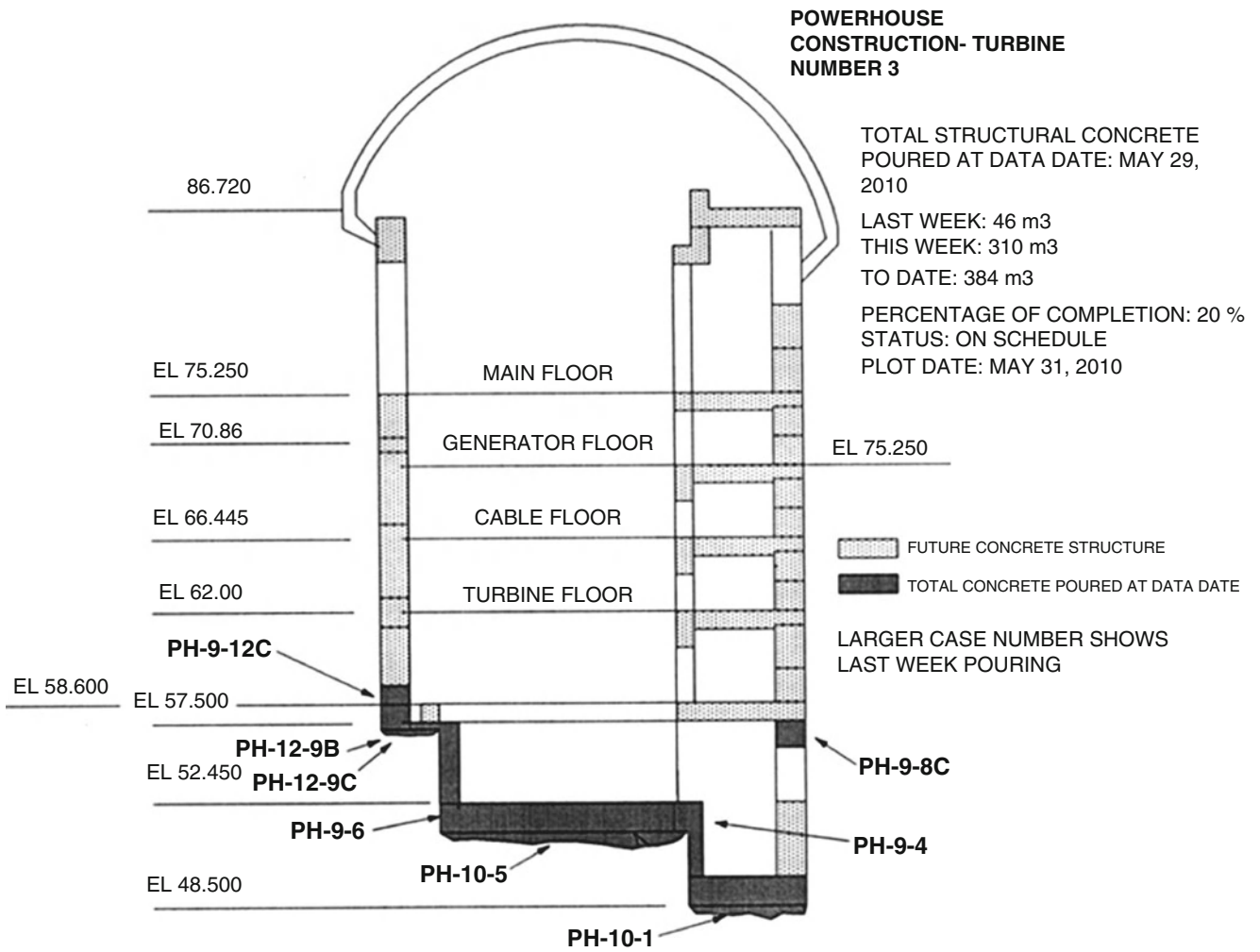


Fig. 16.11 Graphic information on work done for the foundation for a Pelton hydroelectric turbine – Observe also the tailrace, or discharge channel from the turbine

By the end of the **eighth** week the ratio is 8, therefore, its relationship with the **fourth** week value is $8/14.5 = 0.55$.

Finally, by the end of the **sixtieth** week the ratio is 5.35. Its relationship with the ratio in the **eighth** week is $5.35/8 = 0.67$.

The average reduction is then 0.632.

In Fig. 16.13, the learning curve shows an irregularity in the week ending November 1; in analyzing the reason, it was found to be caused by a vein of rock category B while the balance of the excavation was of category A, and that produced a change in the operation, thus decreasing productivity.

In order to get analytical results, it is customary to determine if the learning curve format is similar to other well-known trend types such as linear, logarithmic, exponential, power, etc. In other words it is necessary to 'adjust' the learning curve to some of the above mentioned. In this case the learning curve adjusts very well, even at first sight, with a 'power curve', that is the curve in whose equation one of the variables is raised to a certain power. Using Excel features and with the actual values from the

contractor, one obtains the power curve or 'trend line' depicted dashed. This trend line is the geometrical loci of the statistical averages from a set of data.

The mathematical expression of this line, easily obtained with Excel, is 'y' (Ratio) = $33.63 x^{-0.635}$, where 'x' is the number of weeks.

The exponent in the variable 'x' (-0.365) expresses the average reduction factor from one accumulated week to its double. Notice that this value coincides with the value found above (-0.362) when comparing ratios. It is necessary to consider that normally a trend line does not coincide exactly with the learning curve, and this case is not an exception. Look for instance at data on November 01, where the equation says that it should be

$$y = 33.63 \times (6)^{-0.635} = 10.77.$$

which is smaller than the actual value of the corresponding ratio which is 15.2, therefore there is a discrepancy between

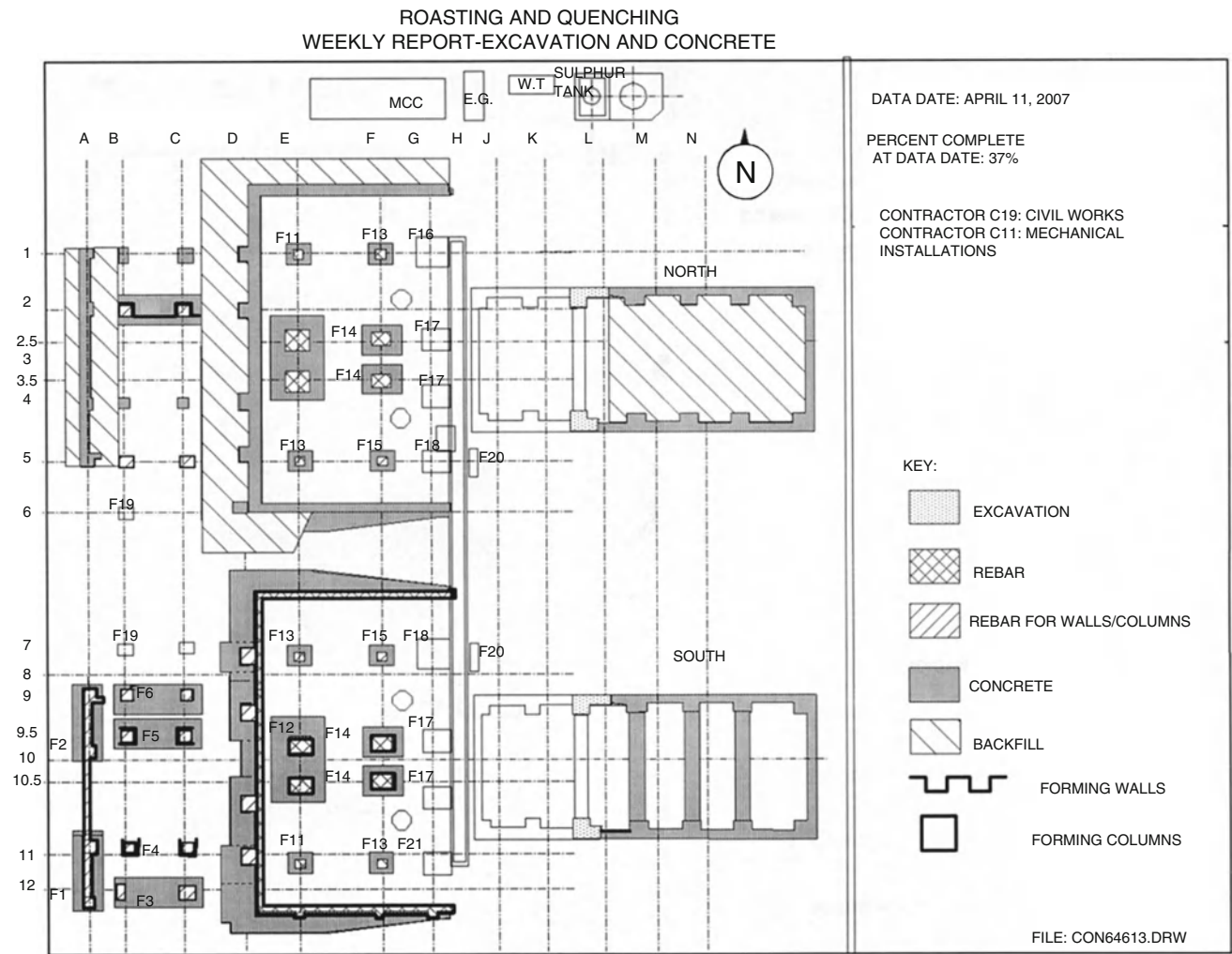


Fig. 16.12 Roasting and quenching area

Table 16.6 Ratios between man-hours/m³ of rock excavated and time

<u>1</u>	2	3	<u>4</u>	5	6	7	<u>8</u>	9	10	11	12
Sep. 27	Oct. 07	Oct. 11	Oct. 18	Oct. 25	Nov. 01	Nov. 08	Nov. 15	Nov. 22	Nov. 29	Dec. 06	Dec. 13
34	21	17	14.5	12	15.2	10.5	8	7.5	7.6	7.3	6.2
13	14	15	<u>16</u>	17	18	19	20	21	22	23	24
Dec. 20	Dec. 27	Jan. 03	Jan. 10	Jan. 17	Jan. 24	Jan. 31	Feb. 07	Feb. 14	Feb. 21	Feb. 28	Mar. 07
5.6	5.5	5.4	5.35	5.35	4.8	5.25	5.3	5.2	5.3	5.3	5.4

the theoretical value from the equation and the actual one from the contractor; however the final factor is almost the same because only this value differs from the 24 values considered.

There are also, as expected, small discrepancies in other weeks. This is not a fabricated example, but an actual one, and it is really amazing to check how the two curves fit. Look also at the R² value which is the square of the correlation coefficient between ratios and time; this is a high value

which shows a very good relationship between ratios and time – although it does not necessarily mean the existence of a cause and effect relationship between both – but that confirms the graphic fitting of both curves.

Now a question arises. What is the use of the learning curve?

A contractor, having learned from his experience in similar activities in other projects, how to predict the productivity of a working team, for instance a carpenter’s crew, can

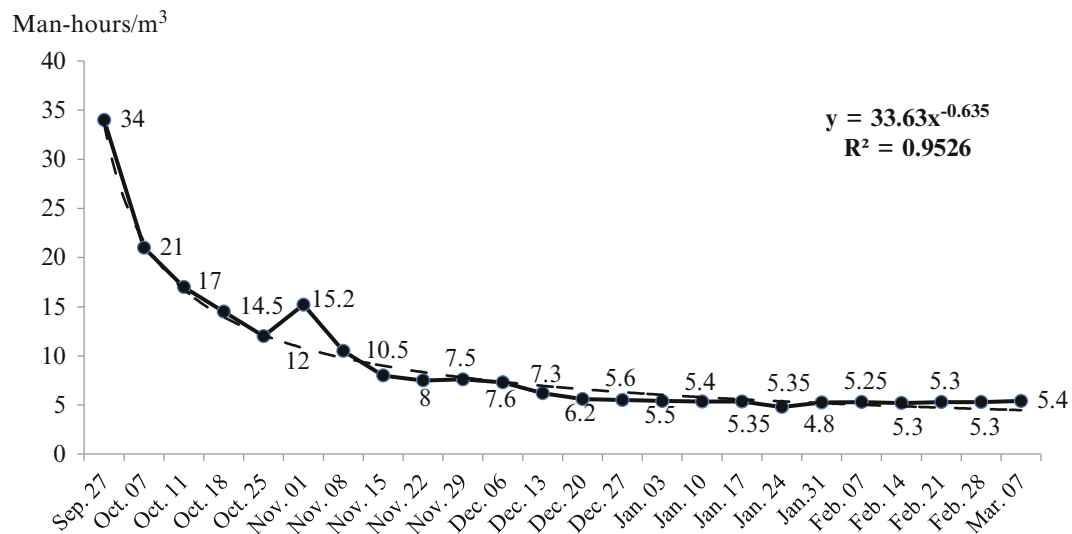


Fig. 16.13 Learning curve depicting relationship between man-hours and cubic metres of rock in boring a subway tunnel

use this information to adjust his costs in a competitive bidding. For a manufacturing project this device can help in determining the future actual cost. As a matter of fact the learning curve was discovered by the Boeing Corp, in the 1930s, when they realized that the cost to build new airplanes was highly predictable (Anthers 2001). He also adds that “Indeed, the equations underlying learning curves can be an essential part of cost estimating, pricing and staff planning”.

The learning curve is very useful in projects such as building a housing development of hundreds of houses. Since the work of excavation for foundations, concrete columns, floors, electricity, plumbing, etc., may be repeated hundreds of times, the average cost for each of them could be far away from the initial estimated cost just by computing materials (which do not change) and man-hours, which do change through the learning process.

16.4 Controlling Manpower (MP) and Man-Hours (MH)

16.4.1 Initial Conditions

In addition to schedule and costs, labour is another of the areas that needs controlling. The constructor must submit with his proposal a schedule with details of quantities and categories of workers assigned to the project, in a similar way as the schedule for activities. When monitoring a project through updating the Gantt chart, it is common to detect delays or advances in certain periods, but it says nothing about the causes for those deviations from the original

planning. Controlling labour can help in understanding the reasons for differences, either positive or negative. Labour is usually monitored from two different points of view namely, (a) the quantity of personnel affected in comparison with that planned, and (b) the efficiency of the team, that is the ‘Labour Performance Factor’ (LPF).

16.4.2 CASE STUDY: Man-Power Control in the Construction of a Chemical Plant

An example is proposed concerning the construction of a chemical installation working with ore which is roasted to drive sulphur off.

16.4.2.1 Contractor’s Man-Hours (MH) Schedule

Figure 16.14 shows two areas.

Left: Data from contractor,

Right: The Gantt chart and the S-curve, or man-hours baseline.

Observe that there is a blend of units, tons, m² and MH; weights are assigned to each task, which is done by calculating the ratio between MH required for each one (in column 4), and the total MH for the whole project.

The corresponding scheduled or planned S-curve in MH is shown at the right in a black dashed line. Further on, during execution of the work, quantities actually installed are supplied by the contractor from his monthly estimate of work done, also shown in the same report in column 7, and the corresponding S-curve depicted in a double dashed line up to the status date (December 31st). Please notice that advance of work in the Gantt chart is not indicated here.

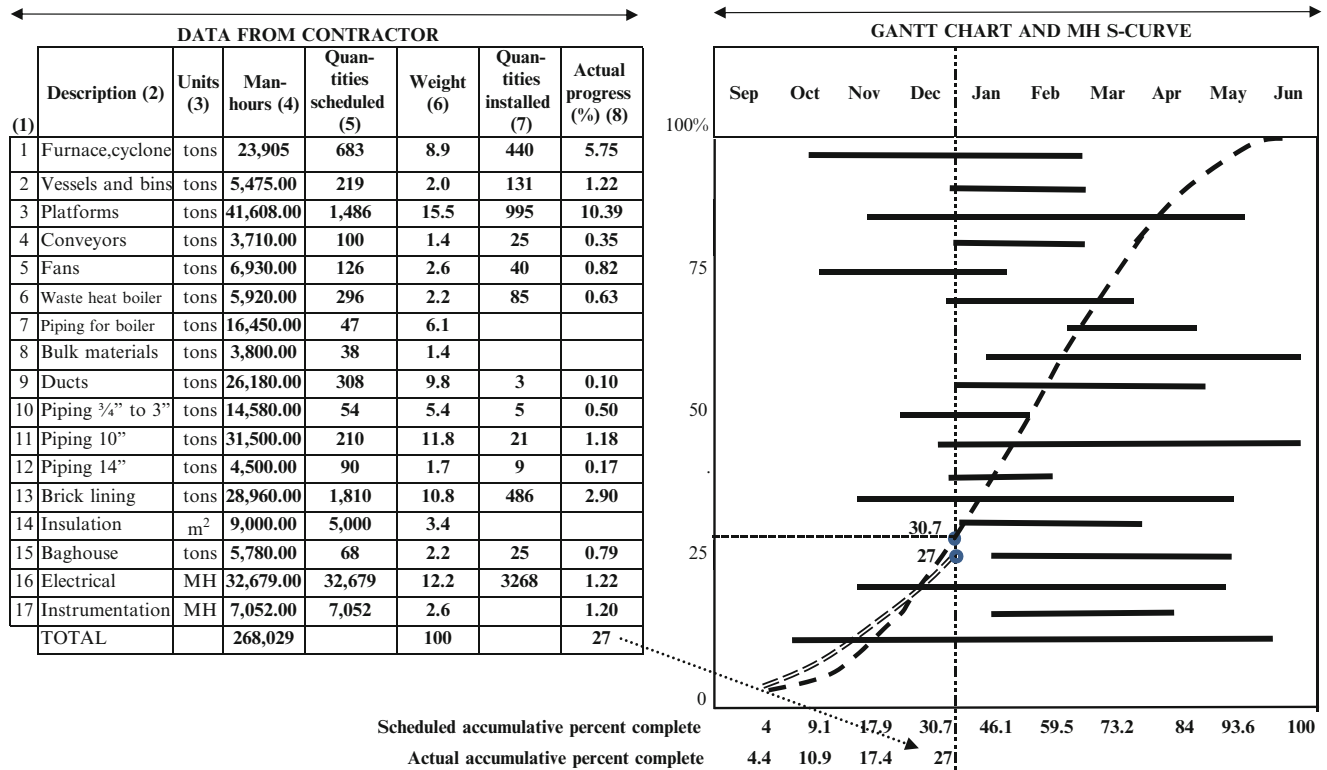


Fig. 16.14 Gantt chart and S-curve – Man-power control in the construction of a chemical plant

16.4.2.2 Measuring Project Advance

Now it is possible to measure at status date the advance of the project; for instance taking as an example task (1) ‘Furnace and cyclone supply and installation’:

$$\begin{aligned}
 &= \frac{\text{Quantities installed}}{\text{Quantities scheduled}} \times \text{Weight} \\
 &= \frac{440\text{tons}}{683 \text{ tons}} \times 8.9 = 5.75. \tag{16.6}
 \end{aligned}$$

This procedure is followed for each task, and the total progress of work at status date is the summation of these values, which in this case is 27% (bottom of column 8). This quantity is also placed at the bottom of the figure in the December column. In so doing the last two rows show both the cumulative schedule advance and actual cumulative advance.

16.4.2.3 Man-Hours Breakdown Schedule

Normally, the contractor also submits his man-power estimate broken-down in both trades (or else manual and non-manual), and months, and corresponding man-hours as depicted in Table 16.7. This table gives for the last month (June) the same value shown at the bottom of the fourth column of Fig. 16.14.

Actual Man-Hours Breakdown

Table 16.8 illustrates in the same detachment actual man-hours spent. Their percentage at each month is in row K ‘Total Labor Percent Complete’, which is the ratio between actual man-hours spent and the total. That is, for the first month it is

$$\frac{11,800}{268,029} = 0.044 = 4.4\%.$$

Theoretically, in December, these percentages should coincide with the advance of work, but there is a deviation since advance of work is 27% while scheduled as 30.7% (Fig. 16.14).

This difference indicates that man-hours spent are behind schedule as seen by comparing the two S-curves. Notice that the opposite happened at the beginning of the plan when actual man-hours spent were ahead of the plan.

Man-hours are computed based on an 8 h/day shift per worker, working 5 days/week, and 4.10 weeks/month. Table 16.8 depicts actual MH values up to December.

16.4.2.4 Labor Performance Factor (LPF)

It compares the MH estimate with actual values and work done. To compute the LPF the following formula is used (example for December).

Table 16.7 Scheduled man-hours base line – Man-power control in the construction of a chemical plant

	September	October	November	December	January	February	March	April
A. Non-manual: supervisors	6	8	13	19	23	20	20	16
B. Manual average	60	76	131	191	229	200	204	161
C. Total (A + B)	66	84	144	210	252	220	224	177
D. Direct labour man-hours	10,721	13,669	23,587	34,308	41,276	35,916	36,720	28,947
E. Cumm. man-hours	10,721	24,390	47,977	82,265	123,561	159,477	196,197	225,144

Table 16.8 Actual man-hours spent – Construction of a chemical plant

	September	October	November	December
F. Non-manual: supervisors	5	2	2	12
G. Manual average	54	85	85	117
H. Total (F + G)	59	87	87	129
I. Direct labour man-hours	11,800	17,400	17,400	25,800
J. Cumm. man-hours	11,800	29,200	46,600	72,400
K. Total labour percent complete	4.4	10.9	17.4	27.0
Labour performance factor (LPF)	1.00	0.94	1.32	1.17

$$\frac{\text{Scheduled MH (from Table 16.7) (row D)} \times \text{Actual percentage (in decimal) of completion (from Figure 16.14)}}{\text{Actual MH (from Table 16.8) (row I)} \times \text{Scheduled percentage (in decimal) of completion (from Figure 16.14)}} \quad (16.7)$$

$$= \frac{34,308 \times 0.27}{25,800 \times 0.307} = 1.17$$

Some sort of allowed variance must be contemplated. For instance it can be established that $0.9 < \text{LPF} < 1.10$ is normal, and no actions should be taken.

16.4.2.5 Analysis of the LPF

According to Fig. 16.15, it can be seen that:

In September there is an increment of 9% in Progress as well as an increment of 9% in MH, and therefore the ratio is equal to 1. It means efficiency.

In October there is an increment of 20% in Progress as well as an increment of 27% in MH. This increase in MH exceeds the increase in Progress, and therefore the ratio goes down to 0.94. It means less MH efficiency or a low or conservative MH estimate.

In November there is a decrease of 3% in Progress, as well as a decrease of 36% in MH. The decrease in MH largely surpasses the decrease in Progress. The ratio sharply goes upwards to 1.32. It means an improvement in efficiency or a very high MH estimate. This high value calls for an investigation.

In December, there is a decrease of 12% in Progress, as well as a decrease of 25% in MH, and the ratio improves to 1.17. It means that MH has decreased but much less than Progress. It means that probably efficiency improved, and/or

maybe there are other reasons for the decrease in Progress (could be for instance bad weather).

There is an aspect that must be considered and have the contractor alerted and it is the general trend upwards of the LPF

16.4.3 Man-Power and Man-Hours

Normally in his proposal a contractor establishes the number of people or manpower (MP) that will be working in the project. It is also necessary to learn about the distribution of said personnel in the work as well as its breakdown in its different trades. For this reason the contractor normally submits its manpower figures as shown in Table 16.9.

Once the work has started he produces a similar document but with actual manpower, as shown in Table 16.10.

Figure 16.16 makes a graphic comparison of scheduled and actual manpower throughout the project life. The analysis of this histogram shows that, in general, the contractor did comply in excess with the roster of his workers since the actual figures are always, except for the second month, higher than the personnel scheduled. This positive discrepancy is also summarized in his daily average with actual average of 46 against a scheduled average of 36.

Fig. 16.15 Labor performance factor trend – Construction of a chemical plant

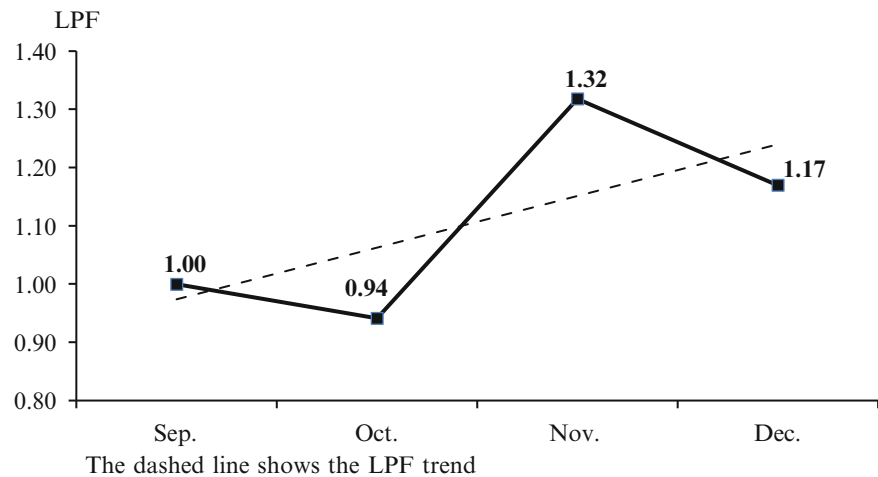


Table 16.9 Scheduled man-power breakdown, distribution and daily average – Construction of a chemical plant

	March	April	May	June	August	Average
Staff	1	2	3	3		1.50
Craft						
Laborers		4	1	3	2	2.17
Cement finishers				2		0.33
Carpenters			6	3	4	2.17
Operating Eng.		3	13	22		11.17
Surveyors			1	1		0.33
Mechanics	102	7				18.17
Total craft daily avg.(Sch.)	102	14	21	31	6	36

Table 16.10 Actual man-power breakdown, distribution and daily average – Construction of a chemical plant

	March	April	May	June	August	Average
Staff	1	2	3	3		1.50
Craft						
Laborers		4	1	3	2	2.17
Cement finishers				2		0.33
Carpenters			6	3	4	2.17
Operating Eng.		3	13	22		11.17
Surveyors			1	1		0.33
Mechanics	102	7				18.17
Total craft daily avg.(Sch.)	102	14	21	31	6	36
Total craft daily avg.(Act.)	120	11	31	42	10	46

A similar analysis can be performed for man-hours (Table 16.11).

Table 16.12 shows the actual man-hours breakdown.

And the corresponding histogram is seen in Fig. 16.17.

Again, the average actual man-hours surpass scheduled man-hours except in the second and third months.

This analysis can suggest different conclusions. For instance if actual man-power surpasses scheduled man-power it could mean that the contractor either estimated a lower man-power and then realized that he would need to raise it to comply with the schedule, or else it could be that efficiency was lower than expected. A similar analysis can be done for man-hours.

Fig. 16.16 Average scheduled vs. actual manpower histogram – Construction of a chemical plant

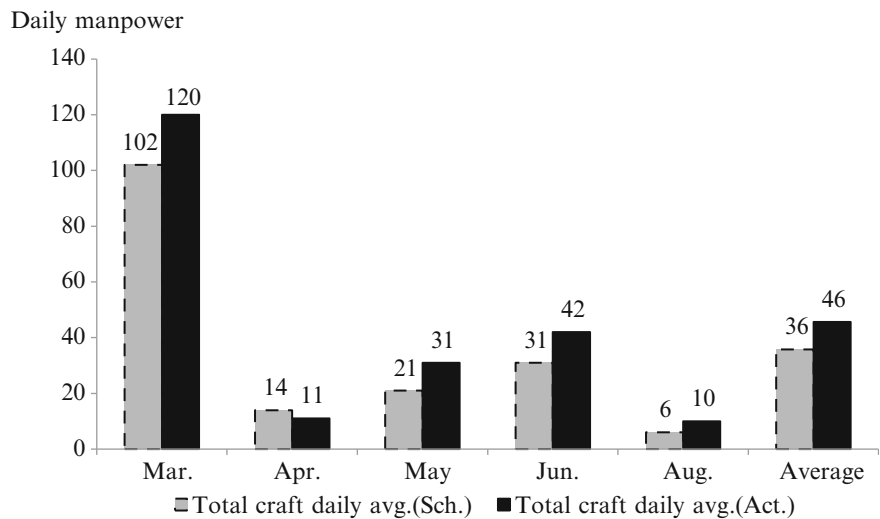


Table 16.11 Scheduled man-hours breakdown, distribution and daily average – Construction of a chemical plant

	March	April	May	June	August	Average
Staff						
	158	624	1,023	502		577
Craft						
Laborers						
Cement finishers		802	259	555	143	387
Carpenters				458		76
Operating Eng.			1,745	687	200	439
Surveyors		521	4,127	6,222		3,029
Mechanics			201	194		66
	17,136	1,050				3,031
Total craft daily avg.(Sch.)	17,136	2,373	6,332	8,116	343	7,604

Table 16.12 Actual man-hours breakdown, distribution and daily average – Construction of a chemical plant

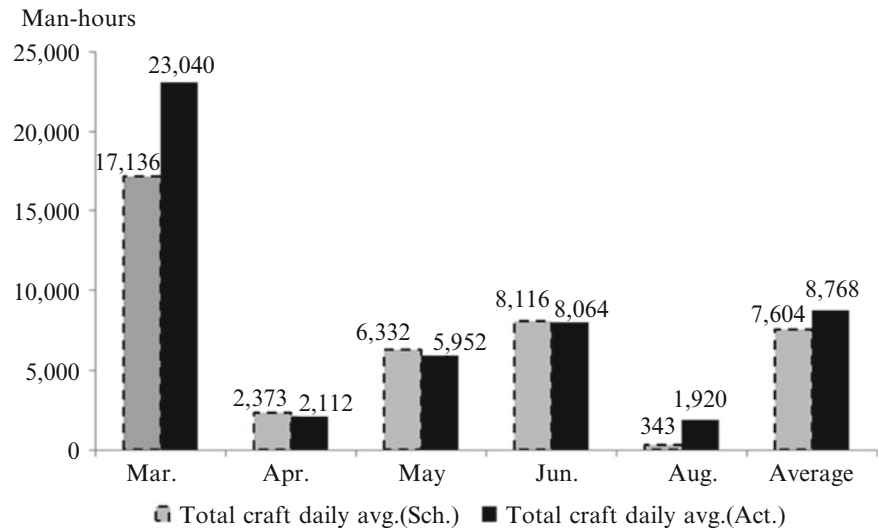
	March	April	May	June	August	Average
Staff						
	158	624	1,023	502		577
Craft						
Laborers						
Cement finishers		802	259	555	143	387
Carpenters				458		76
Operating Eng.			1,745	687	200	439
Surveyors		521	4,127	6,222		3,029
Mechanics			201	194		66
	17,136	1,050				3,031
Total craft daily avg.(Sch.)	17,136	2,373	6,332	8,116	343	7,604
Total craft daily avg.(Act.)	23,040	2,112	5,952	8,064	1,920	8,768

16.5 Combined Labor Progress and Man-Hours Performance Report in an Ore Treatment Plant Project

Table 16.13 shows a report on June 30, 2009, where work progress as well as man-hours are shown together. In this mining project report notice:

1. It considers the following fields: Quantities, man-hours, unit man-hours, earned man-hours and percent complete
2. In Quantities: notice the (4) 'Current budget' and (5) 'Current forecast', as well as (6) 'Forecast' because quantities can change from the original estimate. Also notice columns (7) and (8) for work done to status date, as well as for last week.

Fig. 16.17 Average scheduled vs. actual man-hours histogram – Construction of a chemical plant



3. In Man-hours: Notice the (9) ‘Current budget’ and (10) ‘Current forecast’. It also shows actual MH and earned MH, both to date, in columns (11) and (12).
4. In unit man-hours: Columns (13–16) show ratios. For instance, column (13) indicates ratios between man-hours and quantities installed. Thus, for task (300) ‘Concrete’ the value 6.26 obtained by dividing 92,789 man-hours (column 10), by concrete quantity of 14,844 cubic yards (column 5), means that 6.26 man-hours are needed for each cubic yard of concrete.
5. That was for the budget estimate. The actual value to date is 5.851, from 101,917 man-hours used (column 11) and 17,418 cubic yards of concrete produced (column 7). It means then that actual values are lower than estimated. However, during the last week, 2,219 man-hours were spent in this task (not shown in the table), which produced only 223 cubic yards (column 8); therefore the ratio $2,219/223 = 9.95$ man-hours/cubic yard, indicates a poorer performance for that week.
6. Earned man-hours. Column 17 shows the ratio between actual to-date man-hours (column 11) and earned to-date man-hours (column 12). Considering ‘Piping’ for instance the ratio is $6,939/6,610 = 1.05$, and indicates that man-hours actually used slightly exceeds the scheduled man-hours.
7. Percent complete. This column indicates for each task the percentage of completion. Thus, for task (200) ‘Steel’ for instance, the advance is 59.8%. It shows amount earned (column 12) against estimated (column 9). Since on data date there should have been a total of 75,422 t of steel placed, and only there is only 45,118, there is a considerable delay, or only about 60% has been accomplished.

As can be appreciated these reports breakdown the whole project and gives information about progress on each task as well as performance.

16.6 Cost Estimate at Completion

Estimate At Completion (EAC) is another often used and very important procedure; it gives an estimate of something that owners and companies always want to know, and it is how much the project will cost, or put it in another way, how much money has still to be disbursed or spent until completion. Even when this analysis cannot guarantee a final figure, it can furnish enough accurate information, in accordance with the assumptions considered.

It is logical to think that the estimated cost at completion (EAC) equals work already done valued at actual costs, that is (ACWP), plus work to be done valued at budget cost, that is (BAC-BCWP), and this difference affected by the contractor’s efficiency (CPI) for the balance of the project.

The formula is then:

$$EAC = ACWP + \frac{BAC - BCWP}{CPI} \quad (16.8)$$

where:

$$CPI = \frac{BCWP - BAC}{ACWP} \quad (16.9)$$

However this is true only if the contractor’s efficiency holds, otherwise the EAC will reach another value. Regarding the CPI (Christensen 1994) refers to a research done in USA about 155 government contracts that reached the following conclusions:

1. Past contractor’s performance (CPI) normally replicates in the future;
2. The CPI does not change by more than 10% once the project has been 20% completed. The research found that in most cases it worsens as the project advances to its

Table 16.13 Combined labor progress and man-hours performance report

		PROJECT: ORE TREATMENT PLANT												As of: June 30, 2009			
		CONTRACTOR: MINING DEVELOPMENT CONSTRUCTION COMPANY						CONTRACT: OTP-01									
		LEVEL OF DATA: 1															
Cost code	Description	Unit	QUANTITIES						MANHOURS						Eamed MH To date	Percent complete To date	
			Current budget	Current forecast	Forecast	To date	This week	Current budget	Current forecast	Actual	To date	Forecast	To date	This week			
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
100	Earthwork	CY	334,888	338,638	338,638	715,487	20,749	21,169	27,295	20,040	0.062	0.062	0.062	0.062	0.038	1.36	96.5
200	Steel	Tons	3,424	4,743	4,743	4,743	75,422	78,288	34,012	45,118	16,505	16,505	16,505	13,19	15,086	0.75	59.8
300	Concrete	CY	14,592	14,822	14,844	17,418	90,744	92,789	101,917	91,432	6.26	6.26	6.26	5.851	9.95	1.11	100
400	Mech. Bulks	Tons					127,760	252,132	15,390	8,156						1.89	6.3
500	Mech Equipment	LT	1	1	1	1	174,937	176,373	73,878	51,463						1.44	29.4
600	Piping	LF	124,186	119,186	119,186	18,716	138,023	126,600	6,939	6,610	1.062	1.062	1.062	0.370	1,364	1.05	4.7
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
900	Structural	LT	1	1		1	26,848	30,547	11,115	10,370						1.07	38.6
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1200	Wire	IF	1,202,658	1,199,058	1,199,058	1,199,058	41,035	85,040	82,993	5,000	634	0.069	0.069	0.121	2,530	7.89	0.7

completion, and the EAC tends to get larger when computed using the CPI on short periods (6 months).

After a time the contractor normally proposes an EAC value, which is called 'Latest Revised Estimate at Completion', or (LRE). The main question here is to evaluate how accurate or reasonable the contractor's estimate is. To measure the reliability of his value Christensen suggests using another indicator called 'To-Complete Performance Index' (TCPI) whose formula is:

$$TCPI = \frac{BAC - BCWP}{BAC - ACWP} \quad (16.10)$$

BAC is the 'Budget estimate at completion' and clearly the formula shows a ratio between work to be done and available money to be spent. Since the CPI is a measure of efficiency, this formula indicates the expected efficiency to finish the work. If this TCPI is compared with the CPI and if, for instance TCPI (after a 20% completion) is larger by 10% of the CPI value, it will show that the budget was too optimistic, since the final cost will be greater than the original.

A similar index has been developed but instead of considering the BAC takes into account the contractor's LRE, which of course is more accurate because these estimates are based on past performance and appraisal from the contractor's point of view and experience. The formula (Christensen) is:

$$TCPI_{LRE} = \frac{BAC - BCWP}{LRE - ACWP} \quad (16.11)$$

Again, if $TCPI_{LRE}$ is larger by more than 10% of the CPI value and after the 20% of the job is completed, it is concluded that the LRE is too optimistic.

16.6.1 CASE STUDY: Estimate at Completion Report in a Textile Mill Expansion Project

The YYU Cotton Ltd. textile company decides to increase its industrial capacity by expansion of existing facilities into a new tract of land. Table 16.14 shows the main activities for this new project, which are valued in both hours and US\$ units. Work started in December 2007 and they want to check performance at the end of July 2008. The table shows:

Column 1: Activities to perform,
 Column 2: Activity coding from the Work Breakdown Structure,
 Column 3: Units. Two units are considered: Man-hours and US\$,
 Column 4: BAC: Budget cost At Completion. This was the first estimate made some months before commencing construction,
 Column 5: EAC: Estimate at completion, made on December 1st 2007,

Column 6: BCWS: Budget Cost of Work Schedule, partial, by activity, on December 1st 2007,
 Column 7: ACWP: Actual Cost of Work Performed, partial, by activity, on July 31, 2008,
 Column 8: BCWP: Budget Cost of Work Performed, partial, by activity, on July 31, 2008,
 Column 9: CV: Cost Variance. This is: $BCWP - ACWP$,
 Column 10: SV: Schedule Variance. This is: $BCWP - BCWS$,
 Column 11: BV: Budget Variance. This is: $BAC - EAC$,
 Column 12: EAC: Estimate At Completion (by contractor), and according to the development of work,
 Column 13: PC: Activity Percent Complete. This is: $BCWP / BAC$

16.6.1.1 Discussion

Considering that the project is clearly completed by more than 20%, and using the values from Table 16.14, it is possible to build Table 16.15 for comparing CPIs, for both man-hours and US\$. The last column details the conclusions when comparing if the TCPI and $TCPI_{LRE}$ exceeds by more than 10% the CPI value.

As example, for 'Site preparation'

$$CPI = \frac{BCWP}{ACWP} = \frac{16}{5} = 3.20.$$

$$TCPI = \frac{BAC - BCWP}{BAC - ACWP} = \frac{80 - 16}{80 - 5} = 0.85.$$

Since TCPI is much lower than CPI it appears that the budget was too pessimistic.

$$TCPI_{LRE} = \frac{EAC - CV}{LRE - BCWP} = \frac{75 - 11}{75 - 16} = 1.08.$$

The project has clearly been completed by more than 20%. The last column details the conclusions when comparing if the TCPI and $TCPI_{LRE}$ exceed by more than 10% the CPI value. Since $TCPI_{LRE}$ is much lower than the CPI this also confirms that the budget evaluation was too pessimistic.

16.7 Controlling Work Certificates

Work certificates must reflect work actually done in a period. Checking is done through visual inspection, evaluating the amount of work done and its concordance with approved drawings and with actual measuring when possible. Quantities taken off must match quantities of work reported by the contractor, and this report must be signed by the construction manager or the engineer or architect in charge of the work.

Table 16.14 Estimate at completion report – Textile mill expansion project

								CV	SV	BV	Contractor's	Percent
								Cost	Schedule	Budget	EAC estimate	complete
	WBS	Unit	BAC	EAC	BCWS	ACWP	BCWP	variance	variance	variance	(LRE)	%
1	2	3	4	5	6	7	8	9	10	11	12	13
Site preparation	41013	MH	80	75	72	5	16	11	-56	5	75	20
		US\$	5,085	1,980	4,575	132	1,017	885	-3,558	3,105	4,346	
Excavation	41014	MH	1,057	1,189	1,012	891	423	-468	-589	-132	1,411	40
for columns		US\$	68,483	68,283	65,545	52,178	27,393	-24,785	-38,152	200	81,767	
Concrete	4101	MH	6,680	5,916	6,360	4,359	3,741	-618	-2,619	764	6,789	56
		US\$	426,120	354,069	405,706	261,312	238,627	-22,685	-167,079	72,051	411,453	
Steel structure	4102	MH	7,371	6,651	5,912	2,450	2,064	-386	-3,848	720	7244	28
		US\$	467,335	376,710	374,832	142,947	130,854	-12,093	-243,978	90,625	436,288	
Sewage	4205	MH	15,310	16,652	15,310	13,279	9,645	-3,634	-5,665	-1,342	19,687	62
		US\$	763,153	980,989	763,153	784,678	480,786	-303,892	-282,367	-217,836	1,141,988	
Metalworks	401	MH	1,467	966	1,041	322	293	-29	-748	501	1,496	20
		US\$	91,939	55,845	65,003	18,453	18,388	-65	-46,615	36,094	89,775	

Table 16.15 Comparing estimates at completion from contractor

Activity	CPI	TCPI	TCPI with LRE	EAC estimate
Site preparation	3.20	0.85	1.08	Too high
	7.70	0.82	0.33	
Excavation for columns	0.47	3.82	1.68	Too low
	0.52	2.52	1.71	
Concrete	0.86	1.27	2.14	Too low
	0.91	1.14	2.18	
Steel structure	0.84	1.08	1.36	Moderate
	0.92	1.04	1.27	
Sewage	0.73	2.79	2.02	Too low
	0.61	-13.12	1.94	
Metalworks	0.91	1.03	0.83	Good
	1.00	1.00	0.78	

The report must include all comments about anomalies, defects or poor craftsmanship found. It also must confirm that the work done is in compliance with the building consent provisions that is the permit issued by a local authority for a construction or building work. In some circumstances if there are changes in the project an amendment to the building, consent may be necessary.

It is convenient to develop commodity curves for aggregates. These curves are built as S-curves in a similar way as work scheduled. Data for their construction come from concrete needs according to the pouring schedule and considering the proportion of gravel, sand, Portland cement and other components in the concrete mix.

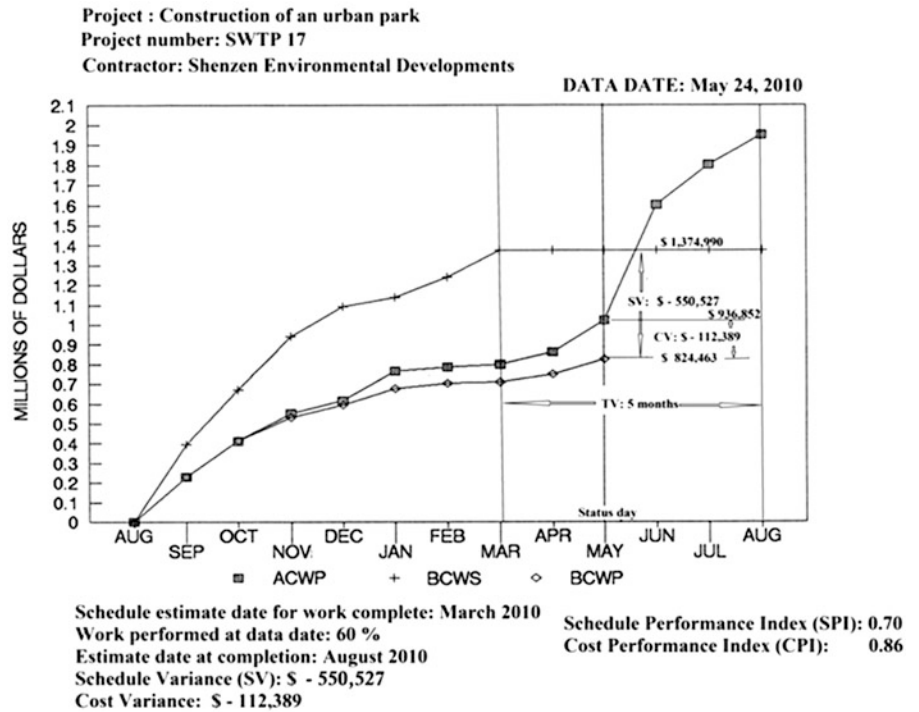
16.8 Controlling Aggregates and Other Inputs

When aggregates are produced on or near the job site, that is, when they do not come by a supplier, it is necessary to control their production since their lack or shortage in fabrication in quantity, and availability in time can stop work. It is possible then to measure the production of gravel and sand but it is perhaps more convenient to measure production of its composite, that is concrete.

16.8.1 CASE STUDY: Construction of an Urban Park

The project aims at the demolition of old and disused structures as well as dismantling a no longer used railway yard, and the construction of a park involving a pedestrian bridge, landscaping, a water fountain and a children’s playground. The project is underway and there is interest in knowing projected data at its completion. Figure 16.18 illustrates the BCWS, BCWP and ACWP curves and the status date is May 24, 2010.

Fig. 16.18 A case: Analysis at status date and forecasting at completion



As can be seen, the project should have been finished by March 2010 (this is known because from then on the BCWS becomes horizontal, that is there is no more work to be done), however at the status date the project is only completed by 60%. All the variances and the indexes are shown in the figure. A reason for this delay is that in March the design was substantially modified, increasing the scope of the project and escalating the costs. The change in design to the original pedestrians-only bridge consisted in including two additional bike lanes, as well as a new LED light system not contemplated before. For that reason, and although the foundations need not be altered, it will be necessary to widen the deck to accommodate the bike lanes, which will provoke a sharp increase in actual work to be performed, which is not reflected either in the BCWS or in the BCWP. The increase in the ACWP is \$112,389. Table 16.16 shows information that can be gathered.

- Recognition of university excellence,
- International papers published by the university professors,
- Books published by university professors,
- Number of different post-graduate courses, for M.Sc. degrees,
- Number of different courses for Ph.D. degrees,
- Time to complete graduate degree studies,
- Etc.

16.10 Controlling Equipment Status

See Project Materials Management – Sect. 10.5.

16.9 Controlling Compliance of Strategic Planning

Monitoring the strategy adopted for the project is performed using indicators or metrics that are particular to each project. For instance, in a university project aiming at reaching in 5 years time a certain number of students and at the same time improving quality, a series of indicators can be used, such as:

- Number of students,
- Number of students enrolled and their trend,

16.11 Controlling Drawings Production

In a large project, there must be a schedule for drawings production which is normally a task developed along with progress in the project. Table 16.18 shows a document used to report status and progress for each drawing.

The starting point for any drawing production is the general schedule for the project, since in there can be found when each task needs a specific drawing. This is the input to column (10) 'Date needed'. The date for commencing the work on a certain drawing can be calculated backwards from the time that it is needed and taking into account all the necessary steps. Thus, in this example, work for drawing CC-192-3, needed by the 'International Builders Inc' (11),

Table 16.16 Information from Fig. 16.18 – Forecasting completion in the construction of an urban park

Work complete as per baseline schedule at data date:	Should have been 100% at May 2010	The work should have finished in March 2010
Estimate date for work complete	August 2010	The work is forecasted to complete in August 2010
Estimated delay at completion		5 months
Budget at completion (BAC)	\$1,374,990	
Change orders and addenda at completion (EAC)	\$112,389	
Revised estimated cost at completion	\$1,487,379	
Modifications	\$406,242	
Estimate at completion based on actual figures at May	\$1,576,999	See Sect. 16.6. The EAC value comes from this calculation $EAC = ACWP + \frac{(BAC-BCWP)}{CPI} =$ $EAC = 936,852 + \frac{(1,374,990-824,463)}{0.86} = 1,576,999$
Work complete as per actual work performed at data date:	60%	
Schedule variance (in dollars)	–550,527	When we compare amount of work performed valued at budget cost, versus work that should have been done as per the base line, that is: $BCWP-BCWS = 824,463-1,374,990 = \$-550,527$. This figure indicates that the project is behind schedule. That it there was a work that should have been done equivalent to \$550,527
Cost variance	112,389	When we compare the amount of work done as per the baseline, versus the equivalent in dollars of the amount of work actually performed, that is: $BCWP-ACWP = 824,463-936,852 = -112,389$. This amount corresponds to change orders and addenda
Schedule Performance Index (SPI)	$BCWP/BCWS = 824,463/1,374,990 = 0.49$	That is the ratio between BCWP at this date and BCWS at this date
Cost Performance Index(CPI)	$BCWP/ACWP = 824,463/936,852 = 0.88$	That is the ratio between BCWP at this date and ACWP at this date

contractor on September 01, has to be started no later than June 12 (6). It is then advisable for the project office to schedule its work using a logic diagram and Gantt chart for their production and resources allocation, as well as considering all the complementary other drawings that are related to a particular one, and which also may belong to a different contractor.

Most probably a large amount of information already exists since drawings were used for take-off purposes (see Sect. 12.1.5), however, the level of detail may be now different and most important, at take-off time probably no attention was paid to availability of resources and links with other drawings. Drawings must be prepared following ISO standards such as ISO 01.100.30 in general and for instance ISO 3766:2003 for special items such as concrete reinforcement.

16.12 Controlling the Issue of Technical Reports

In some projects there is lack of information about how to proceed in some tasks, in the sense that there could be several possible technical options. This case is different from the one examined in Chap. 8 where there were several

possible feasible projects or alternatives to analyze and then selecting the 'best'; here the problem is that it is not known how to proceed because there is no background information and many unknowns. It is the case for instance when the project involves cleaning a highly contaminated river, with its bottom severely polluted with heavy metals. It is surely possible to dredge the river, extract the mud and then treat it; and then, how do we treat the mud?

The answer is unknown and perhaps it is not a bad idea to leave the mud as it is and just work with the future discharges into the river. In this case, the project actions and steps are based on highly technical information grounded in research about how to proceed, risks involved, destination of waste, special health protection measures for workers, etc. Another example is the nuclear electric generation industry, where despite so many years of nuclear electric plant operations, there is still no reliable method in sight for disposal of radioactive wastes, although diverse options have been adopted.

A solution for problems of this nature consists of undertaking a series of studies which require research and tests, which are specific for each situation and whose output can offer guidance about different procedures Table 16.17.

Table 16.17 Drawings production control

Project: Construction of industrial building for ABC Beer Co.										DATA DATE: July 31, 2011		
Department	Drawing #	Associated	Description		Schedule	Forecast	Actual	Percent	Date needed	User	Man hours	Responsible
1	2	3	4	5	6	7	8	9	10	11	12	13
Civil construction												
Drawing #:	CC-192-3		Excavation for foundations for equipment	Start	06/12/2011	07/03/2011	07/03/2011	89	09/01/2011	International Builders Inc.	45	D.K. Wright
				Authorized	06/19/2011	07/23/2011	07/27/2011	100			103	
				First revision	07/17/2011	08/06/2011					5	
				Second revision	07/24/2011	08/16/2011					7	
				Approv. for const.	08/02/2011	08/19/2011					6	
		FD-192-5/B	Embedded instruments	Start								
				Authorized								
				First revision								
				Second revision								
				Approv. for const.			06/19/2011	100				N. Jackson
.....
.....
Mechanical												
Drawing #:	CM-342-17		Bottling line	Start	05/07/2011	05/02/2011	05/06/2011	80	10/12/2011	Brewing equipment Corp.	154	C. Robinson
				Authorized	05/18/2011	05/18/2011	05/18/2011	90			123	
				First revision	06/08/2011	06/04/2011	06/16/2011	35			346	
				Second revision	07/09/2011	07/31/2011	07/31/2011	95			176	
				Approv. for const.	08/13/2011						187	K. Smith
.....
.....

16.13 Factors Affecting Production

In large and repetitive operations such as new road construction, skyscrapers erection, manufacturing, etc., it is of interest to find out the factors, elements or aspects that have the largest influence in production output. By identifying these factors and by determining their relative importance regarding the output, it is many times possible to increase efficiency; i.e. this procedure usually permits enhancement of the whole operation by focusing efforts on those factors that really matter. Statistical analysis can help in this endeavour by linking production, whatever it might be, with the different intervening aspects, and employing statistical regression, as exemplified in the next Section.

16.13.1 CASE STUDY: Determining Factors Affecting Production in Hand Tools Manufacturing

A hand tool equipment manufacturer produces a large array of tools such as ring and open end spanners, rotational tube torque wrenches, pliers, screwdrivers, hammers, and specialty kits and sets. The company uses special steel that comes in different shapes and sizes; the adequate shape is then selected according to the tool to be manufactured.

The raw material is chrome-vanadium steel that undergoes a series of processes that commence in heating and forging, followed by other operations such as annealing, punching, drawing, surface grinding, etc. It is then of interest to know the factors affecting production, which, even when it is the output of a highly automatic process, still depends in a large measure on human action. To identify the factors that have the most affect, regression analysis was used to determine relationships between the dependent variable (y) (output), and four independent variables (x_i), which are:

- x_1 = Percentage of non-manual over manual man-hours, which can be interpreted as a measure of supervision;
- x_2 = Learning curve ratio (cumulative man-hours over cumulative production);
- x_3 = Manual man-hours (all trades);
- x_4 = Manual man-power (labourers and operating engineers);
- x_5 = Rejection of faulty final product, measured in kg.

Multiple log regression analysis was used.

The period under study covers 14 weeks, from October 14, 2009 to January 22, 2010, however, the last 2 weeks in December 2009 were not considered.

The regression equation obtained using multivariate regression analysis is:

$$y = 7.73x_1 - 4.01x_2 + 1.42x_3 + 0.02x_4 - 0.13x_5. \tag{16.12}$$

Table 16.18 Interpretation of sign of variables

Variable	Interpretation of the arithmetic sign
x_1	The positive sign shows that production increases when this ratio increases, i.e. when the relationship between non-manual and manual man-hours rises, which can be read as a measure of effectiveness of supervision.
x_2	The negative sign indicates an inverse relationship, i.e. that cumulative production increases as cumulative man-hours decreases. This is a consequence of the 'learning effect' (see Sect. 16.3.2).
x_3	The positive sign shows that the larger the man-hours, the greater the output.
x_4	The positive sign indicates that the larger the man-hours, the greater the output, which is logical.
x_5	The negative sign shows an inverse relationship, that is production decreases when rejects go up

Notice that the arithmetic signs are correct since they are interpreted as explained in Table 16.18.

Equation 16.12 may be used to forecast production by modifying any or all the coefficients of the independent variables. For instance, assume that supervision – that is variable x_1 , is increased in 1%, by assigning more foremen, who also train workers, to the production line. In this case production will rise 7.73%.

Using a little more statistics – considering the standard deviations of each variable – Eq. 16.12 can also be used to determine the relative influence on production of each one of the variables considered.

Table 16.19 Log of rock blasted in the first 10 working days – Forecasting average daily advance and prediction for a road project

Day	Cubic metres of rock blasted
1	10
2	17
3	28
4	55
5	4
6	6
7	32
8	35
9	50
10	28

16.14 Forecasting Techniques

It is often the case that advances of a repetitive work measured in m^2 , m^3 , tons or whatever other units, follows a sort of sawtooth pattern, that is, a series of highs and lows in production until it levels to a more uniform rate. It is of interest to use these values to predict or forecast future average production. However, when these averages are calculated they are influenced by these early large fluctuations and then their prediction power is low. There are several averaging methods such as the 'Rolling average', the 'Normal average' or using a 'Trend line'. See example in next Section.

16.14.1 CASE STUDY: Forecasting Average Daily Advance and Prediction for a Mountain Road Project

16.14.1.1 Computing the Average

This case applies to the construction of a mountain road with rather steep slopes. Construction begins with clearing the future path and removing vegetation. Then, proper construction commences following the sequence of drilling, blasting, rock removal, and rock disposal, and using loggers, drill operators, shot fires, etc. Table 16.19 shows in m^3 the daily amount of rock blasted.

These values are depicted in graphical form in Fig. 16.19 and for the same period.

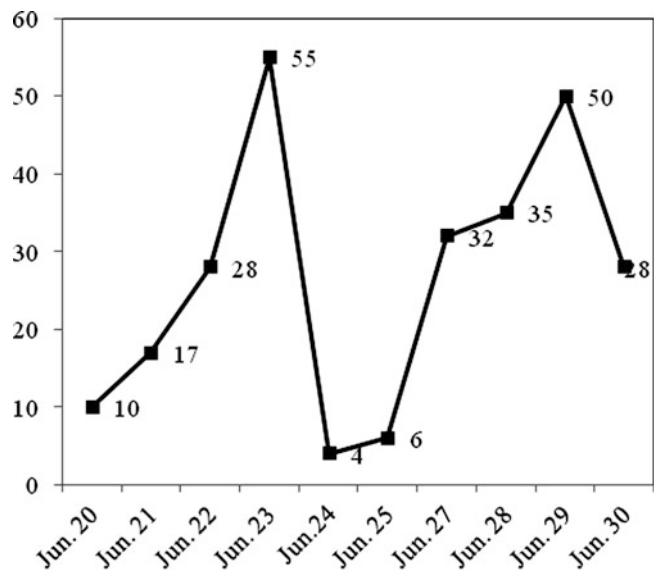


Fig. 16.19 Graphic of rock blasted daily in the first 10 days of operation – Forecasting average daily advance and prediction for a road project

There are several approaches to answer this question, and they rest in using averages as a function of time. Linking the successive averages with a line produces a 'trend line', from which future values can be deducted; the mentioned several approaches refer to different kinds of averages.

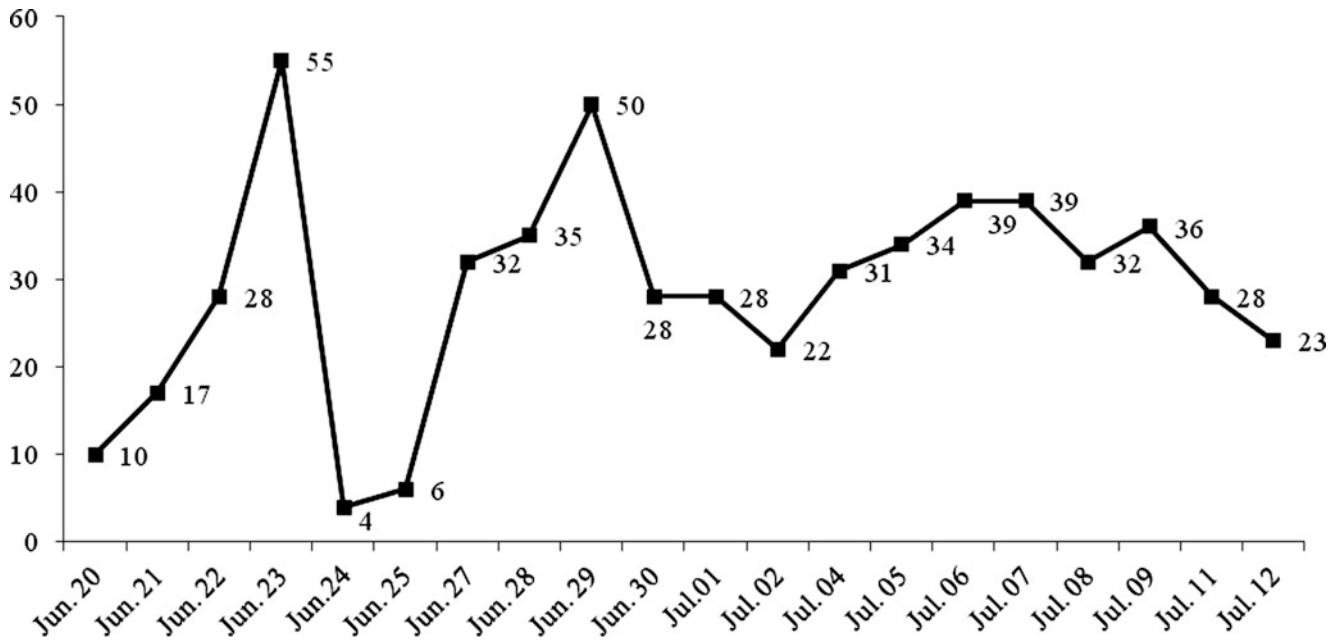


Fig. 16.20 Rock blasted daily in the first 20 days of operation – Forecasting average daily advance and prediction for a road project

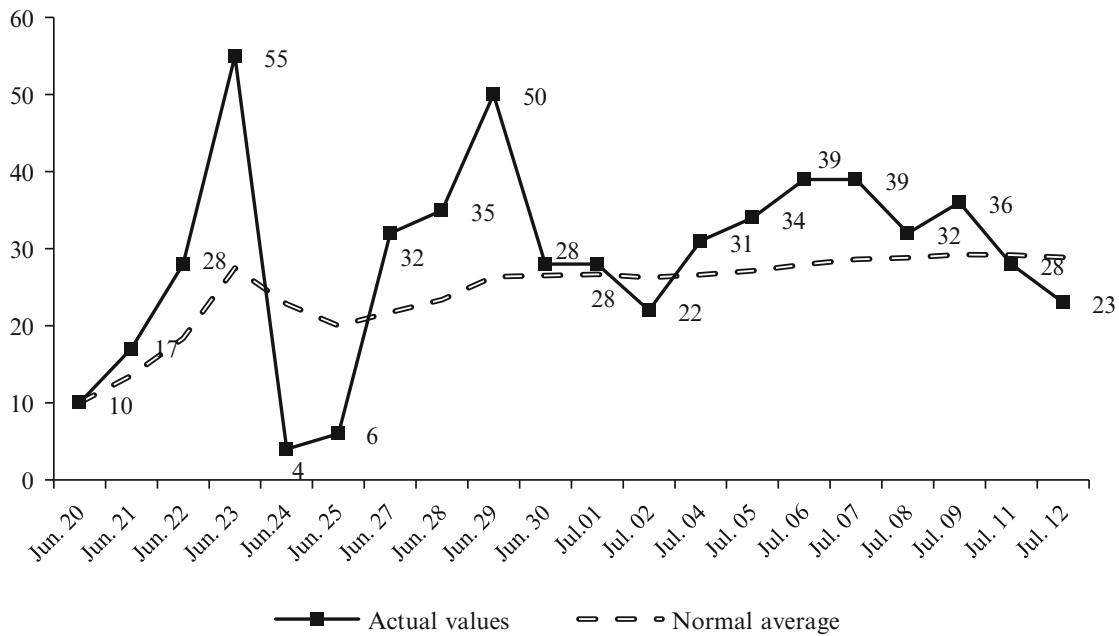


Fig. 16.21 Rock blasted daily in the first 20 days of operation and using normal average – Forecasting average daily advance and prediction for a road project

We will examine two different types, 'Normal average' and 'Rolling average'.

1. *Normal average.* Starting with the first day value of 10 m³/day, and 17 m³/day for the second day, the normal average value is

$$\frac{10 + 17}{2} = \frac{27}{2} = 13.5\text{m}^3.$$

Considering the average at the third day, it will be: $\frac{10+17+28}{3} = \frac{55}{3} = 18.3$, and so on. Ten days later the graphic of rock blasted and removed is depicted in Fig. 16.20.

Figure 16.21 depicts the original data and the normal average for these 20 days

Notice that the normal average trends to stabilization since the 9th day of operation.

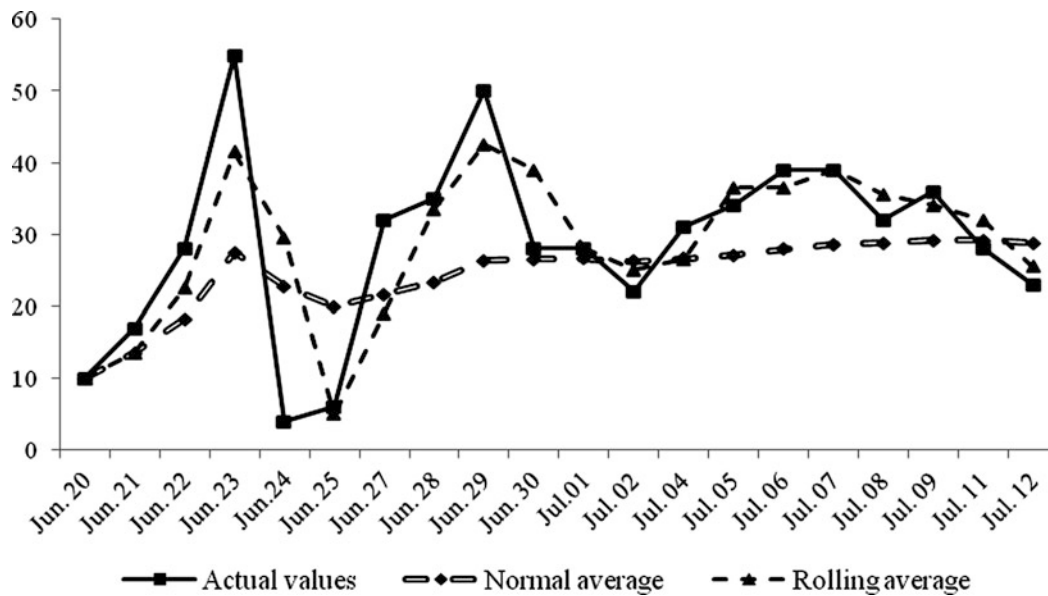


Fig. 16.22 Graphic of rock blasted daily in the first 20 days of operation and using rolling average – Forecasting average daily advance and prediction for a road project

2. 'Rolling average'. It works by breaking the whole period (20 days), into a number of equal sets of days, in this case the set comprised 2 days. The average was found for each set and values of the sets obtained. Figure 16.22 depicts the original data and the normal average for these 20 days. Notice that the rolling average appears to adjust better to the original data, however, it is also not very well defined or stabilized.

Nevertheless, observe that in the 20th day the *normal average* is 28.9 m³/day and the *rolling average* is also 25.5 m³/day, therefore it is expected that future rock blasted production will be around those values, and as a matter of fact, the *actual* value for the 20th day was 23 m³/day.

Which of the two methods is better? It is a matter of applications. The rolling average is more suited for large variations in the short term, and is much utilized in financial analysis because it gives different weights by dropping the old values and favouring the new ones. Normal average instead gives the same weight to all values.

16.14.2 Prediction

For prediction we can use another tool, grounded in 'Regression analysis', i.e. we try to draw a line that indicates the trend and that allows us to make a prediction. This is easily done in Excel. Start with the curve in Fig. 16.20.

1. Double click left button to select the curve with the mouse,
2. Click the right button: a drop out menu will appear,

3. With the left button select the type of curve that at simple sight looks more appropriate. There are six different types.

4. With the left button select 'Equation' and 'R²'.

5. Enter

Excel will display the trend line, its equation and the correlation coefficient 'R'.

In this case the 'Potential' type was selected, and the result can be seen in Fig. 16.23. The equation, depicted in Fig. 16.23 is

$$y_i = 11.59x^{0.3577} \tag{16.13}$$

To check its accuracy choose any day, for instance the 10th, compute the output and then compare it with the actual output.

$$y_{10} = 11.59(10)^{0.3577} = 26.41m^3.$$

This average value (26.41 m³) is close to the actual value for the 10th day which is 28 m³. Then, it is possible to estimate the average production of rock blasted per working day for the rest of the work. Assume for instance that the duration of the work was estimated in 90 days. We now can compute the values for each day which is easily done in Excel applying formula 16.13 and then copying it up to day 90. In this case this calculation gives a range of values of m³ blasted between 34 m³ on the 21st day to 58 m³ for the 90th day. Its average is 46 m³/day.

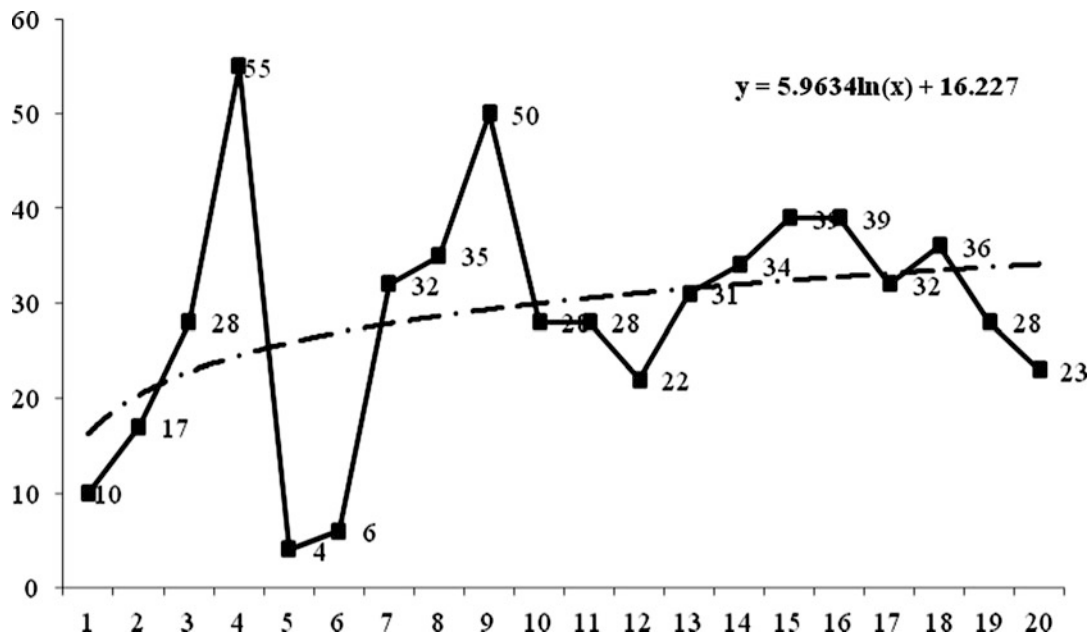


Fig. 16.23 Determination of trend line – Forecasting average daily advance and prediction for a road project

It is realized of course that the improvement from 34 to 58 m³/day is due to better organization, coordination between teams and practice, in other words to the learning process, as commented on in Sect. 16.3.2.

Control also must check the way the product is poured to avoid air pockets (air comes from the concrete truck's agitator drum), by using concrete vibrators. Of course these are only a few of the many controls that can take place for quality in a job site and are cited only as examples.

16.15 Production of As-Built Drawings

Production of as-built drawing proceeds along with the development of the work. For this reason its schedule closely follows the schedule foreseen for construction drawings as well as work completed, and the same type of report format can be used as explained in Sect. 16.12. An example of an as-built drawing can be found in Sect. 17.1.

16.16 Controlling Quality

See Chap. 15.

During the construction period there are many areas where quality control must be exerted, for instance in the proportion of gravel, sand, Portland cement and other components in the concrete mix. In mechanical and metallurgical operations, it is very often necessary to measure steel hardness by the Rockwell hardness method. In heavy construction works the temperature of concrete, especially in hot and very cold places, must be constantly verified in order to assure its quality, as well as to test using one of several methods, the quality of concrete delivered at the job site, that is, fresh concrete, as well as already placed and hardened concrete.

16.17 Controlling Environmental Protection

All projects inevitably produce environmental damage, considering alterations of the soil, the landscape, courses of water, deforestation, air contamination, etc. These impacts are usually taken into account in planning, and nowadays an Environmental Impact Assessment (EIA) is mandatory in projects exceeding a certain size. Normally this assessment produces norms, procedures and work to be done to reduce impacts or to reverse a damaging action, consisting for instance in a commitment to replanting trees, when the existent ones are logged because of a project requirement, and usually replaced in a larger number than those removed.

However, there are a number of 'offences' to the environment that are consequences of the development of the work itself and which are clearly predictable and evitable, and this is the aspect that this section addresses. The following list, admittedly incomplete, enumerates a series of events that occur in many projects and that can be evitable, when there exists a good environmental control.

- Accidental contamination of courses of water, by spills,
- Alteration of wild life. In some extreme cases, it is necessary even to transport animals because their interaction with humans is dangerous for both. For instance, in a

- hydro project in Western Canada, located in a paradisaical mountainous place it was necessary to remove black bears that lived near the camp area; this was done by suspending them individually by a harness to a helicopter and transporting them to a more distant area,
- Damage produced to vegetation and wild life by dust produced by trucks. This is common in mining operations especially of the open pit type,
 - Fuel, oils and toxic spills into the soil. Usually produced by faulty or in bad repair mechanical equipment, such as trucks and construction equipment,
 - In a mining operation there is always the chance of breaks, filtrations or percolation from a very toxic pond, called 'Tailings pond' which stores liquid residues from chemical processes. There have been very serious accidents of this kind, either by percolation into the soil producing aquifer contamination, or because of a break in the dam that forms the pond, thus contaminating unprotected soil or a river, or by poisoning to death birds that drink from the pond. Therefore a strict control is needed,
 - In large construction camps in remote places and with a sizable population of workers, construction of small sewage treatment plants is mandatory, and the effluent usually discharged into a course of water. Project controls must check and keep a log of the quality of said effluent,
 - In municipal projects such as the construction of a new landfill, it is mandatory to cover the bottom of the undertaking (a natural ground depression or an excavation) with high density plastic whose sheets are welded together in order to offer a tight water proof barrier to liquid leachate. However, tests have to be periodically conducted on water in aquifers to detect if traces of leachate have contaminated them. This could happen due to a break in the plastic lining which could be provoked by the garbage load and or the leachate, or by a faulty welding in the plastic sheets,
 - In road construction, especially in mountainous terrain, special care and control must be exerted when disposing

of blasted rock, because usually it is placed on a mountain slope. If there is a river or creek at the bottom, the debris can cause its damming, to say nothing if there are trees in the slope. It is project control's duty to check compliance,

- Temporary pavement is placed in some camps especially in places too dry, or too wet, or with abundant snow. In that case, when the project is finished and the camp dismantled, project control must make sure that the place is restored to its original condition including removing the pavement, and the site left free of garbage and debris.

16.18 Controlling Risk

See Chap. 6.

16.19 Controlling Compliance of Safety Regulations

See Chap. 14.

16.20 Conclusion of This Chapter

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Abstract

Even when the project is finished, at least physically, its closing is important; everything must be neatly ‘tied-up’. This chapter deals with that aspect and briefly analyses different issues that must be considered from the project execution to anything that was related. It is standard practice to summarize at closing time everything that was learned from the project’s execution, information that can serve as a useful future reference for study of the project as an example and for application to other projects.

Keywords

Lessons learned • Communication with client • Client comments • Suggestions • Contractor • Work organization, as built drawings

17.1 The Importance of Proper Closing of a Project

In Sect. 1.1 a project definition was given as “*A temporary, specific and normally unique undertaking aiming at achieving a precise goal, and involves the execution of a series of activities in a certain order. It is temporary because it has a start date and also a finish date*”.

That is, it is an undertaking with normally a precise start and often with a not so precise finish. There are reasons for this sometimes imprecise finishing or closing date, especially if it is a complex project involving many areas of expertise. The main objective of the project, say the construction of buildings, the installation of equipment, the paving of internal streets, the starting of a production line, a mall construction, etc., may have been attained,. But there are likely to be many loose ends, which can take an unpredictable time to be tied up, thus delaying closing out the project. Also, there are instances when legitimately the project continues even when all deliveries have been honoured on time; an example is when the guaranty by the contractor assumes responsibility for hidden defects for a certain period, or for being in charge of operating the plant for a certain period and instructing the client’s personnel.

However, besides these special circumstances, a project has to be handed over to the owner on time, on budget and with maximum quality. As a matter of fact, the closing out of a project is the last of a series of steps throughout the life of the project, because in reality deliverables are usually made on a monthly basis and are the basis for progress payments to the contractor. Does it mean that the project closes with the last deliverable? Not really, since there are a set of provisos to comply with; they are:

- The act of reception or conformity from the owner, that is, the formal acceptance.
- Project review. This is a critical history and review of the project, determining:

Project execution

- How good was the compliance of milestones?
- How good was the estimate of durations?
- If there were cost overruns explain why.
- If the project was delayed specify reasons.
- If there are items pending, define the date of their finishing.
- What lessons were learned?
- Were there many changes in the project? If affirmative, explain why and their origin.
- How accurate were cost estimates?,

- What about project monitoring and control? Were large differences detected in measurements during monitoring? If affirmative, what course of actions were taken?
- What got flying colours?
- What percentage of the project scope has been completed? If the answer is less than 100% explain why.
- What went wrong, if anything?

Communication with client

- Are there any suggestions as to improved reports to the client?
- Were client payments on time?
- Has the client any operational suggestions?
- Did the client interfere with the work? If affirmative, explain.
- Did the client introduce changes? If affirmative, explain consequences in time and funds.
- How good was the relationship with the owner, client and/or stakeholders? Were there unusual problems? If affirmative, explain what and why.
- Mention client's comments and opinions, negative and positive.
- Was it necessary for the constructor to assume financing of his own work longer than expected?

Risks

- How many unforeseen risks appeared and how were they addressed?
- How effective were countermeasures or safeguards taken? Were they worthwhile?
- Were risk effects less than or more than expected?
- What about foreseen risks? Did threats materialize? If they did, were they properly addressed? Were they justified?
- What percentage of the project costs were due to actions to counter risk?

Safety

- How many offences were detected by inspectors regarding workers not using the mandatory safety equipment?
- How many serious accidents occurred and why?
- Were there fires? If affirmative explain why.
- What about machinery protection?

Environment

- Make sure to document that the jobsite has been cleaned and delivered in its original condition. Naturally this applies to construction camps and to dedicated facilities erected for the project, such as kitchens, trailers for accommodation, sewage services, etc., as well as fences, gates, barriers, temporary pavement, etc. If relevant, do not forget to mention environmental improvements made on the site, such as

trees planted, rehabilitated areas, demolition of old structures, a new garden, etc., especially if some of these improvements are beyond the scope of the original proposal. This speaks very favourable about the entity that performed the project management, and probably puts it in the first quadrant of the Kano model (see Sect. 15.8).

- Were there accidental gas releases to the atmosphere, soil contamination with fuel, oil, or chemical products? If affirmative explain why.
- Were there fines imposed on the contractor or workers because of contamination?
- What measures were taken to protect the environment other than those foreseen?

General

- Are there any suggestions regarding changing the way some things were done?

Materials management

- From the organization point of view was there any interference between the Project Manager (PM) and the Construction Manager (CM) generating confusion in the lower echelons?
- How was the relationship with suppliers? Did they comply in time and quality? If the answer is negative, explain what was done.
- Make a list of the best suppliers regarding delivery time compliance and quality, as well as goodwill to solve problems.
- What important results can be summarized from inspecting material on the suppliers premises and on the jobsite?
- What items were rejected and for what reasons?

Personnel

- Were there enough people to manage the project? If the answer is negative, explain areas affected and measures taken to ameliorate the problem.
- Were there problems with personnel? If affirmative enumerate the most important and actions taken to address them.

Drawings and specifications

- Were there problems for delivering on time drawings approved for construction?
- Was the process of preparing drawings efficient?
- What about specifications, special reports and changes?

Contractor/s

- How the general contractor leadership rated?
- How was the contractor performance from the point of view of project management?
- What about equipment efficiency?
- What about labour efficiency?
- What about work quality?

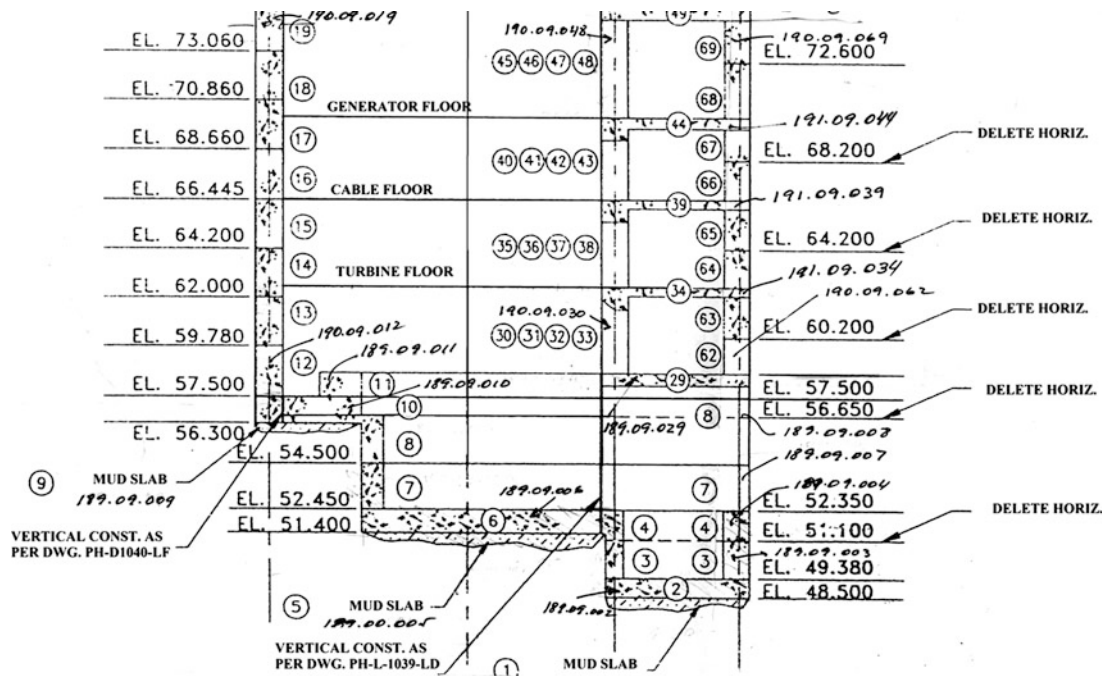


Fig. 17.1 As-built drawings for powerhouse structure

Work organization

- How good were communications during the project?
- What about daily meetings? Were they too general, too short or too long?
- Inform all departments of the project management entity, in writing, that the project is finished and that no more invoices, memos, reports, claims, changes, etc. must be accepted.
- Make all the necessary transfers of equipment, documents, drawings, manuals, specifications, permits, approvals from local authorities, etc., to the client.
- Make sure the client receives a set of as-built drawings, i.e. those documents reflecting how the work was actually done. Figure 17.1 depicts an example of such a drawing.

17.2 Closing the Project with Suppliers

Make sure that written information signed by an authorized person is sent to suppliers, sellers and vendors in order to let them know that the project is finished and closed and that no more purchasing orders must be accepted.

17.3 Closing the Projects with Hired Personnel

Make sure that written information signed by an authorized person is sent to people especially hired or contracted for the duration of this project to let them know that the project is finished and closed and that their services will no longer be required at the stated date.

17.4 Conclusion of This Chapter

The importance of this aspect has been highlighted and a series of different subjects suggested for consideration, including in particular a very important aspect as the 'as-built' drawings.

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