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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

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3.1.1 Project Manager Attributes

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

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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.

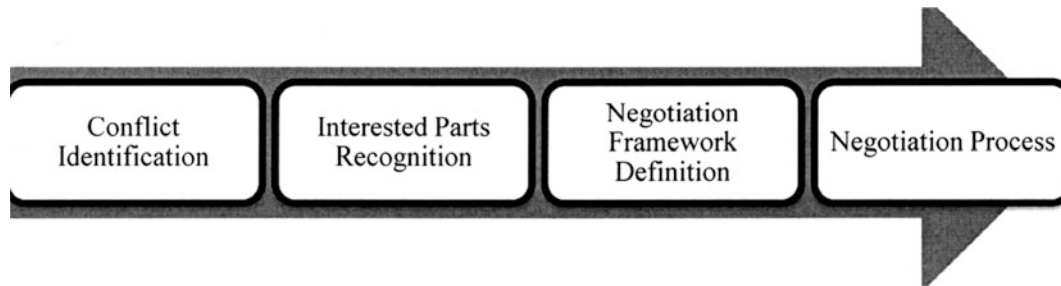
As usual in negotiation processes there is not a right or wrong style to use. It depends on the issue to be negotiated, the sort, quantity and quality of information each party may consider for the process and many other personal circumstances leading to choose one or the other style. Even it might be 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

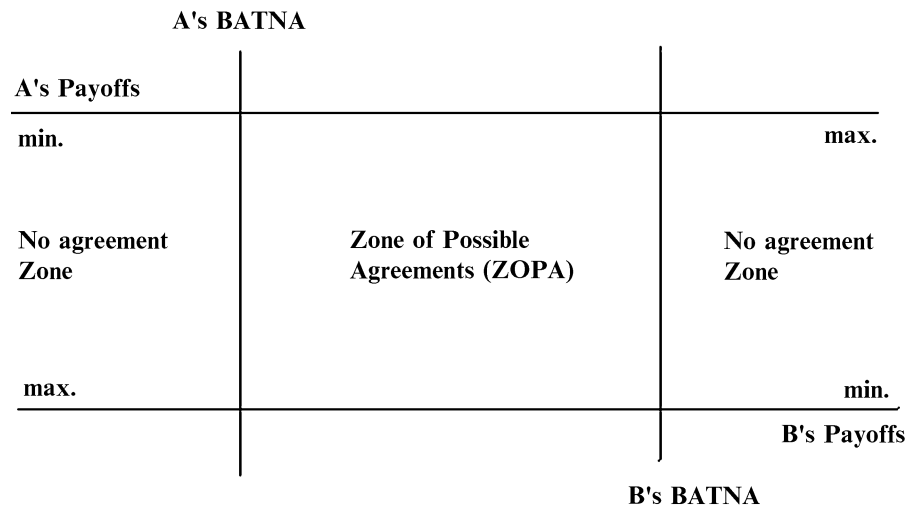
During this stage the interested parties have to define their own interests, determine the set of options for each issue under negotiation and evaluate the possible combinations of options with respect to their interests. Specific tasks involved in this stage are the following:

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.

¹ The 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).

² A 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

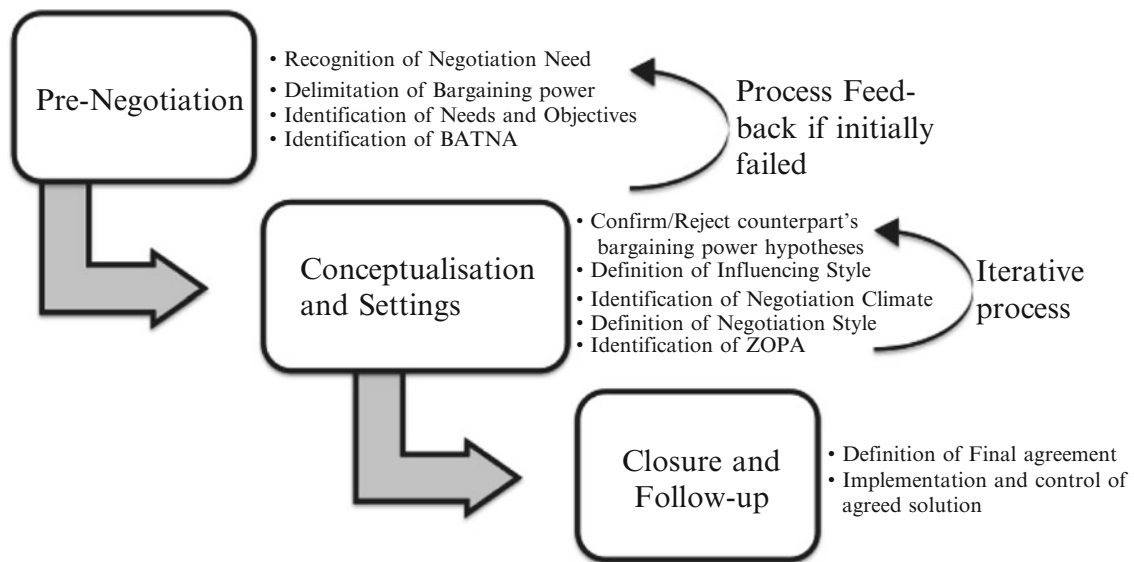


Fig. 3.3 Negotiation process in three stages

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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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.

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Fig. 6.1 What is the risk of a project?

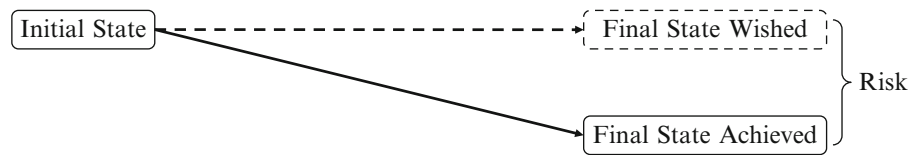
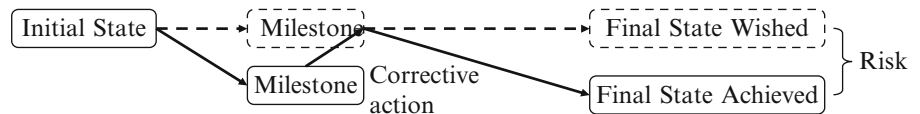


Fig. 6.2 How to reduce the risk in a project



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

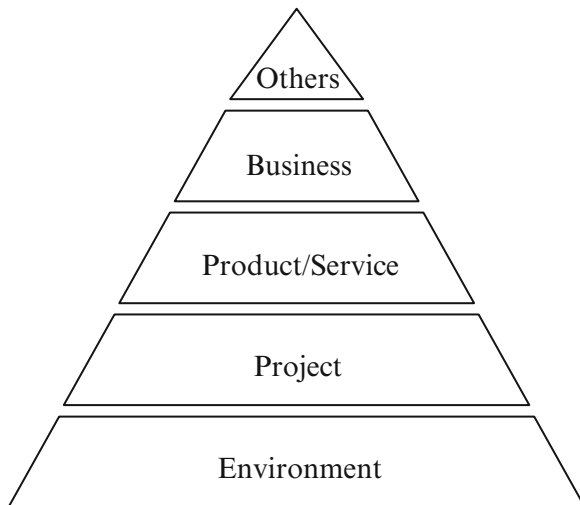


Fig. 6.3 A project within the organization

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

¹ The 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:

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

- 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:

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

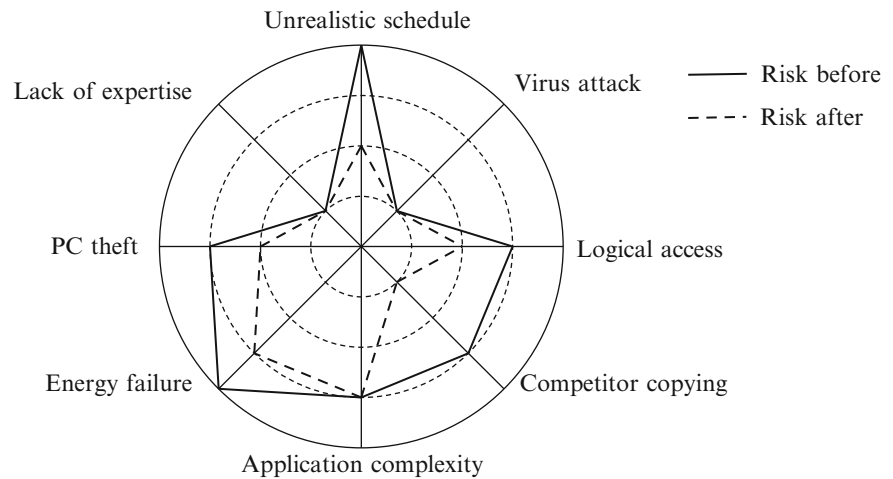
Where ' $\Delta \text{Probability}$ ' corresponds to a decrease of the occurrence as a consequence of the actual preventive safeguard measures, while ' ΔImpact ' relates to a decrease in the impact because of the actual healing safeguard measures.

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 $\Delta \text{Probability} = 100\%$ 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.

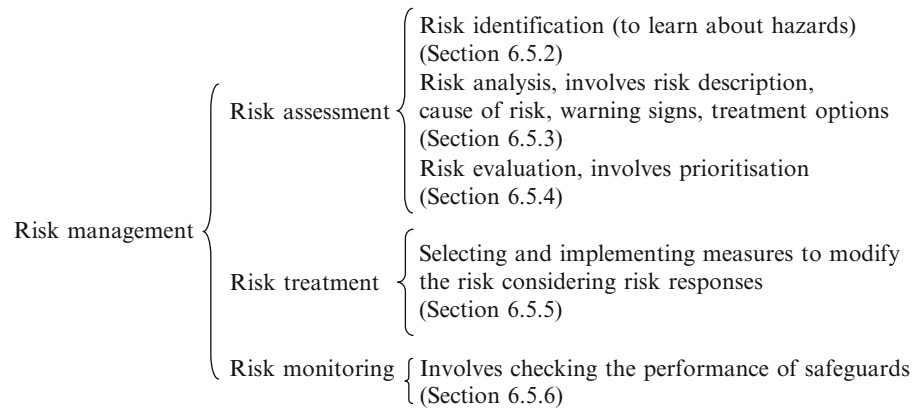
In this sense, risk management is a process that manages the resources available in the project to limit the difference between the wished for and achieved final states. If the difference exceeds the prescribed threshold, the risk of non-fulfilling the project objectives is present, and in order to ensure 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 life-cycle, 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.

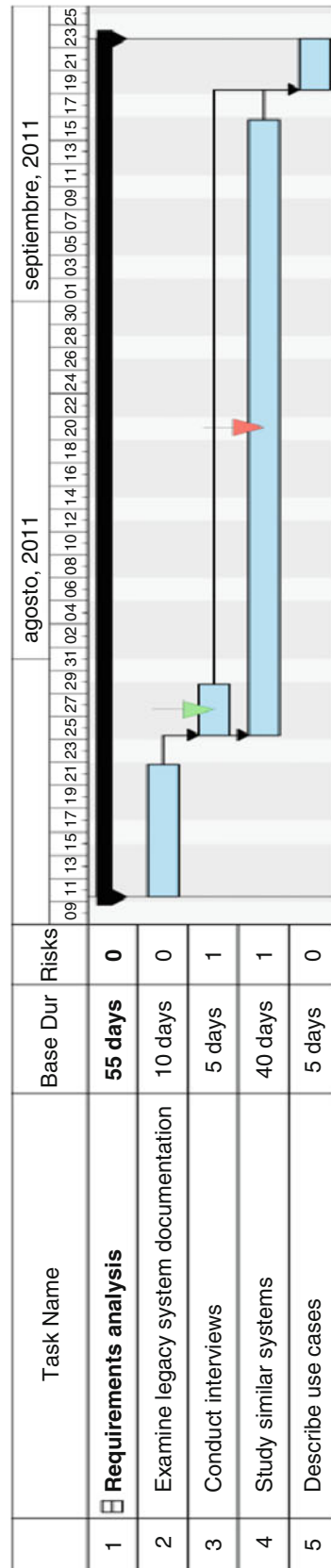


Fig. 6.7 Gantt chart illustrating requirements analysis stage – Software development project (Risky Project screen shots reproduced with kind permission of Intaver Institute Inc.)

	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.)

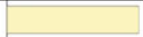
	Name	Type	Risk Assigned To	Sensitivity Chart	Ranking
1	Risk: Couldn't find appropriate documentation	Risk	Task 4: Study similar systems		0,949
2	Risk: Client will be busy and will not be able to participate	Risk	Task 3: Conduct interviews		0,256

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.

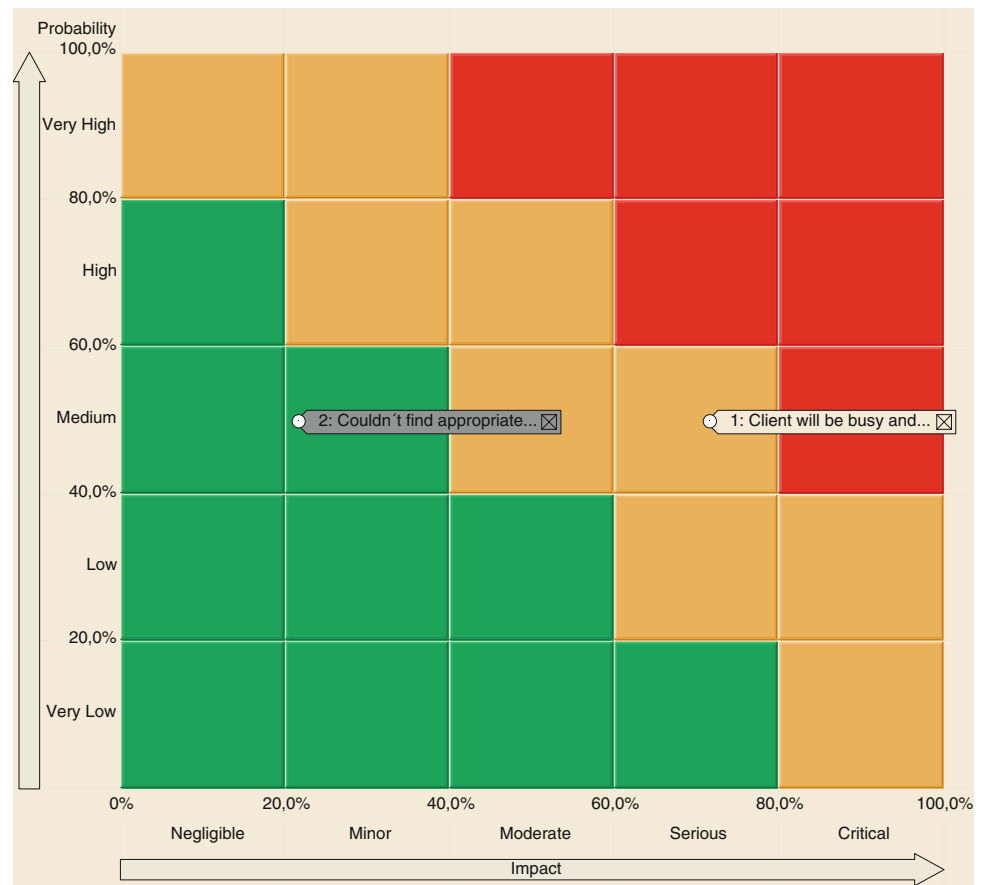
Now, coming back to non-critical task 3, if the delay associated with the threat exceeds the float of the task, it becomes critical, and consequently affecting the project duration. Figure 6.9 shows a sensitivity chart, i.e. how the two considered risks affect project duration, when the delay associated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

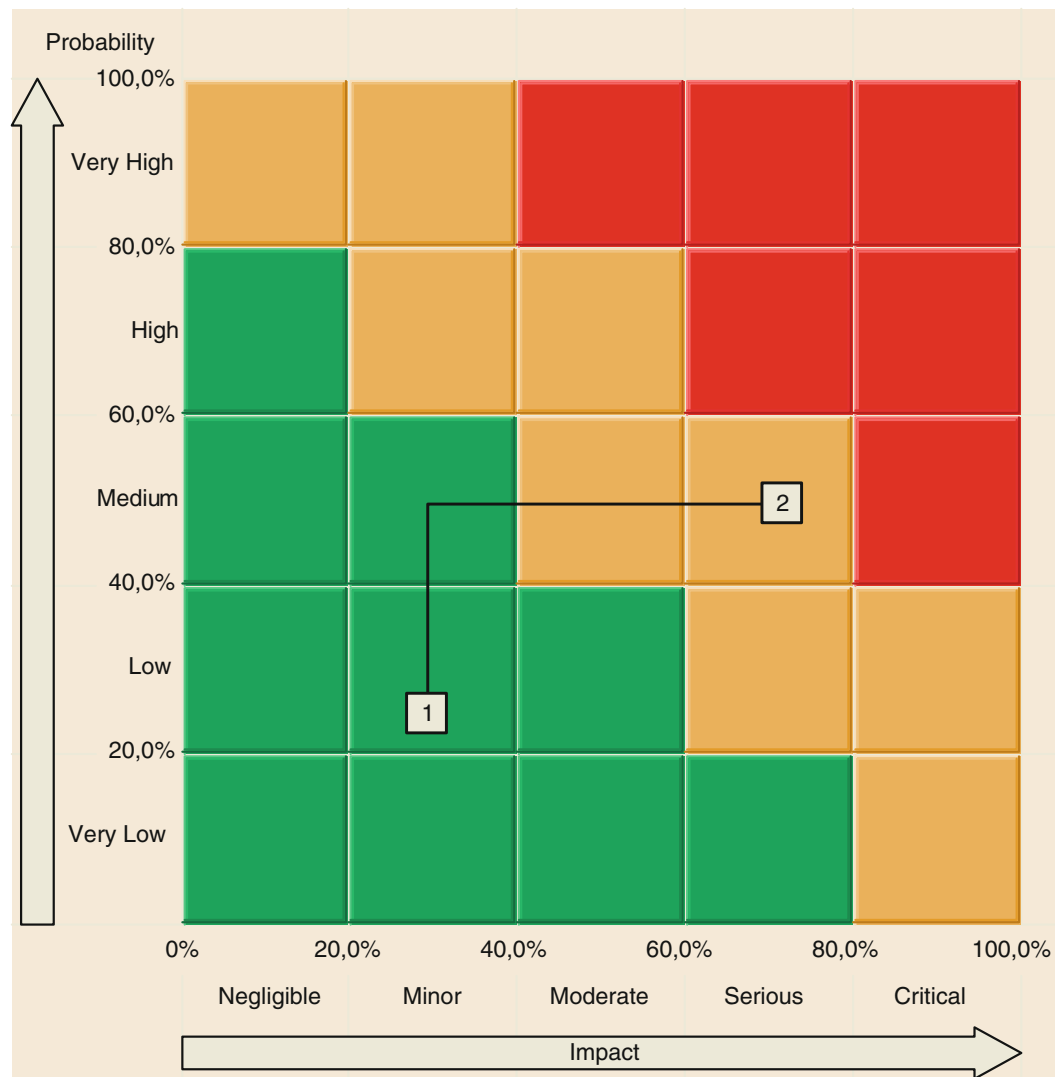


Fig. 6.11 Waterfall diagram or analysis of mitigation efforts – Software development project (Risky Project screen shots reproduced with kind permission of Intaver Institute Inc.)

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
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
C – Buildings construction, electrical, plumbing, etc	11,262	3,479	14,741	11,962	6,257	18,329	4,983	1,209
D – Ancillary equipment	3,793	4,766	8,559	7,423	5,378	12,801	7,866	3,371
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,

² This 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

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 2.41:1, 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

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.

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

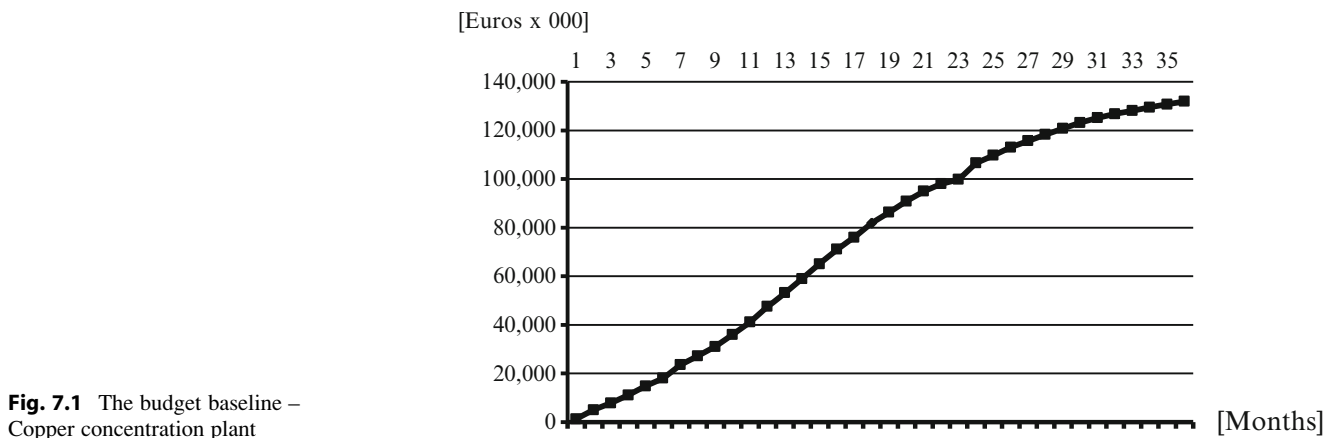


Fig. 7.1 The budget baseline – Copper concentration plant

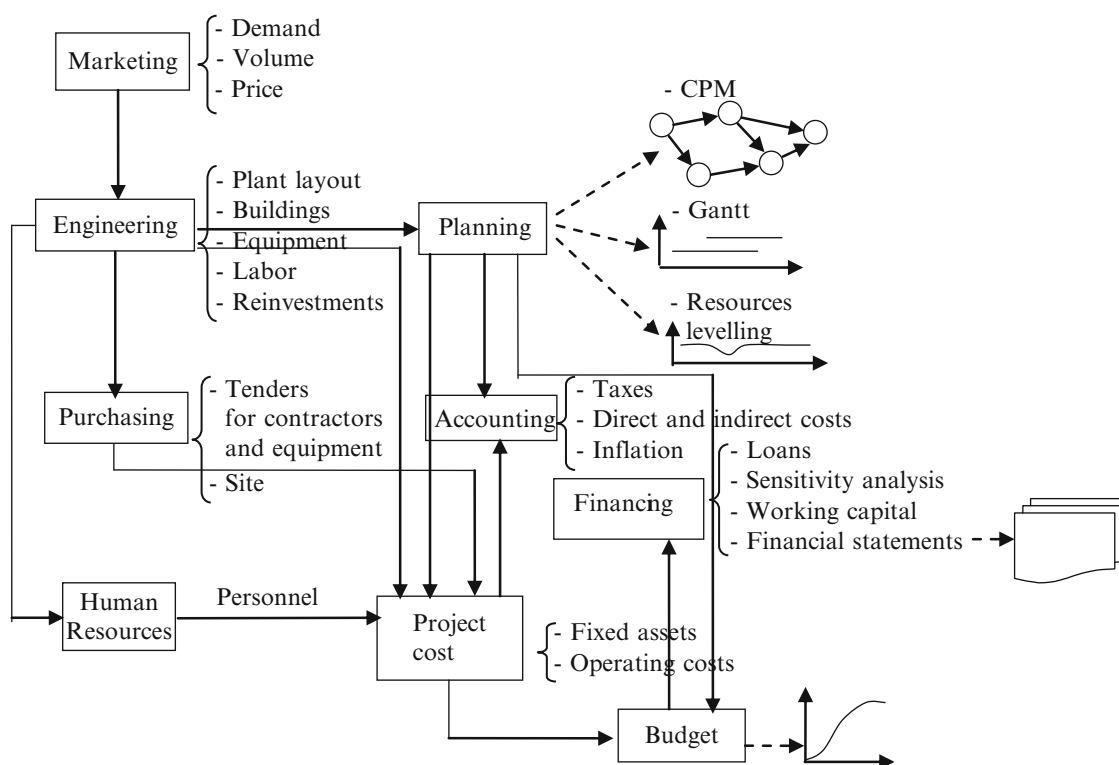


Fig. 7.2 Information flow for a project financial analysis

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*	18,522	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%	Diff. between A & Var. 4 [%]
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.

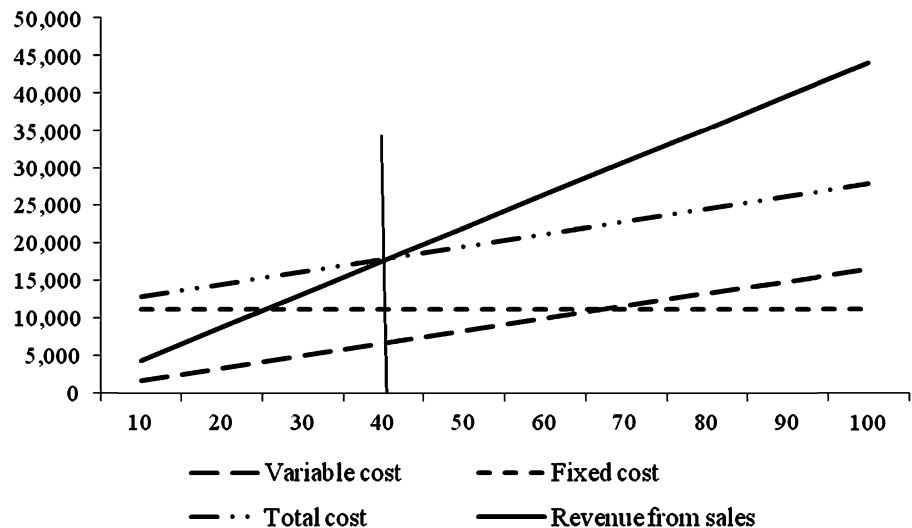
Variable 4. *Process equipment*. Although computerized equipment is used requiring fewer personnel to operate, they are quite expensive. This heading also includes the cost and maintenance of large trucks employed in ore transportation from the open pit mine to the crushers.

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

$$n = \frac{\text{Fixed cost}}{\text{Unit sale price} - \text{unit variable cost}} \quad (7.2)$$

$$n = \frac{11,200,000}{(441 - 165.8)} = 40,700 \text{ tons} \quad (7.3)$$

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

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.

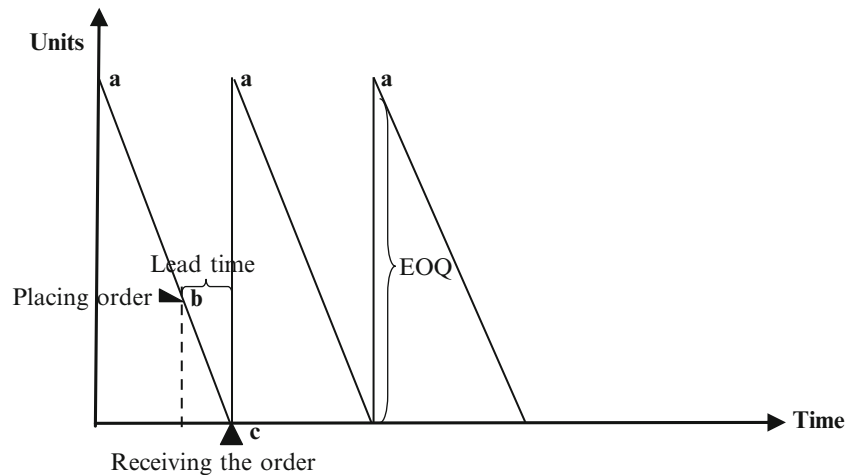
The Project Manager thus faces the dilemma of deciding the best policy; without a doubt a tradeoff must be made between these different costs in order to reach a compromised or balanced solution, and considering that the problem varies according to the type of project. A typical example pertains to elements 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	Information needed from the engineering or design department – 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	– 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
	– 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.	Information needed from the engineering or design department – 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	– 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	– List of qualified suppliers – Background information on suppliers – Previous experience with some suppliers	– 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	– 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	– 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	– 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.	– 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: – 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	– 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.)		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
Number	Description							
1	2	3	4	5	6	7	8	9
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,

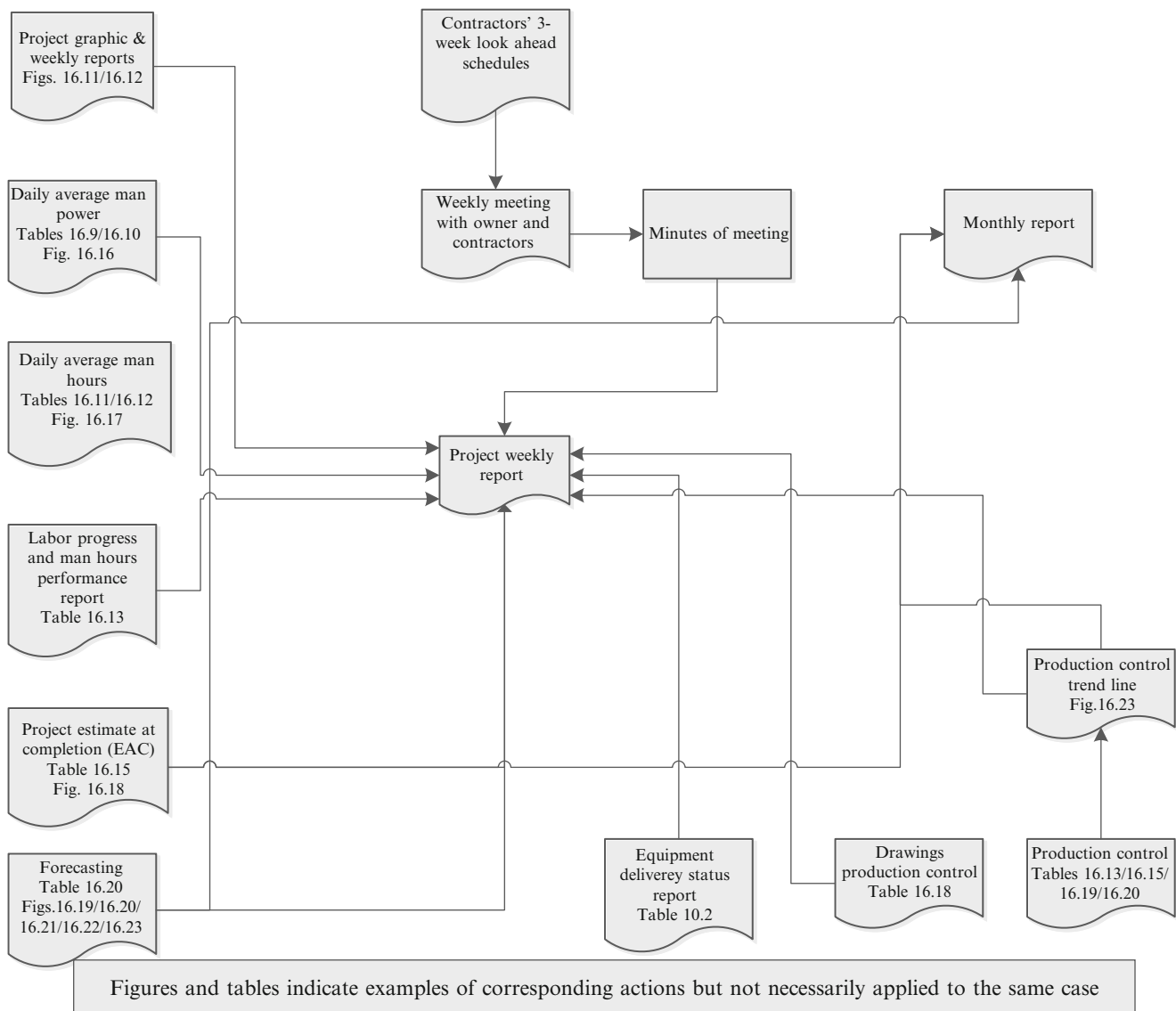


Fig. 11.1 Project graphic and tabular reports

- 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.).

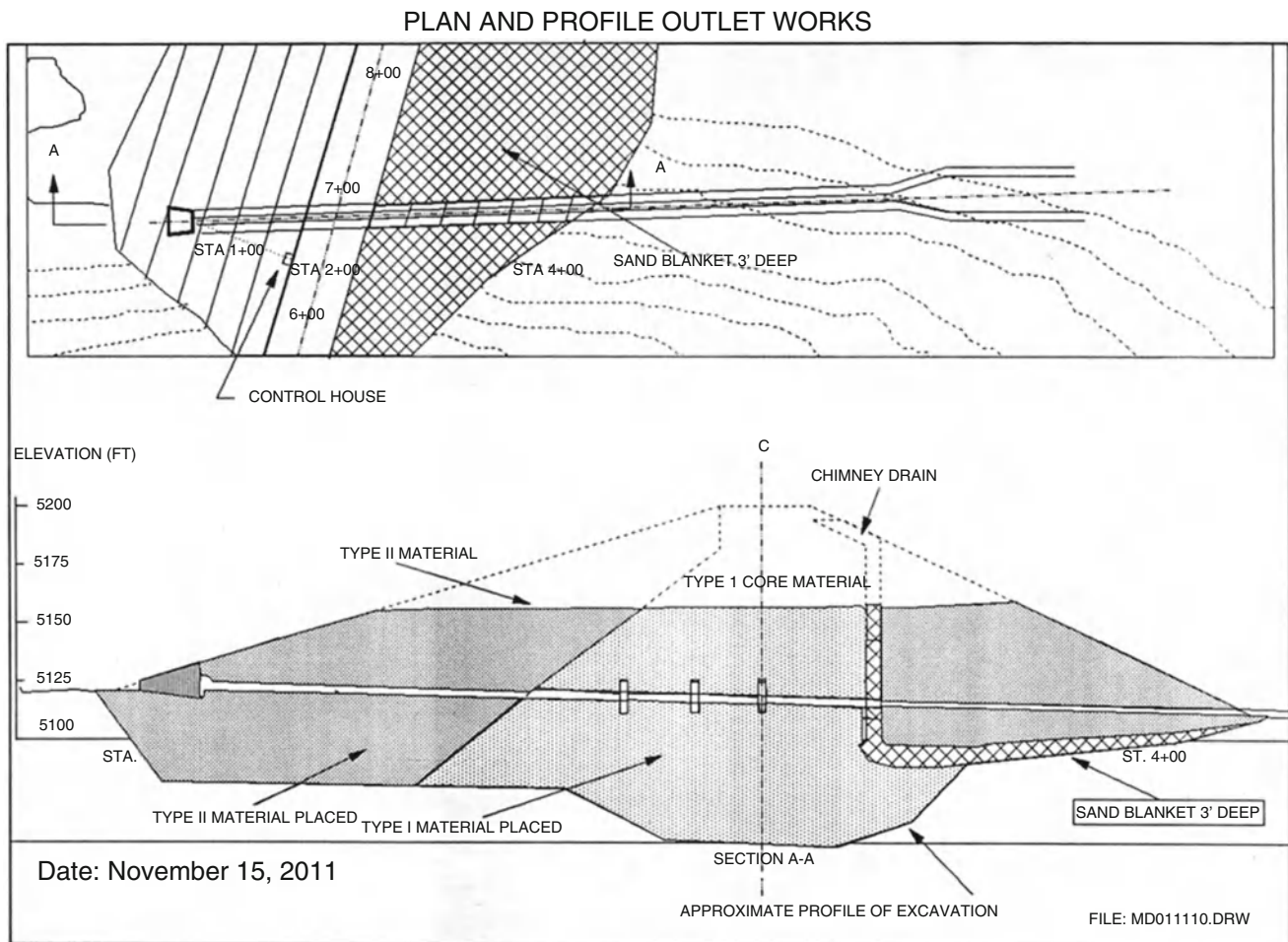


Fig. 11.2 Reporting status of work at November 15, 2011 – Dam construction

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,

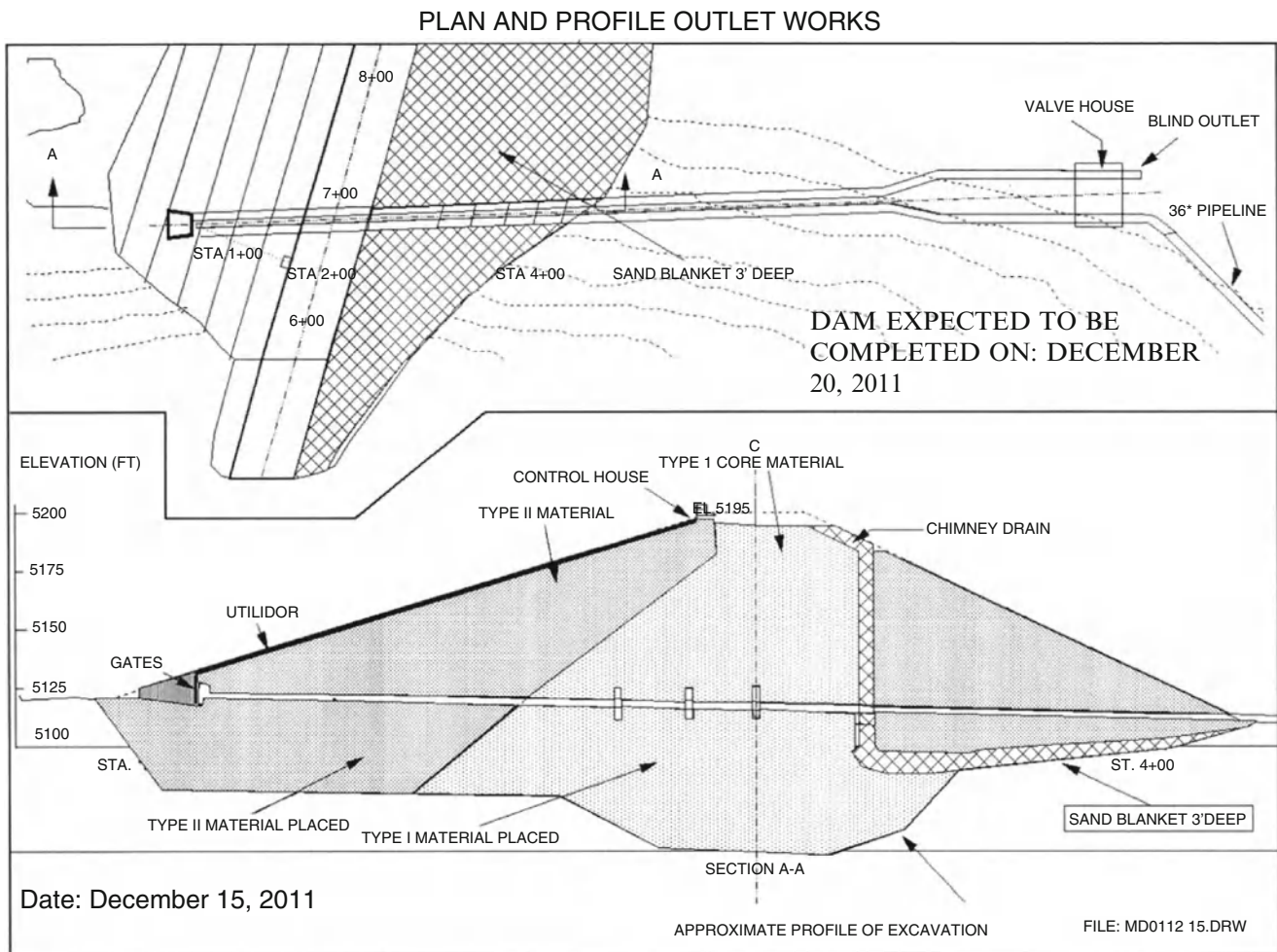


Fig. 11.3 Reporting status of work at December 15, 2011 – Dam construction

- 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.

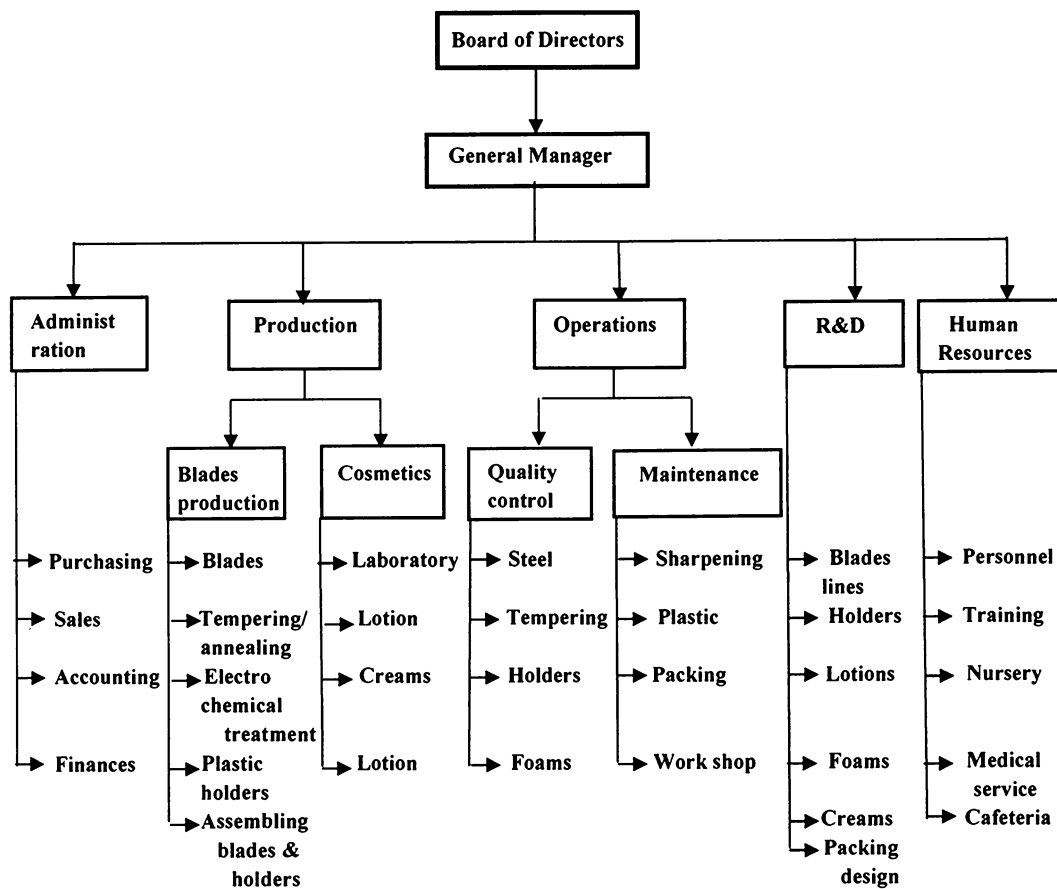


Fig. 11.4 VCC organization structure – Diagnosis in an enterprise and proposal to install an ERP

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

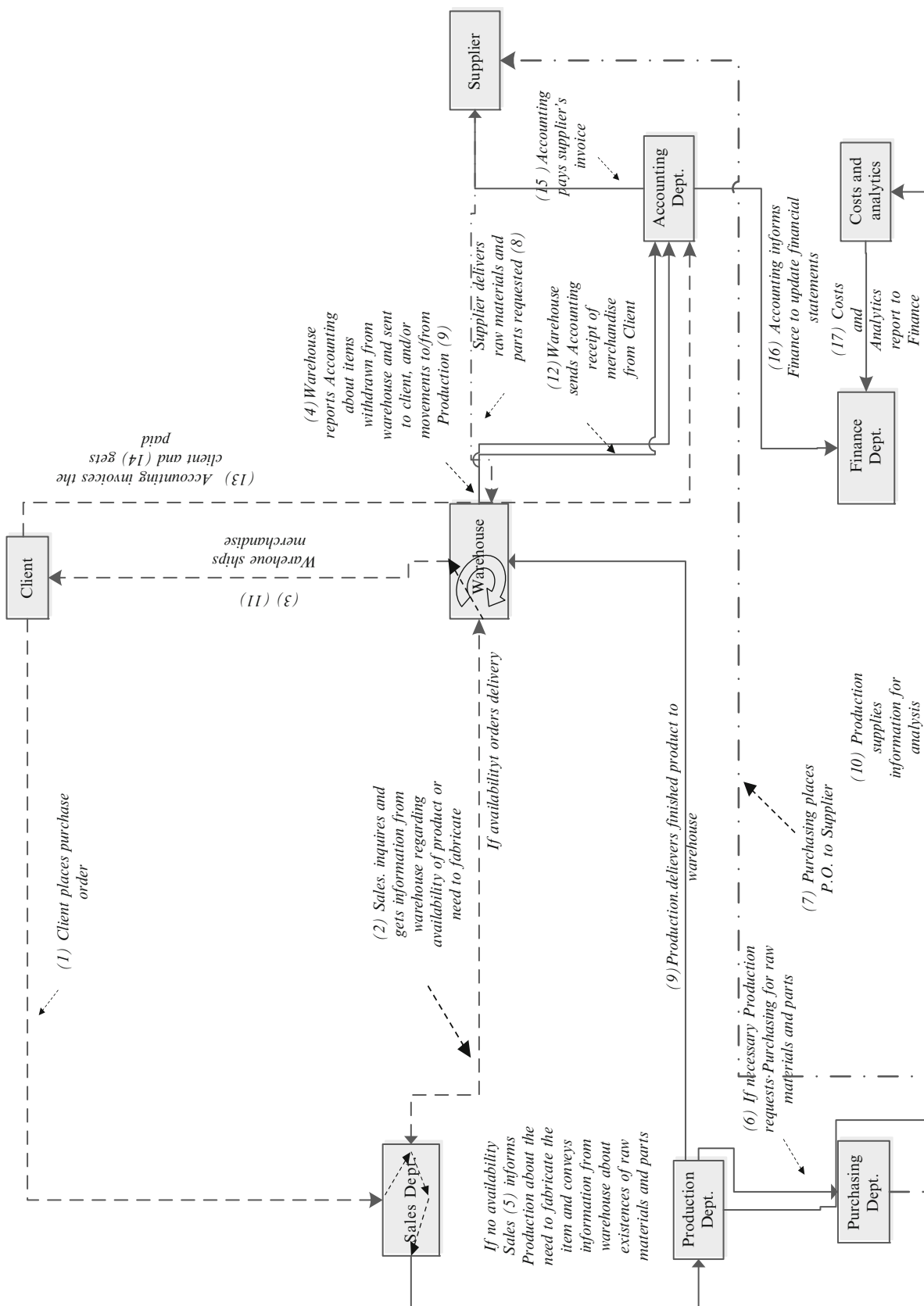


Fig. 11.5 Flow chart for a purchase order from a client – Diagnosis in an enterprise and proposal to install an ERP

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 it 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:		1		1							

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

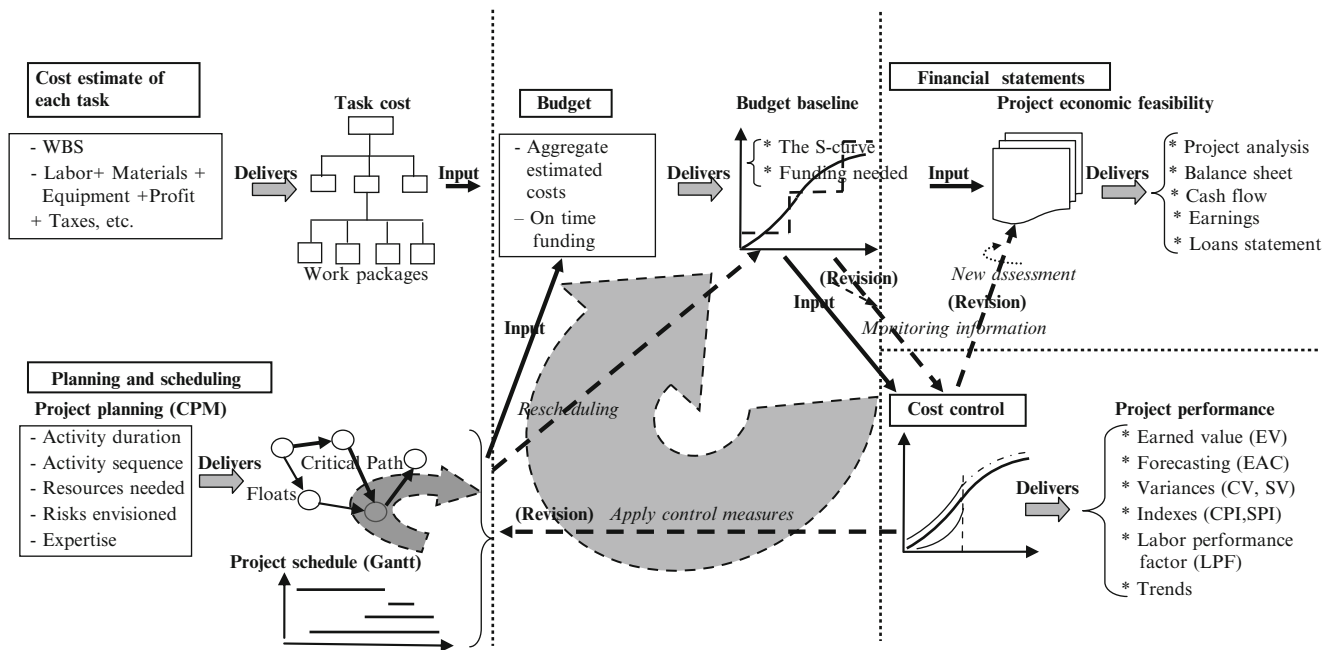


Fig. 12.1 Interrelationship between costs, scheduling, budget, financing, monitoring and cost control

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 SO_2 , NO_x and other contaminants, which react with water contained in the atmosphere to produce weak acids such as H_2SO_4 (sulphuric acid) and HNO_3 (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 per unit	Cost (€/unit)	Total (€)	Accumulative (€)
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:

Materials cost : $0.10 \times 1.22 \times 2.44 \times 86 = 25.60$

Labor : $22.33 \times 0.025 = 0.56$

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 #	Task	2011		2012					June	July
		Year	Month	November	December	January	February	March		
	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	
13	140							140		
14	11,000							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		
24	9,000									
25	6,000									
26	21,420									
	Partial			13,600	7,030	19,122	45,809	47,643	47,503	67,849
	Cumm.			13,600	20,630	39,752	85,561	133,203	180,706	326,760

Fig. 12.2 Approximate format of partial expenses in a project as function of time

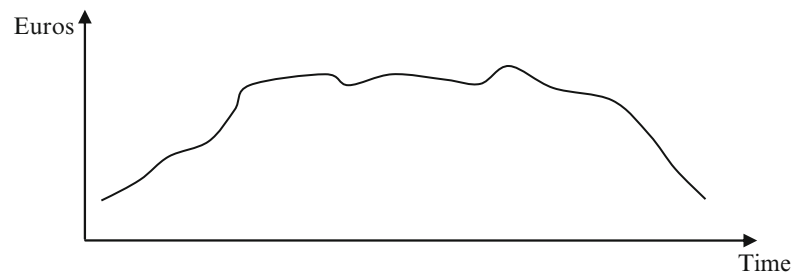


Fig. 12.3 Monthly expenditures for the first 9 months – Budget determination for construction of a dwellings complex

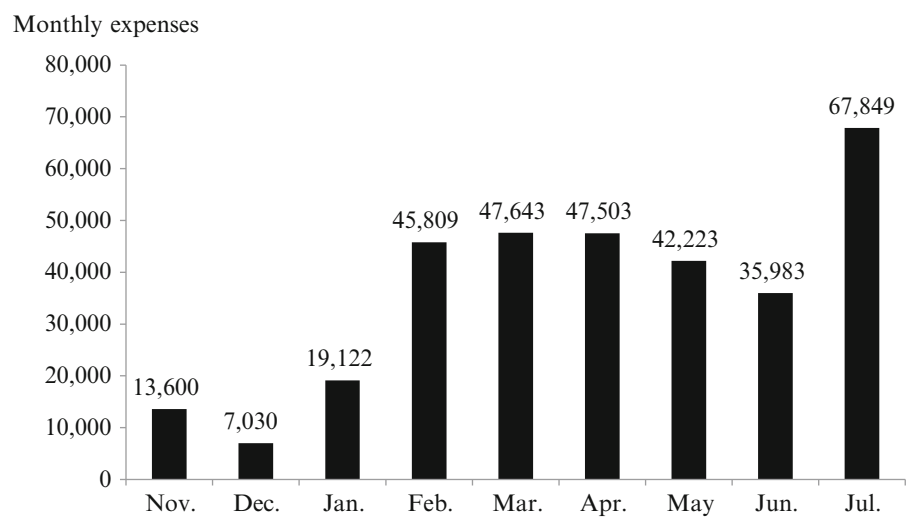


Fig. 12.4 The budget curve or S-curve with accumulated values for the first 9 months – Budget determination for construction of a dwellings complex

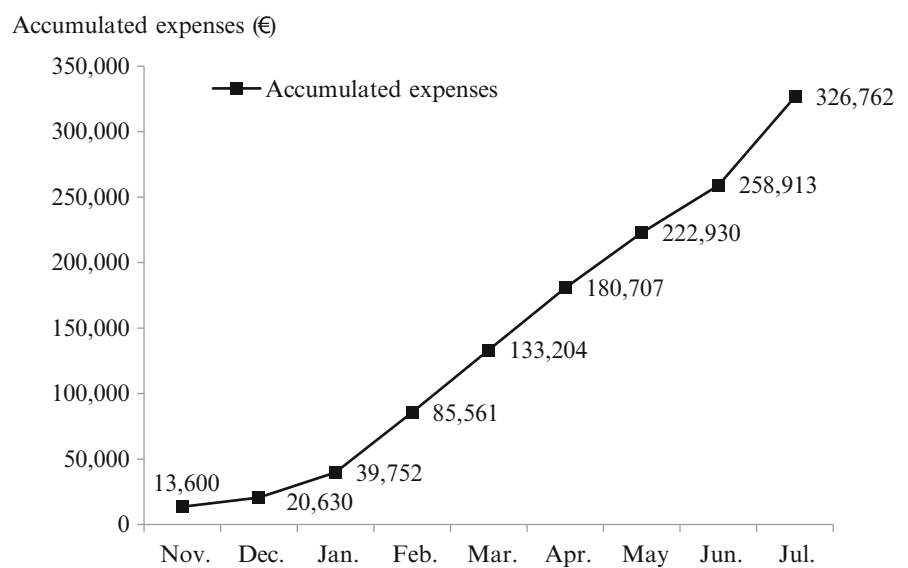
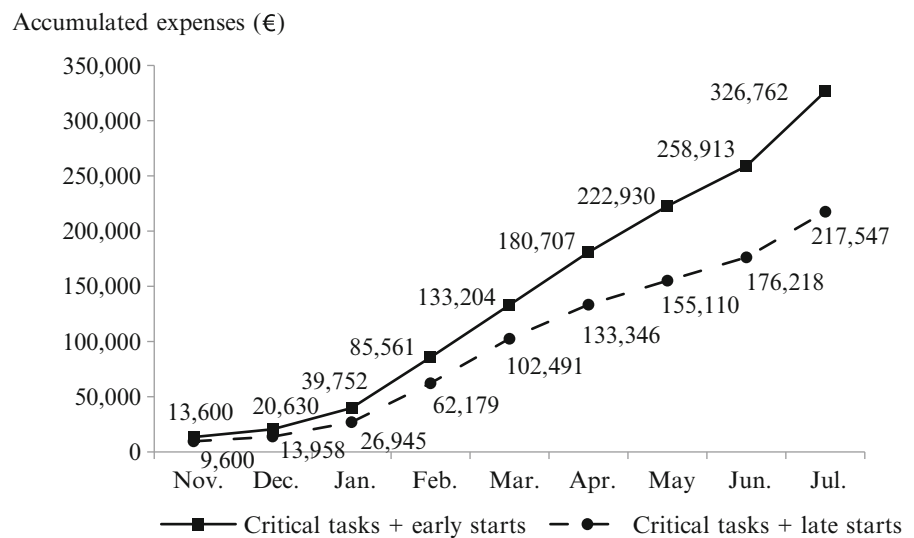


Fig. 12.5 Comparison between early and late starts for the first 9 months – Budget determination for construction of a dwellings complex



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	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
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					x
Exposure to fumes			x			x	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	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 stationery 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 people 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,

¹ Occupational 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	☐ Death	☐ Serious Future consequences? Yes No Unknown	☐ 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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