PROJECT MANAGEMENT
Board Game

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Document description:	This ebook will provide the formal theory of Project Management, to help students understand the theoretical foundations of PM and at the same time formalize the knowledge of professionals

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Welcome to the course

One of the largest transportation projects that is currently being constructed in Europe is the Grand Paris Express. It consists of a total rethink, and re-design of the public transportation network in the wider area of Paris, France and its purpose is to develop multi-modal transport solutions, integrated transport services, thus supporting a model of polycentric, urban development.
The project is impressive as it involves the construction of (among others) 4 new metro lines, 200 kilometers of railway lines, 68 new stations etc[1].
However, when people see or hear about such project, they often overlook the work of designers, constructors and builders who were involved in the project and seldom about the people that organized everyone and everything to achieve the impressive feat. They are the *project managers*, the people who took the ideas of the designers and organized the efforts of the constructors and builders, in order to achieve the overall objective in time, under budget and without accidents.
Project Managers need to have skills that are more than technical knowledge; they need to be able to handle risks, organize people and resources, have the ability to organize time and schedules, etc.
Although Project Managers are just a role in projects, their contribution is often not recognized. Nonetheless, the past few decades have given rise to the need of constructing even more impressive projects to address the challenges of our century. Think for example of the need to develop energy production stations that are not harmful to the environment and at the same time must be able to provide electricity to an increasingly demanding population. Or think of the consequences of climate change and the need to develop works that would prevent entire cities from sinking below sea level.
Thus, the world needs Project Managers that are exquisitely trained and educated with the skills to solve any problem, small or big.
The PMBOG course is intended for students who want to understand the theoretical foundation of Project Management, or for professional managers who wish to formalize their practical knowledge. But the target group is not limited to those two categories: Project Management is involved in every aspect of everyday life: from renovating a room in the house to organizing a wedding. As a result, the PMBOG course is intended for those people who wish to gain the skills to better organize their lives.
For that reason, the course covers several elements of the Project Management discipline: cost management, quality, time, organizing resources and more. The course will be written and conducted in a way that is accessible to everyone without sacrificing its mathematical and scientific rigor. Finally, the material that will be developed during the course will be freely available at the project's website and will involve exercises that will allow the participants to investigate how the approach could play-out in a project.

Rationale, aims and learning outcomes of the course

The overarching aims of the course are to:

- To provide the opportunity for students to understand the foundations of Project Management

[1] https://www.societedugrandparis.fr/info/grand-paris-express-largest-transport-project-europe-1061

- To provide an education in Project Management and the techniques that are used in real-life projects.
- To provide a coherent learning process that offers the opportunity for continuous professional development
- To equip students with an intellectual capacity to investigate how they can apply Project Management techniques to small and big project

These aims have been used to define the content of the modules that you are studying, and also to develop a set of learning outcomes, that are the educational attainments that you will have achieved on successful completion of each module and your course.
The overarching learning outcomes of your course are listed within the programme specification included as an appendix to this handbook.

Modules available

The course has a modular structure that allows for a variety of potential exit points should a student not complete the full course of study. Each module is a self-contained block of learning with defined aims, learning outcomes and assessment: module titles and module codes are given above. This course offers two level of education:
Basic: In the basic module, the students (or course participants in general) will learn about:

- The basic concepts of Project Management (Chapter 1)
- The Processes that are involved in Project Management (Chapter 2)
- To identify the scope and limitations of a project (Chapter 3)
- To learn how to manage time in projects (Chapter 4)
- To learn how to manage cost in projects (Chapter 5)

After the basic modules, the course will delve into more technical aspects that are mostly targeted to professionals. However, this does not mean that they cannot be attended by people with no prior knowledge on Project Management. On the contrary, the courses will offer a top-down view of each of the aspects of the advanced level with real-life case studies etc. before continuing with more mathematical elements. The advanced level of the course includes:
Advanced:

- Quality Management (Chapter 6)
- Risk Management (Chapter 7)
- Resources and Procurement Management (Chapter 8)
- Communication and Stakeholders Management (Chapter 9)
- Project Integration Management (Chapter 10)

1 Introduction to Project Management

The term *project* is nowadays widely acknowledged and frequently used in the common language, referring to a non-repetitive series of actions, aimed at delivering a certain result.
From a more discipline-oriented perspective, among the most recurring definitions of what a project is, we can find:

- "A project is a temporary endeavour undertaken to create a unique project service or result" (Project Management Institute)
- "A project is a single set of activities designed to produce a defined result with a clear start date and the end and an accurate allocation of resources" (Harvard Business School, Project Management Manual)
- "A project is a complex undertaking, unique, of predetermined duration, aimed at achieving a clear and predefined goal by a continuous process of planning and control of differentiated resources and interdependent constraints of costs-times-quality" (R.D. Archibald)

What emerges at a first glance is that all the definitions provided above highlight the same distinctive elements of a project: the definition of a clear set of objectives, to be reached through a series of (generally) complex and interrelated activities, within a pre-determined time and operating within specific boundaries defined by a constrained amount of human and financial resources.
Therefore, among the most typical and recurring variables that characterize a project, we can always find *Quality* (of the output/goal to be realized/reached), *Time*, *Cost* and *Resources*.
Even though "carrying on a project" is a common expression, widely used by everyone, when it comes to managing a project in an effective and efficient way, we can say that there is nothing like "common". Projects are (with some exceptions) characterized by a high level of complexity, determined by the uniqueness and originality of the results/goals to be reached, by the need of coordinating and working with people from different contexts and background (that are part of the *project team*), by the pressure of different stakeholders that all have different degrees of interest and influence over the project's outcomes.
The existence of these critical and complex aspects, combined with the singularity and non-repetitiveness of each project (there are not two projects alike), brings to understand why, throughout the last 70 years, we have witnessed the emergence and rising importance of the *Project Management (PM)* discipline, to help managers and practitioners successfully navigate through this complex environment.

1.1 Project Management: When and Why?

Nowadays, five distinctive application areas for PM have been identified and acknowledged. These categories group every possible application of PM in managerial contexts. Nonetheless, there are some exceptions: organizing a marriage, for instance, is a complex and (hopefully) unique project as well, and hardly falls into one of the previous categories, even if it could be identified as an "Engineering-to-order" commission. Anyway, the principles, best practices and tools that will be illustrated here, are still valid for every possible activity falling under the definition of project.

These categories can be characterized by mean of the perspective (internal vs. external or market-oriented) and the degree of knowledge of client specifics, as detailed in Table 1:

- New Product Design/Development
- New Service Design/Development
- Management of highly customized jobs/orders
- Business/Organizational process improvement
- Public research and international cooperation

Table 1.1 Application areas of PM

		Client Specifics	
		Unknown	***Known***
Perspective	***Internal***	Public research and international cooperation	Business/Organizational process improvement
	External	New Product Design/Development New Service Design/Development	Management of highly customized jobs/orders

1.2 Defining project success and failures

Developing and embracing the PM culture and mind-set is, unfortunately, not enough to ensure the success of a project. According to the uniqueness of each project, giving a universal definition of success might appear as ambiguous, but research in the field of PM showed that all projects are characterized by the same critical success factors, as shown in Figure 1. These factors were identified by Pearce and Robinson (1997), and they are:

- Executive direction: referring to the role of executive management in supporting a project by avoiding resistances and ensuring the disposal of the right (needed) amount of resources.
- Project Team: represented by all the personnel directly involved in the project and answering directly to the Project Manager, who are in charge of conducting project tasks/activities and can exert a clear impact on projects' success.
- Innovation strategies: including every plan or decision that direct project activities towards the creation of a long-term advantage based on dynamic capabilities. These internal dynamic capabilities mediate the positive effect of strategy on innovation and market success.
- Internal factors: including everything from within the organizational boundaries that can foster/support or block/slow down project activities, with a particular attention to internal stakeholders, e.g. functional managers.

- External factors: including everything from outside the organizational boundaries that can foster/support or block/slow down project activities, with a particular attention to external stakeholders, e.g. suppliers, regulatory bodies, public authorities.

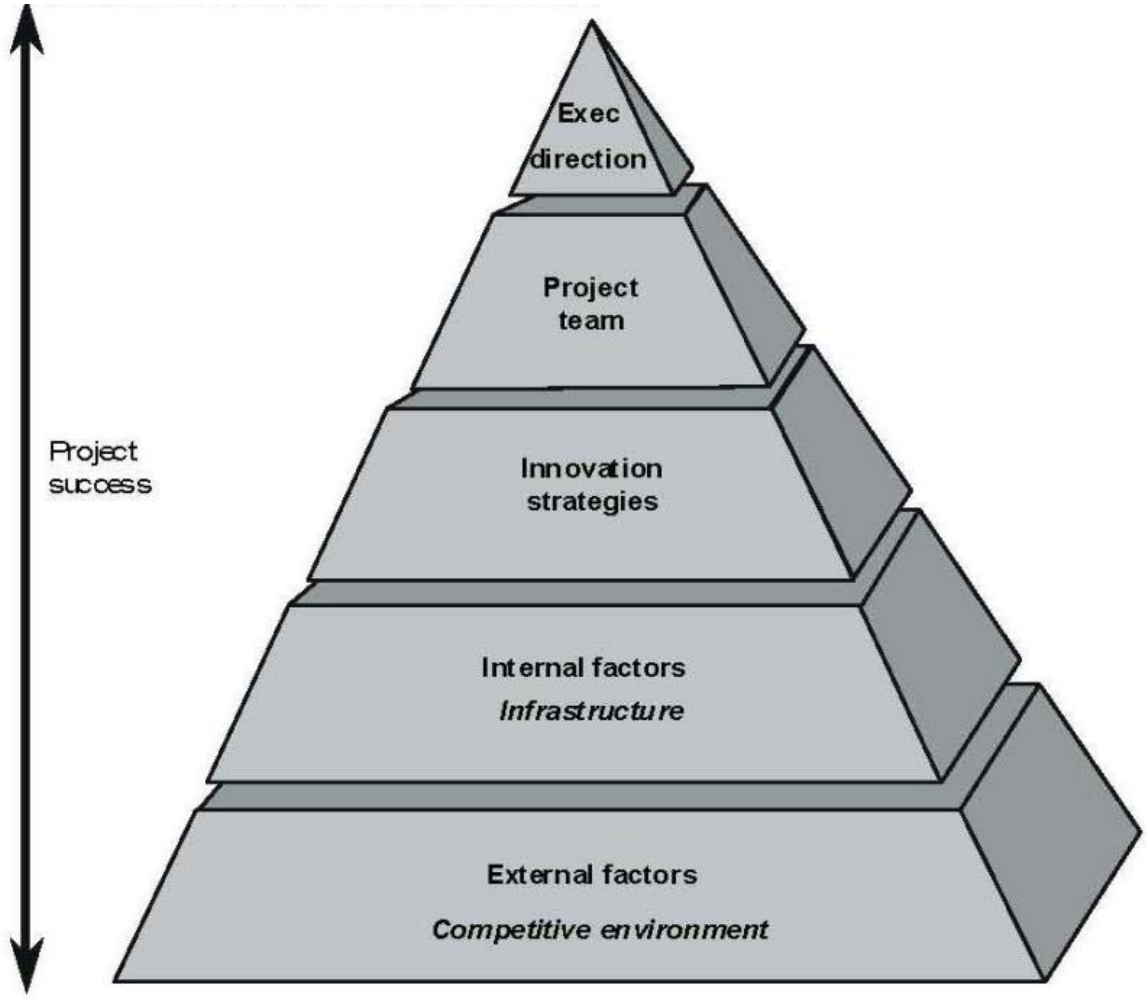

Figure 1.1 Critical Success Factors of projects (Pearce and Robinson, 1997)

All the above elements jointly determine the success or failure of a project, whether a certain amount of effort and attention has been devoted to each dimension of not. In some cases, an extra effort in one or more areas (like Project Team or Executive direction) can overcome obstacles coming from the external environment, for instance, ensuring the project success. The graphic tool showed in Figure 1 can be particularly useful also from a backward perspective, to analyse a project that has been concluded and perform a critical analysis of factors which have determined the success or failures.

1.3 Operations Management and Project Management

Another key element to understand the importance and need of PM, lies in its distinction with *Operations Management (OM)* and all those routine activities that constitute the majority of an organization's business, with the exception of those which mainly work through projects.

As already anticipated above, while OM refers to the management of routine activities (therefore, characterized by repetitiveness and standards), PM is mainly related to the area of extraordinary and innovative activities, with few or no reference standards, and characterized by change.
Even though both OM and PM are constrained by *Quality*, *Time* and *Cost*, these dimensions follow two completely different set of rules, as shown in Table 2.

Table 1.2 Comparison of Quality, Time and Cost for Operations Management and Project Management

		Operations Management	**Project Management**
Performance	***Quality***	Respecting conformity	Increasing quality
	Cost	Standard costs	Budget
	Time	Standard times of operations	Time to Market Duration of activities

In the context of OM, Quality is strongly linked to the concept of *conformity*, in accordance with the key principles of Total Quality Management. However, the conformity standards to which OM needs to adhere, directly derive from innovative activities of product and/or service design and development, which are carried on the "PM universe". A similar difference there exists for Cost in OM and PM: while in the former, performance is determined by the respect of standard costs, in the latter case (and, in general, for all innovative activities) there are no standard costs to be considered as a reference, and therefore performance is measured upon the respect of the assigned budget.
For what concerns Time there are very few differences, mainly in the definition of the reference, which is the standard time of operations and delivery time for customers in OM, and time to market (namely, the time needed to produce and sell to the market an innovation, starting from its conceptualization). The objective, in both cases, is to conduct and close activities according to the expected time references while avoiding delays.
Summarizing, we need to state that both OM and PM play a fundamental role for the wealth of an organization, by carrying on different purposes. OM is constituted by an on-going set of activities, aimed at providing an efficient and continuous production flow, with stable references based on historical data (which determine standards), while controlling the routine performance and ensuring the achievement of expected results. On the other hand, PM lives in the realm of Innovation: it has a discontinuous nature, being each project characterized by a beginning and an end, a unique set of goals and constraints, and its main aim is to "fuel" the company through innovations and improvements, to ultimately benefit and assist the OM day-to-day activities. Table 3 summarizes these differences.

Table 1.3 Different perspectives between Operations Management and Project Management

	Operations Management	**Project Management**
Activities	Continuous	Intermittent
Focus	Periods	Projects
References	Stable	Uncertain
Goal	Production	Creation
Control	Feed-back (actual)	Feed-forward (forecast)
Decisional centres	Cost accounts	Investment accounts
Key Business functions	Purchase; Production; Sales	R&D; Design; Engineering

2 Project phases

The life cycle of a project includes the various stages through which it passes during the course of the work and can be defined through points of departure and arrival. Each arrival point is characterized by a specific result called "output" or intermediate "deliverable" which constitutes a starting point for the next phase.
Project management can be divided into 5 distinct phases:

1. Start-up
2. Planning
3. Execution
4. Monitoring and control
5. Closure

The debate on the actual number of phases in the project management life cycle is still open as these phases often overlap. However, each of the phases has very specific characteristics and results that differentiate it.
The first two phases – start-up and planning - are pre-project phases, meaning all the preparatory work that project managers and their team carry out to lay a solid foundation. Most of the action of the project occurs during execution. The monitoring and control phase is performed simultaneously with the execution, while the closing phase is an evaluation at the conclusion of the project.

2.1 Start-up

The start-up phase is the one in which the project is formally launched, clarifying its objectives in terms of benefits and expected results. All the assessments made at this point in the project cycle will be decisive for its ultimate success.
The first process, the definition of the contract, requires a careful analysis of the project and an estimate of its ability to produce profits. The start of the project necessarily requires a formulation of objectives that must be set in agreement with the customer (internal or external) and uniquely measurable. Starting from the objectives and project specifications, the project manager will compile a description of the scope with respect to which an initial planning of activities and allocation of resources will be carried out. The project scope, project scope in English, includes in its definition both the characteristics and functions that distinguish a product, service or result, and the activities that will lead to its realization. The project scope management activity, in English Project Scope Management, has as its main objective to ensure that the project includes all the activities required for its effective and efficient completion, and that the objectives are clearly defined.
After verifying its feasibility and defined its scope, it finally passes to its formal approval through the project charter. The project charter is the document that formally authorizes the project and sanctions its launch. This document is usually drawn up and published by the project sponsor and gives the project manager formal authority over the project. This means that the project charter allows the project manager to have the necessary resources to complete the project activities.
Typically, the level of detail and information in the Project Charter vary according to the size of the project and the breadth of the scope. The basic information contained in the project charter are:

- commercial opportunities or needs that justify the start of the project;

- rough description of the product requirements, or more generally of the final output;
- objective or justification of the project;
- name of the project manager and level of authority that comes to him assigned;
- environmental factors and organizational resources;
- analysis of the influence of the main stakeholders.

The start of project activities is usually publicly promoted with the kick-off meeting. This meeting is attended by the client or his representatives, the main stakeholders, the project sponsor and the project management team. One of the fundamental objectives of the kick-off meeting is to make fundamental decisions relating to the revisions to be made to the project and the final acceptance of the order, thus linking the project activities to the ordinary management activities of the organization.

2.2 Planning

After the start-up phase of the project, we move on to the planning phase. Very often the haste or the desire to go directly to the implementation phase leads to underestimate this phase and not to dedicate the necessary time to it. Instead, it is a crucial phase for the whole process, which can determine the success or failure of a project. In particular, many activities are carried out such as defining a detailed cost plan, organizing the resources involved, defining a careful strategy to deal with the risks associated with a project and stakeholder management. It is during this phase that some fundamental documents are drawn up. The Gantt Chart, the Work Breakdown Structure are just some of the tools used by the project managers during this phase. The output of this phase is the Project Management Plan, documentation that is then submitted to all stakeholders for final approval.

The main Project Management plan can be presented both in summary and detailed form and can be composed of one or more auxiliary plans, which represent the real integration between the project activities and which must be detailed in proportion to the specificity of the project scope.

The development of the main Project Management plan involves the integration and coordination of all the different plans relating to the different aspects of quality, time and cost, as well as resource planning. It defines how to execute, monitor, control and ultimately close the project.

Once defined, the plan must be approved and subsequently "frozen"; in this way it will act as an initial "baseline" for the control and closure phases of the project. In any case, the master plan must be monitored and continuously integrated with changes suggested by feedback from the monitoring of the activities performed. In general, the plan should describe:

- the life cycle of the project and the activities associated with it (the WBS);
- the main inputs and outputs (deliverables) of the activities in relation to the project objectives,
- the methods of execution of the work and the places where they will be carried out;
- the relationships between project activities;
- the descriptions of the tools and techniques to be used for the execution of the project processes;
- the methods of monitoring and controlling the activities;
- the modalities of implementation of the changes;
- the methods of maintenance and use for safeguarding the integrity of the performance measurement baselines;
- the needs and methods of communication between stakeholders.

Alongside the main plan, the fundamental auxiliary plans in Project Management must be envisaged, i.e. plans for:

- project scope management;
- management of personnel recruitment;
- quality management and process improvement;
- scheduling management;
- cost management;
- procurement management;
- communication management;
- risk management;
- stakeholder management.

In these plans there are also some auxiliary components, such as:

- list of milestones;
- resource calendar;
- quality baseline (the scope baseline);
- scheduling baseline;
- cost baseline;
- risk register;
- stakeholder register ("stakeholder register").

2.3 Execution

Execution is the central phase of the project since the product or service is created and will then be supplied to the client. In this phase, most of the added value is created and most of the budget is spent.
The main task of the project manager in this phase is the coordination of all technical and organizational interfaces and the performance of a series of actions that are as effective as possible, with the aim of being able to complete all the activities that were established in the planning phase. The fundamental objective for the project manager in the execution phase is to keep the project within the established plans, intervening in case of need.
The execution of the project translates operationally into the management of deadlines and milestones. Among these, the most important are those provided for in the contract and those that identify the transitions between different phases.
Other than directing and managing, the execution of the project also requires the implementation of corrective actions. During the execution of the project work, it is usual to have to make some changes to the planned work resulting from specific customer requests within the contractual limits or for revisions in costs, in the project budget or in the scheduling of activities. Changes can therefore be requested directly or indirectly activated after a thorough analysis of customer expectations.
There are relevant topics that need to be considered during the implementation of a project:

- Information management: The management of information on project activities must be aimed at communicating to stakeholders and the project team all the data necessary for an efficient and

effective completion of the project. Information must be collected and distributed on a regular basis and with standardized tools and practices so that it is known by all.

- Project team and conflict management: During the execution phase of the project, the project manager must work to ensure that there is a development of the project team, both from the point of view of the growth of individual skills and in the interaction and integration between the members of the group. The dual objective is to increase individual skills and create cohesion and a collaborative attitude in the group by raising the level of mutual trust both at work and personal level.
- Quality assurance: the assurance of the quality system must ensure that the internal processes of the project are in line with the previously defined and planned quality policies; in fact, the requirements set out in the organization's quality system must be fully satisfied and if possible improved by following an established and formalized process

The project execution phase ends with the achievement of the objectives defined during the initial planning and delivery of the final output.

2.4 Monitoring and control

Execution and control are usually considered as a single phase of the project life cycle since they are carried out simultaneously, even if in reality they are two distinct processes. In fact, the execution is the phase relating to the realization of the planned activities, while the control allows to verify that the execution is in line with the planning.

Monitoring and control is a fundamental activity that allows to evaluate the progress of the project with respect to the set objectives. The purpose of this phase is in fact to highlight any deviations from the original plan and, if necessary, to intervene when it is necessary.

The measurement of the management variables of quality, time and cost makes it possible to make an objective assessment of the project situation and to use previous estimates as a basis for standardizing and making project activities more accurate. Furthermore, they express hidden criticalities and opportunities, facilitating management's decision-making process. This continuous process of analysis and data collection therefore does not take place as an independent phase, but throughout the execution of the project, allowing the project manager to take any corrective actions if unexpected events or deviations from what was previously set occur. It is, in fact, through the performance indicators that it is possible to make important decisions on an informed basis, thanks to the objectivity of the project progress measurement tools.

In summary, monitoring represents a continuous control over time which results in the following steps: (1) measuring, (2) detecting and (3) correcting. The monitoring process basically involves detecting the progress of the project in terms of:

- time spent;
- money spent;
- criticalities encountered in the execution of the activities;
- physically carried out work (documents issued, prototypes made, etc.);
- activity completion estimates;
- effectiveness of preventive actions to cover risks.

The method of collecting data must be appropriately selected based on the organizational situation in which it operates, the size of the project and its complexity. Therefore monitoring can be conducted through:

- interviews with the managers of the work packages;
- meetings on the progress of the project;
- feedback in the form of periodic reports.

In addition to the choice of detection methods, the frequency with which it will take place in line with the control needs of the project must also be defined.

2.5 Closing

Finally, there is the Closing phase in which, in the event of a positive outcome, the acceptance of the result by the client is formalized and payments are finalized.

The closing phase requires the company to release the latest deliverables to the customer, including the final output of the project. However, the project team must fulfil other tasks: from the formal and administrative closure of the contract to the preparation of the final documentation, which officially ends all activities. These documents, which will serve as the foundation for future projects, will contain important information such as the assessment of the risks and performance obtained, and an in-depth analysis of the differences between what was expected in the definition of the scope and the results actually achieved. The main documents that should be filed are:

- documents describing the product and the project (plans, specifications, technical documentation produced, issued and attached, etc.);
- documents relating to changes requested by the customer and approved;
- the performance measurement documents,
- supplier performance reports and documentation produced following any inspection carried out at suppliers, or received from the customer;
- the various reports on the status of the project and on the problems encountered that will be entered in the appropriate register ("issue log");
- financial documentation (invoices from suppliers, invoices issued to the customer, payment receipts, etc.);
- project risk logs and lessons learned.

3 Project Scope management

3.1 Introduction

When using the expression Project Scope, we do not simply refer to its goal(s), i.e. the delivery of a specific output, but rather to a wider concept, implying not only the final output, but the activities and tasks that lead to it.

Indeed, the area of Project Scope Management embraces all the processes needed to ensure the successful completion of the project, meaning that all the work required is understood, planned and performed. When talking about managing the Scope of a project, it mainly concerns the definition and control of what is included in the project (i.e. what should be done) and what is not.

This activity allows to define the "boundaries" of a project in a clear way, so as to allow a clear focus toward the final output. This might appear as a simple and not-always needed exercise, but when projects' dimensions reach a certain extent (in terms of activities to be carried on) it is essential to maintain a focalized attention to what is necessary and what is not, to avoid any "derailment".

From a more practical point of view, if it might come easier to understand the importance of Project Scope Management for the definition of work that needs to be carried on, on the other hand it might not be so intuitive for what concerns the control of what should not be done. Throughout the life cycle of a project, the client might change idea about the requirements, sometimes even more than once. For instance, at the half of the execution phase, new features might be required to be added for the product under development, causing a slow-down (or even a complete stop) of undergoing activities, in order to reconsider the definition of the requirements and/or of the infrastructure, eventually new parts to be designed and realized, and other related complications that would certainly result in a re-planning effort of many activities, causing an extension of project deadline. Project Scope Management in turns allow to monitor these change requests, to refuse them (if it is the case), or eventually to accept them and ensure an effective and controlled re-planning effort, with the aim of avoiding uncontrolled extensions of work.

3.2 Objectives

Project Scope Management aims to ensure that the project includes all the activities required for its effective and efficient completion. Consequently, the activity of managing the Project Scope includes:

- description, definition and planning of the Scope through the creation of a detailed Project Management Plan, which will serve as a basis for all future decisions;
- creation of the Work Breakdown Structure (WBS), i.e. the determination of the breakdown structure of the activities and the subdivision of the main deliverables and work included in the project;
- verification and control (Scope control) to accept changes (Scope change) and avoid uncontrolled "extensions" of the Scope without changes to time, costs and resources (Scope creep) through the formal acceptance of completed project deliverables and corrections made to the project plan.

Project Scope Management must specifically define project outputs, the deliverables, and the work required to obtain them. It is also essential that it clarifies the project objectives (general and detailed): the goal that the company wants to achieve, expressed in the form of defined and measurable results. The project objectives generally include: commercial goals, technical goals, temporal goals (deadlines), cost of the output, total cost of the project.

3.3 Processes

There are six key processes that define and structure all activities need to properly ensure the Project Scope Management. According to the Project Management Body of Knowledge, published by the Project Management Institute, these are:

1. Planning Scope Management: it has the goal of creating a Scope Management Plan, that defines the guidelines according to which the Project Scope will be defined, managed (validated) and controlled;
2. Collection of Requirements: starting from preliminary documents (e.g. Business Case, Project Charter) the aim is collecting all the requirements and needs of stakeholders involved, that will define the project goals;
3. Definition of the Scope: this process main output is the definition of the Project Scope itself, including detailed description of what is going to be realized (project output, project goals) and how;
4. Creation of the Work Breakdown Structure: moving from the Scope definition, this process aims at defining, subdividing and organizing all the work needed to reach the project goals;
5. Scope Validation: this process mainly concerns the formalized acceptance of all project deliverables;
6. Scope Control: has the objective of monitoring and controlling, throughout the whole project life cycle, the status of the Project Scope.

Planning Scope Management concerns the definition and creation of a Scope Management Plan. This document will guide all the other processes, and in particular how the Scope will be defined, how it will be validated, how it will be controlled. This process will be performed at least once at the beginning of the project, in the Planning phase, but it could have some verification moments at predefined stages of the project, or it could eventually be re-opened in case there is a request for changes and/or a need to re-plan some aspects. Starting from the Project Charter and the Project Management Plan (especially for what concerns Quality plans), this process should also consider internal and external factors (that can affect the Scope) as inputs for the definition of the Scope Management Plan. Together with this plan, there is usually the Requirements Management Plan, which defines how requirements will be defined, analysed, prioritized (eventually), tracked, documented and managed.

Collection of Requirements might appear as a non-relevant process, or at least non-essential. Actually, the ability of the project manager and team to meet all project goals is strictly related to this process. The main objective is to determine, to document and to manage all the expectations and needs of the stakeholders involved in the project. These expectations and needs will define the project goals, not only in terms of output to be realized, but also in terms of satisfying of all the actors (i.e. stakeholders) involved in the project, each one with its own set of objectives and interests. This process is usually performed only at the beginning moments of a projects, usually in the Planning phase after the elaboration of the Scope Management Plan. It takes as inputs all the relevant project documents available at the moment (i.e. Business Case, Project Charter, Project Management Plan, Stakeholder Register) to produce a complete and updated list of requirements that will support and guide the definition of the Scope. A useful tool in this process can be the Requirements Traceability Matrix, allowing to map and took note of all requirements, their links with stakeholder/business needs, and project elements.

Definition of the Scope, as the name itself suggests, is the process of definition and description of the Project Scope. Together with the key requirements for the products/outputs to be realized, it includes the

acceptance criteria that will acquire a particular relevance in the *Scope Validation* process. Moving from the Scope Management Plan and the list of Requirements, this process will elaborate and produce the Project Scope Statement. This document will describe and detail the Project Scope, including the major deliverables of the project. One of the main aims of this document is to provide a reference and a guide for stakeholders outside the project team, to communicate the Project Scope and provide a clear and common understanding of it. More in details, the Project Scope Statement will include:

- Detailed characteristics of the product, service, or output to be realized, together with the requirements documentation;
- List of all project deliverables, referring to each output that will be produced, including documentations and reports;
- Acceptance criteria that define the conditions upon which deliverables are accepted once completed;
- List of project exclusions, stating explicitly what falls outside the Project Scope and will act as a reference point for accepting or rejecting additional requests for change from stakeholders.

Creation of the Work Breakdown Structure is the natural following step once the Project Scope has been formally defined. The goal of this process is to produce the Work Breakdown Structure (WBS), a hierarchical structure decomposing the Project Scope into parts of work to be carried out, to ensure that the project meets all the requirements and needs. The WBS can be elaborated with a top-down approach, starting from the Scope Definition and "exploding" it into higher levels of detail, or with a bottom-up approach, which starts from the definition of basic tasks to be performed and then gathers them in clusters up to the Scope Definition. The lowest levels of the WBS represent all the planned work at the highest level of detail (according to project's goals), organized in Work Packages (WP). Each WP is generally associated to the realization of one (or more) deliverable(s), and includes one or more tasks, which are the ultimate level of detail of the work that needs to be carried out. WPs and tasks constitute also the basis for Project Time Management and Project Cost Management activities. The WBS, together with the Project Scope Statement, the complete list of all WPs and all deliverables, constitutes the Scope Baseline, which is the main output of this process.

Scope Validation mainly concerns the formal acceptance of deliverables throughout the project life cycle. It is a necessary process to ensure a formal and undisputable way to the acceptance process, and to maximize the chances that the final output will meet all requirements. This process takes usually place after the Quality Control acceptance of the output(s), and by taking into account the Scope Statement, the Scope Management Plan, and the Requirements Management Plan, it verifies that each output satisfies the corresponding requirements. The difference between Scope Validation and Quality Control process is that, while the latter accepts of rejects deliverables according to their conformity to quality standards, the former ensures their conformity to requirements and needs of the project and/or stakeholders.

Scope Control is the process of monitoring the status and the evolution of the Scope throughout the whole project life cycle, in a continuous effort. This process is also entitled to control and manage all change requests and any (eventual) corrective or preventive action that should be needed. The main goal

is to avoid uncontrolled extensions of the scope without adjusting the time, cost and (eventually) quality plans, labelled as Scope creep. During the execution of the project it might happen that requests for changes, usually called change requests, may be received. Change requests are formal change proposals promoted by the project team, by the client, or by stakeholders, and can also be related to the project scope and in this case they are called scope change requests or refer to documentation or deliverables of various kinds. It can be justified by critical issues that emerged during the execution phase or requests for changes to the output by the customer. Every time that a change request comes, or every time that there is a need to re-plan some activities/tasks in terms of time, costs, quality or resources, the Scope Control process ensures that all modifications are in line with the Project Scope.

3.4 Tools and Best Practices

Work Breakdown structure

The activities that characterize the development of a project can be articulated and represented in groups and sub-groups through a multi-level tree structure called Work Breakdown Structure (WBS). The tree structure of the WBS requires that each of its elements is connected exclusively to a single element of higher level. In addition, all elements must have a code consisting of as many digits as there are tree levels. The definition of the activities and the consequent structuring of the WBS can take place according to two different approaches.

- The first, the top-down approach, provides for starting from the definition of the project (corresponding to the 1st level of the WBS) and to determine the main phases or sub-projects (2nd level); subsequently further segmentations are carried out until reaching the lower levels.
- The second, the bottom-up approach, provides for the identification of activities based on project objectives and sub-objectives, or deliverables. Then the relationships between the activities are identified on the basis of homogeneity in terms of resources and skills necessary for their implementation and then the hierarchical structure is defined.

If the first approach is very useful for redefining some branches from WBS of past projects, the latter is generally more suitable for new projects as it allows for the inclusion of all the activities necessary to achieve the objectives without forgetting any.

The project is subdivided through the WBS into Work Packages (WP). A work package is a set of elementary activities with well-defined links to other work packages and uniquely characterized by internal inputs, outputs and activities. Resources, execution times and responsibilities can be associated with each work package. In doing so, it forms the basis for planning, budgeting, timing and monitoring the progress of the project.

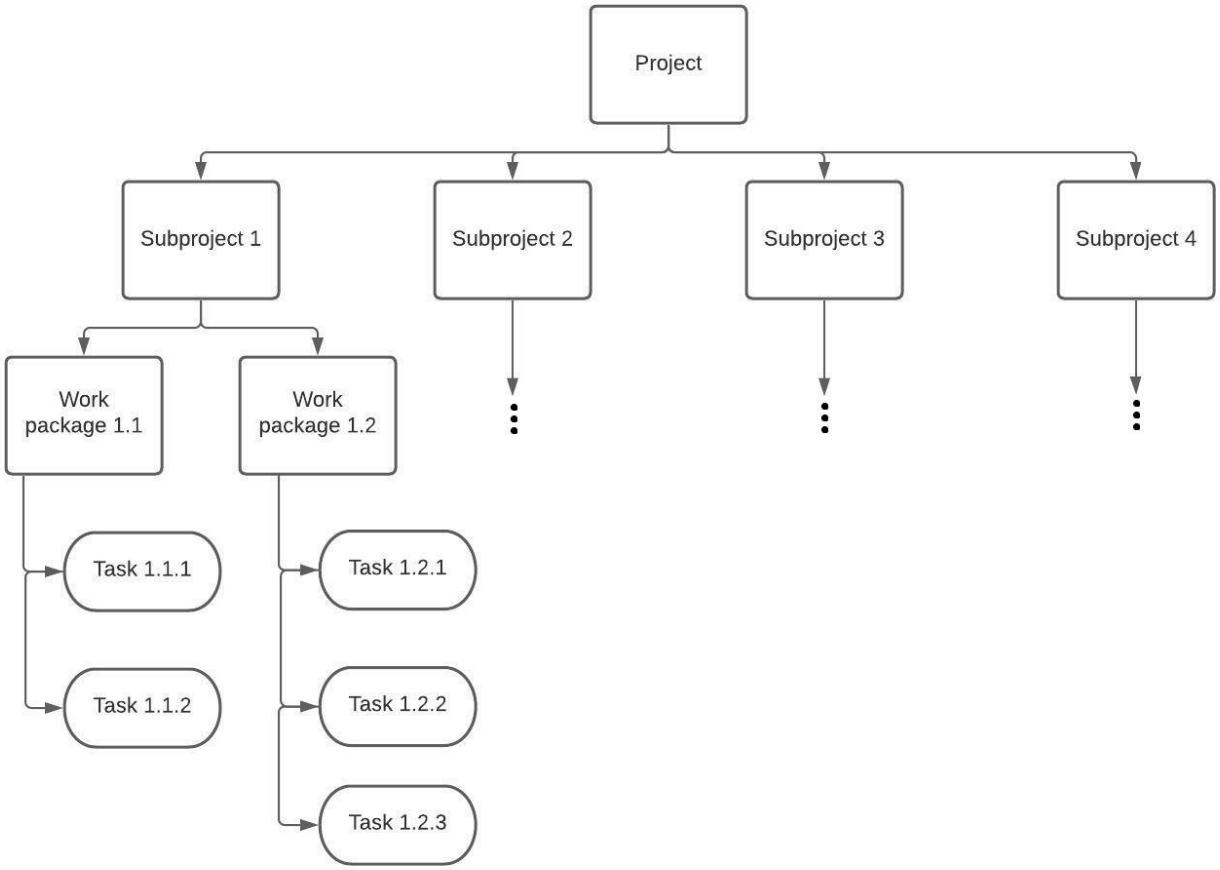

Figure 3.1 Example of WBS

4 Project Time management

4.1 Introduction

Each project, by its definition, is characterized by a closing date, expressly indicated in the contract and / or in the project start-up document. To ensure that the project can be completed before or close to that date, there is a need for a project schedule and careful management of project resources based on that specific schedule. Imagine you want to renovate your kitchen, deciding to do it economically and therefore investing your free time. By doing this, you generally do not decide on an end date in advance or plan a precise schedule of interventions. Also, do not foresee specific working days, you just do it when the opportunity comes. What happens most of the time is that years go by and your project will never be finished. It is for this reason that time management is so critical. Without it, projects would never be completed in a reasonable time, or worse, never actually completed.

Therefore, time represented the first management variable of Project Management to be consistently supported by specific techniques. This is due to the considerable repercussions caused by the variations in costs and times in the large military and civil orders of the second post-war period. The planning of project times is a fundamental activity for project management as it affects one of the fundamental project performances, i.e. time.

Following the activity of breaking down the project into a work breakdown structure (WBS) and a correct drafting of the WBS "dictionary", the activities must be sequenced, estimating their duration and the logical start and end constraints. On the basis of the list of activities, first of all it is necessary to establish the general logic with which the same activities are related to each other, through the so-called dependence ties or relationships or priority constraints, then establish the duration of the individual activities, then develop an overall time schedule of the project.

4.2 Objectives

The main purpose of project time management is to ensure that the execution of project activities is as close as possible to what was planned, intervening with changes where necessary. Some contracts or agreements with the customer, in fact, may include penalties whether the deviations from the approved planning exceed certain levels. Time management must ensure a correct and realistic preparation of the time period allocated to the project, in order to also ensure that an adequate budget is foreseen for it. This realistic time frame is based on the sum of the estimated durations of each critical activity within the project.

In addition, this management requires monitoring of the time actually spent compared to the planned time, providing real-time feedback on the status of the project execution. The tracked time will give the project manager a warning about the project, in case the time is starting to get out of control and the project end date may not be met. Finally, the monitoring of the actual time devoted to project activities will be useful for future projects because, when planning new projects, knowing the actual time spent by an activity from a previous project gives an accurate estimate on the same activity.

4.3 Processes

After defining the tasks (or activities) and the project deliverables, effective project duration management passes through some fundamental processes, which can be summarized as follows:

- Sequencing according to logical precedence constraints of the activities;
- Estimate of the specific duration of each activity also considering probabilistic ranges;
- Scheduling and graphic representation of the project plan;
- Control and potential corrective actions.

The ***sequencing of project activities*** involves the consideration of project activities or tasks that derive directly from the Work breakdown structure, which however does not provide useful information on completion times. In fact, the completion of an activity means the release of a deliverable resulting from work or effort provided by the project resources in a certain amount of time. However, not all activities can start at the same time at the beginning of the project, both because resources are limited, and because it often happens that the production of one or more outputs by one or more upstream activities could serve as a necessary input to carry out downstream activities. In these cases, we speak of activity priority constraints, which can be represented through a project network diagram.

The ***estimate of the duration of each activity***, which requires an estimate of the amount of work required to complete the scheduled activity, takes place after having estimated the overall resources necessary for the execution of the activities. The duration of activities is often difficult to predict, as there are many factors that can influence it, such as the type of activity, the productivity of the resources employed and possible delays caused by unforeseen events. The work to be done on the activities therefore initially involves the discussion and analysis of the durations in specific project team meetings, and they can be deterministic (therefore certain) or probabilistic (i.e. estimated with a certain degree of confidence).

The ***scheduling of the project plan*** often involves the use of network diagramming techniques (e.g. Critical Path Method, PERT), usually used in project management for the elaboration of the project time plan, for the identification of the start and end dates of each individual activity, as well as the identification of the critical path, that is the subset of the project activities that are critical for meeting the project timelines. Identification of the critical path therefore allows a plausible estimate of the total duration and the start and end dates of the entire project; complementarily, it allows to determine the existence, or not, of possible slips (also called "slack time" or "float time"). That is, those periods of time within which it is possible to move the implementation of an activity, without thereby determining an overall lengthening of the project time. Once the schedule of the activities has been defined, these are conveyed into the Gantt chart, which is one of the most used representations of time as well as a graphical interface of many project management software, as it is simple to design and easy to read. For each activity, its start and end date can be read immediately on the temporal abscissa, while the duration of the activity is proportional to the length of the bar; in addition, through the blackening of the bar it is possible to view the progress of the work in reference to a certain date taken as today.

Once the project Gantt has been defined, it is desirable to foresee a process of ***control and potential correction of the project times*** at certain moments, the so-called “milestones”, which act as monitoring moments to approve what has been done up to that moment and enable the activities planned later. The most used symbology to indicate moments of time dedicated to milestones are small rhombuses inside Gantt. They are therefore fundamental points of reference that clearly and unambiguously signal a

significant event or an important decision moment within a project. The purposes pursued during the milestones are manifold. On the one hand, the aim is to ensure that the project has remained well connected to the initially set cost, time and quality objectives, verifying the activities carried out and evaluating the deliverables released. On the other hand, the milestones are useful for verifying the team's production performance and identifying the presence of underloads in resources. During these moments, corrective actions can be taken on the resources used, if necessary, impacting on the definition of the project time plan, for example by postponing the start of an activity. There are two possibilities for levelling loads. The levelling of the times, using the previously calculated slack times, therefore not modifying the overall duration of the project, or the levelling of the resources, exceeding the slack times and therefore extending the overall duration of the project.

4.4 Tools and Best Practices

Gantt chart

Even today, with the necessary changes and the use of advanced digital programs, Gantt charts represent the fundamental reference point for the planning and management of any type of project.

Visually, it appears as a Cartesian diagram, which shows the time scale along which the project develops on the abscissas and the activities necessary to achieve the final goal on the ordinates. The coloured bars, that are generated from the intersection of the data relating to the activities and those referring to the relative durations, allow to have an immediate glance of the timing and things to do.

In projects that require the collaboration of several profiles, the chart represents an indispensable tool as it allows all interested parties to know in detail their duties and their respective timelines and deadlines. Among the features that make it particularly functional is the extreme flexibility, through which it is possible to more easily manage the changes that, almost inevitably, need to be made to the project during construction.

The Gantt chart contains the following data:

- Start and end date of the project
- Activities that define the project
- The tasks assigned to each person involved in the development of the project
- The temporal estimates of each individual activity
- The methods of coordination of activities and related dependencies (which activities can be carried out at any time and which ones must necessarily be carried out before or after certain activities)

The tool greatly facilitates the initial planning process of a project: it allows to define the timeline, establish dependencies between the various activities to be carried out, assign resources in an optimal way, estimate the timing of implementation.

During the execution phases of the project, the diagram is useful to have a clear and immediate overview of the progress of the work. It is an excellent communication tool, for example to provide updates to team members on the status of work. Nevertheless, the usefulness in the execution phase of the project is closely linked to the update, which must be carried out in a precise, detailed and timely manner.

Network diagram

A network diagram is a graphical way to visualize activities and their precedence constraints. Nodes represent activities, and precedence constraints appear as oriented lines connecting those nodes. The network diagram is the starting representation for any time analysis in project management.

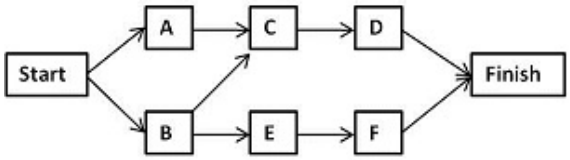

Figure 4.1 Example of network diagram

Critical Path Method (CPM)

The Critical Path Method is a planning technique created in the 1950s by scholars Morgan R. Walker of DuPont and James E. Kelley, Jr. of Remington Rand. It allows professionals who deal with project management to identify which activities, among all those that can be contemplated, are really critical for the purpose of respecting the deadlines and achieving the objectives.

The CPM can be structured in some critical steps. The first step concerns the identification of all project activities, through the analysis of the "leaves" of the WBS. The second step concerns the graphic representation of the sequence of activities according to the precedence constraints and therefore the construction of the network diagram. In the third step, the critical path is determined through a simple numerical exercise. Finally, step 4 aims to determine the so-called slack times (the possible slips of activity).

These steps are fundamental to identify the minimum time needed to complete the project, to calculate the start and end times for each of the activities, to identify which activities can be delayed without delaying the project, and on which activities to intervene to effectively reduce the total duration of the project.

After defining the steps, let's try to put them into practice with a simple exercise. The table shows all the project tasks, with relative duration and indication of the tasks whose completion must necessarily precede the start of the activity considered. Having this data, it is easy to represent the network diagram. While the arrows indicate the precedence, each node relating to a task allows the insertion of 4 numerical values in the 4 cells below the activity’s name, according to the following logic: In the row below, the minimum start (left) and end (right) date of the activity will be calculated. In the row above, vice versa, the maximum start (left) and end (right) date will be calculated. These four values will be fundamental to identify the so-called “project critical path”.

Task	Lenght	Predec.
A	10	-
B	5	A
C	8	A
D	5	B,C
E	10	C
F	6	E,D

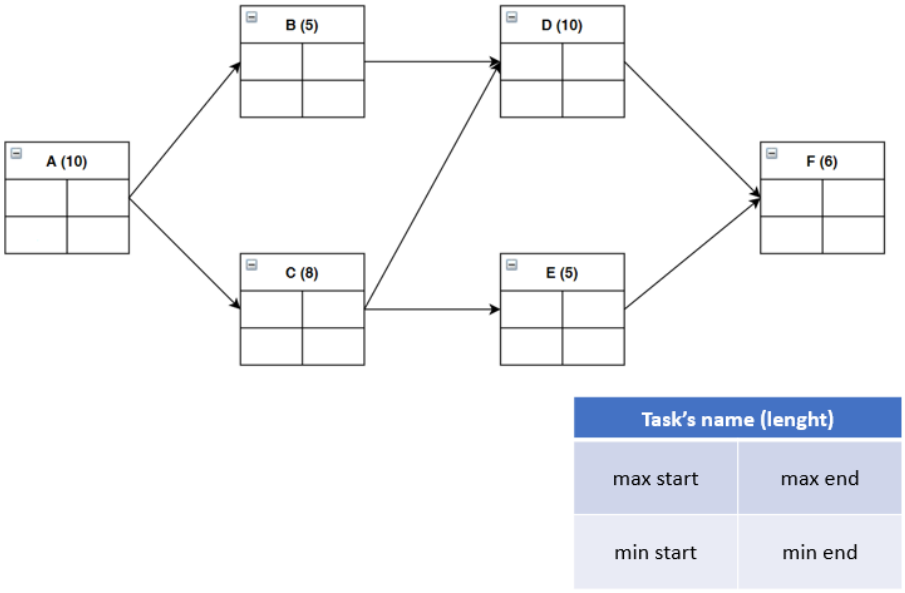

Figure 4.2 First step of CPM implementation

Let's assume, to avoid problems with dates, to calculate the project period in uniform units of time, for example weeks. Given the graph, to calculate the 4 weeks relating to each node, two distinct processes must be followed:

1. starting from the project start date (assuming 0), we move forward on the grid trying to anticipate the start of all subsequent activities as much as possible; in the case of "confluences" of activities, the next one takes as its beginning the date that is furthest forward (with the maximum value) between the minimum end dates of the previous ones.
2. starting from the date of conclusion of the project (calculated at the end of the previous process) we move backwards on the grid; in the case of "branches" of activities, the previous one takes as its end the most backward date (the "min") between the maximum start dates of the following.

We therefore start from the first activity A. Starting from 0, the duration of the activity is added, in this case 10, thus arriving at period 10. Activities B and C can start in parallel once activity A is completed; therefore, the start will be for both at time 10. B will be completed at time 15, while C will be completed at time 18. Activity D can only begin when both B and C are completed. There is a confluence which, considering the previous rule, allows the minimum start of the activity at the highest value among the previous activities, in this case 18. The rest follows the same rule.

The calculation of the maximum start and end dates starts from the last activity F. Starting from period 34, the duration of the activity is subtracted, in this case 6, thus arriving at period 28. Activities E and D must have as their maximum end date the maximum start date of the activity that precedes, so the end will be for both at time 28. Subtracting their duration from both, there will be 18 for D and 23 for E. Activity C had a branch which, considering the previous rule, allows the maximum end of the activity to the minimum value between the maximum start dates of the subsequent activities, in this case 18. The rest follows the same rule.

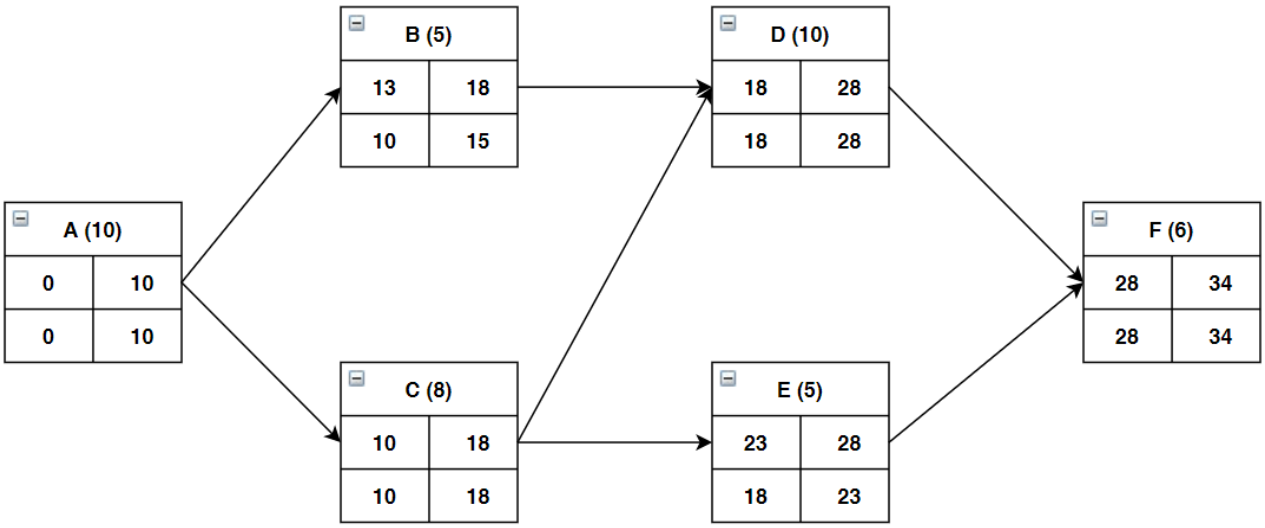

Figure 4.3 Second step of CPM implementation

Once the maximum and minimum start and end dates have been defined, the total slack is the maximum slip, or margin of flexibility available, that an activity can have, such that the start and end constraints of the entire project are respected. From a mathematical point of view, that is the difference between the maximum and minimum start (or end, since the values coincide) dates of an activity.
The critical project path consists of the set of activities which, following these calculations, have a Total Slack equal to 0. This means that increasing the duration of any of these activities will inevitably lengthen the overall duration of the project.

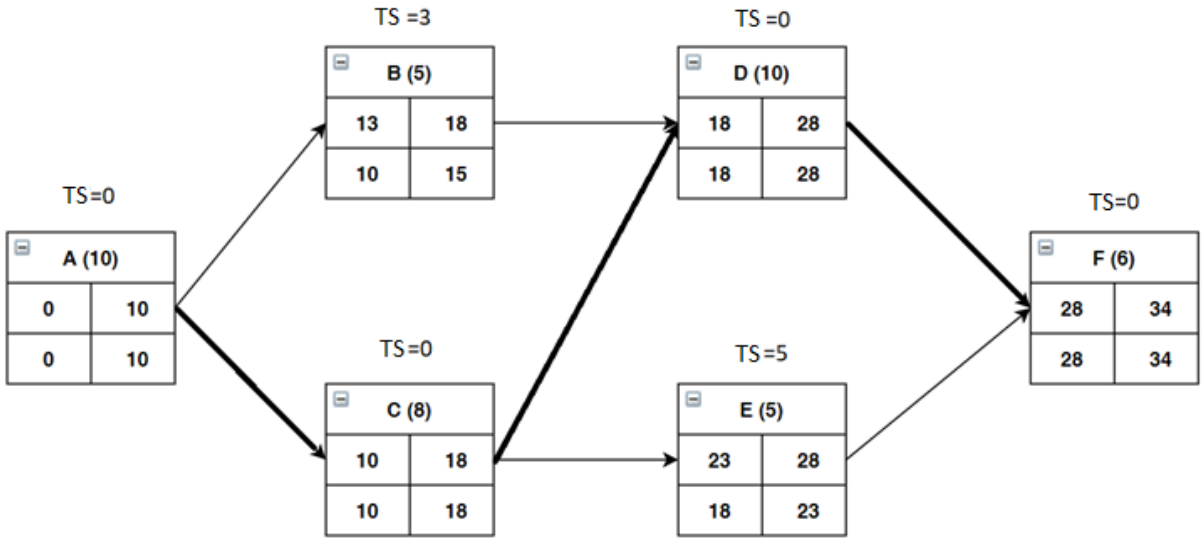

Figure 4.4 Final step of CPM implementation

Program Evaluation and Review Technique (PERT)
PERT is a statistical method of quantitative risk analysis that can be used both for the completion times of the activities and for the costs. In the following, we will focus on the time-based version. The method

makes use of the three-point estimate, considering the uncertainty and risk in the original estimate, thanks to which the accuracy of the estimate of the duration of the activities is increased. In practice, this technique uses three types of estimates, with the aim of defining an approximate range for the duration of the activities:

- Most likely (ml): this estimate is based on the duration of the activity, given the resources that will likely be allocated, their productivity, realistic expectations in terms of availability for the scheduled activity and the relationships of dependence on other participants
- Optimistic (opt): the duration of the activity is based on the analysis of the best scenario, relative to what is described in the most likely estimate
- Pessimistic (pess): the duration of the activity is based on the analysis of the worst scenario, relative to what is described in the most probable estimate.

Having the three data defined above, it is possible to calculate the expected duration and the variance of each activity with the formulas shown.

- expected duration = $d_{exp} = (d_{pess} + 4d_{ml} + d_{opt})/6$
- variance = $\sigma^2 = (d_{pess} - d_{opt})^2/36$

The probability of completing the project in time will be given by the cumulative probability between the extreme left of the Normal Standardized distribution curve and the z point defined as:

$$Z = \frac{T-Te}{\sqrt{V}}$$

Where:
T = Time required by the customer to complete the project
Te = Sum of the expected durations of the activities of the critical path
V = Sum of the variances of the activities of the critical path

A practical exercise can help to consolidate the concepts expressed. Let's assume a project consisting of 6 activities with a total duration requested by the client of 31 weeks. The project manager must understand the likelihood of finishing on time, avoiding penalties for delay. Through analysis, the project manager can extrapolate the pessimistic, optimistic and most probable durations of all activities. At this point he/she can calculate the expected durations and the respective variances.

Table 4.1 Foundamental table for PERT

Task	Predec.	Opt	Most Likely	Pess	Expected duration	Variance
A	-	5	10	12	9,5	1,36
B	A	4	5	12	6,0	1,78
C	A	7	8	10	8,2	0,25
D	B,C	3	5	13	6,0	2,78
E	C	5	10	11	9,3	1,00
F	E,D	5	6	12	6,8	1,36

After identifying the critical path through a simple Critical Path Method (in this case ACDF), he/she will sum the expected durations and variances of the activities on the path.
Applying the formula to derive Z, it will obtain a value equal to 0.62
$Z = (31 – 30,5)/\sqrt{5,75} = 0,62$
Finally, by checking the position of the value on the normal distribution table, he/she will find that the probability of completion of the project in the required time is equal to 73%, while in 27% of cases he/she will not be able to maintain the expected delivery.

Fast tracking

Fast tracking is a corrective action on the project that involves the compression of the overall duration of the project thanks to the overlapping of activities that were previously sequential. It therefore provides for the introduction of a so-called "lead", an amount of time in which two or more activities are carried out in parallel. It is a viable option only in the event of good availability of resources. It involves the production of intermediate deliverables (thus increasing the total number of project deliverables) which will become definitive only at the end of the previous activity, i.e. at the end of the overlap. Finally, it requires a greater exchange of information between overlapping activities to ensure alignment on the scope.

Time Crashing

Time crashing is a corrective action which, by reducing the duration of one or more activities belonging to the critical path, allows the overall project to finish earlier than the current projection. It requires an increase in the resources allocated to the activities in question, so that the activities take less time than they were planned for. This translates into increased costs for overtime, additional resources and subcontracting. Since only an acceleration of the activities along the critical path will compress the duration of the entire project, the crashing action must be preceded by an analysis of the alternatives that can lead to the maximum compression of the duration of the project at the minimum cost.

5 Project Cost management

5.1 Introduction

All projects always require the purchase of any type of material or service. Regardless of the purpose or program projects need funds to complete the work. Without project cost management, the organization could lose its profit as the costs could outweigh the profits.

Bringing everything into an example of everyday life, imagine you want to build a house, the first thing you usually do is to set a budget to respect (as it is rare to have unlimited financial resources). Once you have decided on the maximum amount available, the next step is to divide the high-level budget into expenses for sub-activities and individual elements of the house (kitchen, bathroom, living, etc.). The budget will consequently influence some critical decisions such as: which architect to hire, what comforts the house should have, quality level of the materials used, etc. Without having defined a first budget, these questions risk being left unanswered, moreover it becomes impossible to assess with certainty whether the project, once started, is going in the right direction and respecting the financial resources.

The project budget, in general, is therefore a tool to support project management which refers to a project that is about to be launched and which describes all the economic resources in purely monetary terms, dividing the expected disbursements over time and, at the at the same time, attributing these disbursements to specific project activities. In the case of a contract, the amount available for the project must first be reduced by the expected profit margin; what remains is called the project budget and can include the so-called target costs, i.e. those negotiated ex-ante (for example millions of euros recognized per km of track, for a road) and the estimated costs, i.e. those expected with a certain probability (e.g. the cost of starting up a plant).

5.2 Objectives

The main objective of project cost management is the estimation of the expected costs for each element of the project (activity, Work Package - WP or deliverable), giving information about their correct size, their temporal distribution and their assignment to the organizational managers , in order to develop an overall project budget. The estimate also makes it possible to clarify to the stakeholders what their expectations should be towards the project in terms of quality (which, as we know, is closely linked to the cost), and establish to the shareholders what their expectations should be regarding the expected margin. and the ROI of the project.

The second objective, equally important, concerns the subsequent control based on the comparison between the estimated costs and those actually incurred at a certain date, in order to analyze the deviations from the estimates and evaluate the corrective actions to be taken. This process mainly helps to maintain as much as possible the margin agreed in principle with the shareholders, avoiding loss of money and financial inefficiencies during the execution of the project, but at the same time taking advantage of savings opportunities. This type of control is also a prerequisite for controlling the onset of possible scope creep (uncontrollable expansion of the project objectives that occurs suddenly and without manifesting itself with particular signals) due to aspects not clearly established with the customer during the contract.

Finally, every cost management process should involve generating data that serves as a benchmark for future projects and tracks long-term cost trends.

5.3 Processes

Project cost management is divided into four processes:

- Cost Management Planning, which establishes the operating procedures, policies and all the necessary documentation that will uniquely define how the project costs will be correctly managed.
- Cost Estimating, in which the costs of the resources to be used in the project, and therefore its overall cost, are determined in advance;
- Cost Budgeting, in which the aforementioned costs are optimized in a "budget", whose expenditure over time is described through a curve called "baseline";
- Cost Control, during which the progression of expenditure with respect to the budget must be kept under control and an analysis of the deviations carried out in real time.

During the **Cost Management Planning** process, the management methods on costs to be adopted on your project will be established. In other words, it is about deciding the guidelines relating to "how" the project manager intends to manage the economic resources assigned to the project. At the end of this process, you will get a document called a cost management plan.
Within the cost management plan you will need to clearly and unambiguously define the way in which project costs are planned, structured and controlled. The plan must address various aspects related to cost management including:

- unit of measurement, i.e. defining the size, quantity, capacity, amount, etc. Since the variation in size can cause significant increases in material and manufacturing costs, this is a crucial aspect especially when carrying out project phases in different countries. Establishing a common point of reference can facilitate communication and avoid misunderstandings.
- levels of precision, i.e. defining how close the measured values are to each other, for example the rounding of decimal places in the calculated totals, which could become the cause of significant deviations in the cost estimate.
- level of accuracy and control thresholds, i.e. the regulation of the standards of variation of the minimum and maximum costs.
- reporting formats, i.e. establishing reporting protocols, their format and frequency in all phases of a project.

The **Cost Estimating** process is the moment in which the project manager must first determine the costs of the resources to be used in the project and therefore its overall cost. In the event of a response to a request for an offer, this cost determination should be carried out during the budgeting phase for the formulation of the economic offer and on the basis of the activities necessary for carrying out the project, activities that are typically described in the Work Breakdown Structure (see Scope chapter for further details).
Cost estimates are refined over the project life. In fact, it is possible to distinguish a general estimate of costs from a detailed planning of costs: the general estimate of costs is oriented to a first rough evaluation of the project expenditure, because the database is going to be clearer only when the project is started, making it possible to use more precise methods. General cost estimation often uses parametric or analogy

estimation procedures. Parametric estimation is based on the creation of valuation models that are a function of quantitatively measurable parameters. The estimate by analogy makes an estimate based on previous experience and is delegated to experts or seniors subsequently appointed as managers of the work packages.
The process following the estimate is that of **Cost Budgeting**, which is necessary to aggregate the estimated costs for the individual activities or work packages and obtain the so-called “baseline” of the authorized costs. In this phase, the previously estimated project budget is divided into a preponderant part, called the "baseline", and into a portion set aside as a "management reserve" intended to cover unexpected work within the scope: this latter is particularly important for projects that are configured as orders and in which there are penalties for delayed delivery; given the inevitable uncertainty of some variables, a certain economic margin to cover any penalties in the face of possible delays must therefore be provided.
The baseline, on the other hand, is the real sum available for carrying out the activities related to the project. The baseline is a crucial element of project management, as it allows you to measure performance or conduct an analysis of the value achieved in the project. It represents the curve of the cumulative costs over time of the project. Since generally in the early stages there is a reduced expense, and subsequently a strong increase followed by a flattening of the costs, it has an "S" shape. It is placed on a cost / time Cartesian plan and starting from the origin of the axes, it reaches the point of conclusion of the project, with a temporal abscissa equal to the duration of the project and costs on ordinate equal to the total value of the project. This curve is mainly made up of so-called “Cost Accounts” (CA) linked to Work Packages (WP) that must be carried out by specified resources. These cost accounts are assigned to managers, who are simultaneously given financial resources to cover the effort necessary to complete the work package, uniquely identifying "who does what and with what budget".

Once the project has begun, it is necessary to keep its progress under control, not only of the works and technical performances, but also of the costs, in order to be able to intervene in good time. The **Cost Control** process must follow three steps: detection of costs actually incurred, comparison of actual costs with the budget and analysis of variances. The objectives of this activity are multiple:

- record all changes made with respect to the cost baseline,
- monitor cost trends to detect and understand any deviations from the cost baseline;
- identify the factors that cause changes to the cost baseline;
- implement any corrective measures to bring the cost overrun back within acceptable limits.
- ensure that the requested changes are all correctly agreed upon.

5.4 Tools and Best Practices

Analogous estimating for costs
Analogous estimating means considering parameters such as scope, cost, budget and duration of similar projects previously carried out as a basis for estimating the costs of the current project. The tangible benefit of this technique is the ease of use combined with the speed with which a first estimate is reached. The opinion of the experts, strengthened by their experience, represents a valid tool in order to know what has been gained in terms of knowledge on similar projects previously carried out. The risk lies in

not having objective and verifiable elements, but opinions, in fact, that are subjective and prone to error or underestimation.

Parametric estimating for costs

This is a very widespread technique in some sectors (construction, aeronautics, etc.). According to this technique, the cost is expressed with an analytic function coming from a set of variables. This usually consists of a series of numerical data derived from the main characteristics of the product and therefore a function of parameters such as scope, size of the project, level of performance.

Obviously, all and only those values that are considered to have a certain influence on the final cost of the product are reported in the data set; all other values are discarded in the analysis phase or a priori. These parameters are defined as "cost drivers".

Parametric estimation is more accurate if the historical information used is accurate, the parameters of the mathematical model are easily quantifiable, and the model is scalable and therefore applicable to both small and large projects.

PERT

It is possible to improve the accuracy of the estimate by operating on uncertainty and risk.

The reference technique to be used in this case is PERT (for further details see the Time chapter). The PERT technique uses three estimates (Most Likely, Optimistic, Pessimistic) to find an approximate range of the costs of individual activities.

The expected cost for the activity is estimated according to the PERT technique with a weighted average of the three values

$C_{exp} = (C_{pess} + 4C_{ml} + C_{opt})/6$

Earned Value Method

The method called Earned Value Method is based on the value, according to the budget, of the work actually performed. Given the total project budget and the percentage of work-progress at a given time, it is possible to calculate the Earned Value as a product of the budget for this percentage.

The baseline curve represents the expected trend for project costs in relation to time, costs which are also called Planned Value (PV). Since costs and times are considered in a preventive key, the baseline is also called Budgeted Cost of Work Scheduled (**BCWS**): this term refers to the cost, estimated in the budget, for the planned work.

The control of project costs is carried out using, in addition to the baseline, two other curves, with acronyms similar to that for the baseline:

- the Actual Cost of Work Performed (ACWP) curve, i.e. the curve of the work actually carried out and with real incurred costs, which represents the trend of the Actual Costs;
- the Budgeted Cost of Work Performed (BCWP) curve, the curve of the work actually carried out but at expected costs, which represents the trend of the value indicated as Earned Value (EV).

The need to introduce a third curve (the BCWP) in addition to the baseline and the costs incurred curve may be not very intuitive, but it is of fundamental importance. In fact, once a certain intermediate date has been set, which can be called "timenow", the curve of costs actually incurred, the ACWP, is not known for its following part, since it is not possible to know with certainty how much will actually be

spent in the future. Furthermore, the comparison between the ACWP curve and the baseline may not be exhaustive, because by that date you may have spent as much as expected (i.e. the costs incurred may be identical to those budgeted) but you may have completed less work than expected, with costs however higher, for example due to inefficiencies or delays in carrying out the work. The introduction of the third curve, the BCWP, allows to consider the Earned Value in this comparison: in more detail, it is possible to see how much would have been spent, according to the costs foreseen in the budget, for the work actually carried out.

The Earned Value method, thanks to the comparison between the three curves, allows to calculate two deviations that provide immediate information on the progress of the project. In addition, it also allows to make predictions on the future course of the project. More in detail, it is possible to calculate two different deviations:

- The variance in costs, indicated with Cost Variance (CV), is equal to the Earned Value (EV) minus the Actual Cost (AC). This indicator represents the difference between the expected budget and the amount actually spent.
- The time difference, indicated with Schedule Variance (SV), is equal to the Earned Value (EV) minus the Planned Value (PV). This indicator represents the deviation between actual and planned duration.

In addition to the deviations, it is also possible to calculate two dimensionless indicators:

- The Cost Performance Index (CPI), also called the cost efficiency index, is calculated as the ratio between the Earned Value (EV) and the Actual Cost (AC).

If this index assumes a value lower than 1 it means that we are in a situation of higher cost than estimated, while a value higher than 1 indicates a situation of lower cost.

- The Schedule Performance Index (SPI), also called the scheduling or timing efficiency index, is calculated as the ratio between the Earned Value (EV) and the Planned Value (PV).

Values less than 1 of this indicator represent a situation of inefficiency on times, and therefore delay, while values greater than 1 represent a situation of efficiency, and therefore advance.

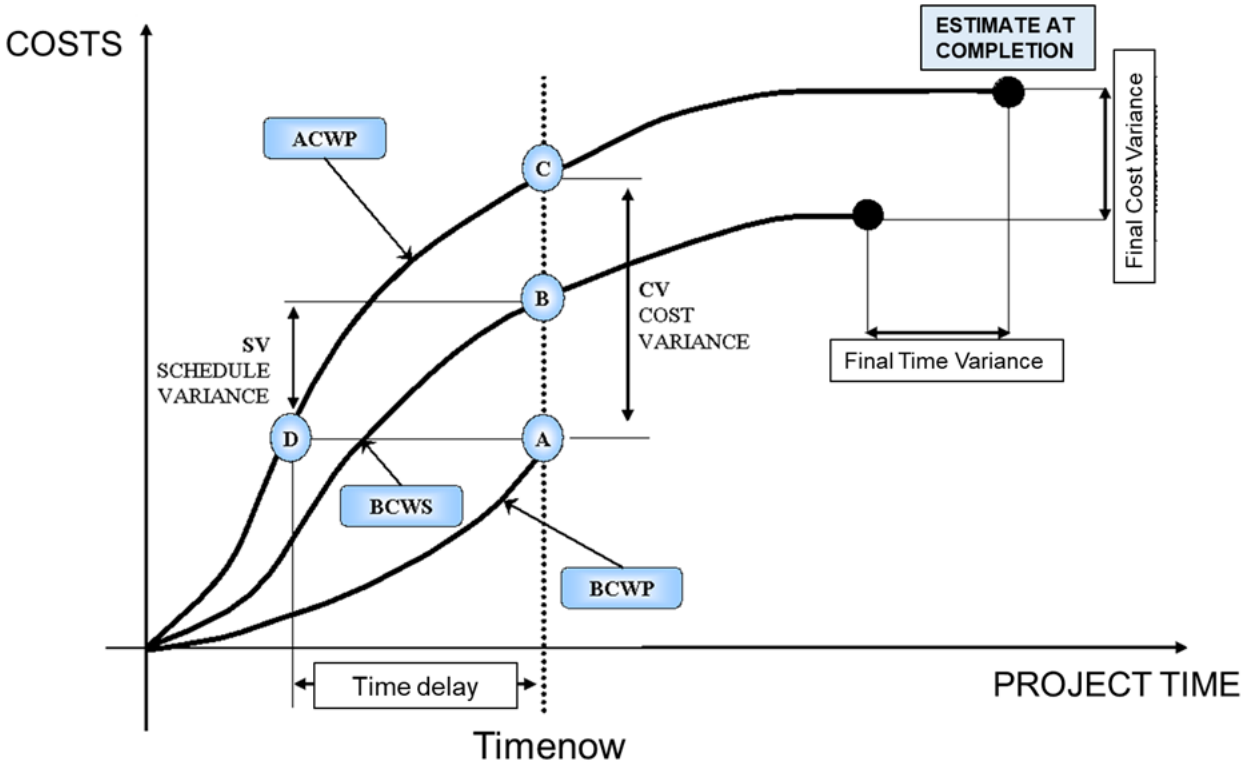

Figure 5.1 Basic elements of EVM on chart

As anticipated, with the Earned Value method it is possible to make predictions on the future trend of the project. More specifically, it is possible to calculate an estimate of the actual costs that will be incurred overall at the closure of the project, called Estimate At Completion (EAC), by simply adding the actual cost (AC) and the estimated cost of residual work, Estimate to Complete (ETC). Based on what is highlighted by the deviations and the indices, there are three possible approaches for calculating the ETC and consequently the EAC:

1) Forecast of the cost at the end of the project based on the expected costs: the efficiencies or inefficiencies found are not considered representative of future performance and therefore any deviations are considered atypical;
2) Forecast of the cost at the end of the project based on the cost performances: the efficiencies or inefficiencies of cost found are considered representative of the future performance and therefore any deviations are considered typical, or characteristic, of the project;
3) Forecast of the cost at the end of the project based on cost and time performances: the efficiencies or inefficiencies of cost and time detected are considered representative of future performance and therefore any deviations are considered typical, or characteristic, of the project.

In summary, if any efficiencies or inefficiencies detected through the CPI and SPI indices should be considered as originating not from randomness but from systematic factors, it is fair to assume that these factors will continue to influence the progress of the project, and therefore the estimate of the budget necessary for completion must take into account these factors, which will increase, in case of systematic inefficiency, or decrease, in case of efficiency, the estimate.

6 Project Quality management

6.1 Introduction

If you asked someone to build you a house, would you want it made of straw and mud? Maybe not. In fact, regardless of what are the areas, characteristics, requirements of the project in question, there is always an imperative: the customer will want the agreed quality for the project to be delivered. It may happen that the customer allows the use of cheap materials or not so innovative technologies for his/her project, but in the end he/she will always evaluate the overall quality of the final project output, based on his/her initial expectations.

In the start-up phase, the customer and the project manager, with the help of the project team, collaboratively define the objectives of the project together with the timing of completion. Project deliveries must therefore meet certain generic industry quality standards as well as customer specific requirements. Therefore, all project outputs - whether they are one or many - must be validated and verified before delivery to the customer. Quality must not only concern the output, but also the processes and activities that produce these results. In general, if the processes and activities that produce the deliverables do not adhere to quality standards, there is a high probability that the output does not meet the delivery quality standards.

Therefore, carefully considering quality is a necessary requirement for all types of projects: from the restoration of sports cars to construction, it is necessary to be able to ensure a good quality of the project and to have the foresight to understand and know all the important details that they concern, that is, what are all the details that transform the project output into a quality output, which therefore guarantees an adequate performance for its use. The role of the PM is therefore expressed in the responsibility of ensuring that the product is built according to the standards in force, in order to have a positive result in the related legal inspections as well as in the inclusion, in the quality management plan, of preventive actions, tolerances and control limits associated with project performance.

The internal quality management systems should have as their starting point the Deming "Plan-Do-Check-Act" cycle which includes four fundamental steps to be considered and applied in sequence:

1. Plan: in this phase the objectives are established and the processes necessary to produce results in accordance with customer requirements and the organization's policies are defined.
2. Do: this phase consists in the implementation of the planned processes.
3. Check: this verification phase provides for the monitoring and measurement of the actions taken to compare the results achieved with the expected objectives.
4. Act: this phase consists in the initiation of new actions to correct any inappropriate processes and to obtain continuous improvement in performance by preparing a new P-D-C-A cycle.

However, quality management must not be limited to satisfying the requirements of the customer and stakeholders in general, or to achieving the project scheduling objectives through the prevention of possible errors or the management of operational risks. The Plan-Do-Check-Act cycle on which quality management is based must be the basis for continuous quality improvement.

6.2 Objectives

The quality management of a project aims to achieve a level of satisfaction with respect to all the implicit requirements and those explicitly declared in its start-up phase. These requirements must perfectly reflect

the expectations of all stakeholders. Consequently, the "Project Quality Management" (PQM) envisages a succession of activities aimed at ensuring that the project meets the needs for which it was undertaken. The PQM includes all those activities that identify a correct quality management policy, the implicit and explicit objectives and the related responsibilities.
In summary, a good quality management process should aim to:

- examine the expressed or implicit needs of each customer and collaborate for a complete definition of the contractual requirements, maintaining and perfecting the collaboration relationship over time;
- comply with the quality standards previously established and at the same time improve them in accordance with the customer's needs in terms of cost, reliability and level of availability;
- provide the customer with documentation suitable for the immediate and full use of the product and service provided;
- assist the customer throughout the project life cycle;
- ensure that the products and services supplied meet the safety and legal requirements and the internal regulations and national and international regulations on quality matters;
- prepare a quality assurance program that incorporates all company policies regarding the previous points;
- involve suppliers in the quality assurance process;

Only when each of these activities is effectively carried out will the PM be able to successfully complete his/her projects and at the same time improve and consolidate their performance, image and competitiveness in the sector.

6.3 Processes

The three fundamental processes envisaged by the PQM for correct quality management in projects are:
Quality Planning, which defines the project's Quality System, identifies the significant quality standards for the project and defines the ways in which to meet them;
Quality Assurance, which proactively implements and controls the Quality System through its systematic assessment in order to guarantee the satisfaction of high quality standards;
Quality Control, which monitors the compliance of the outputs with the established standards and defines reactive corrective policies that envisage interventions aimed at eliminating the causes of unsatisfactory results.

Project quality planning can be a complex process, but it allows an organization to clearly set quality requirements and document all the procedures necessary for managing expectations in this regard. Project quality planning is one of the key components of strategic project management; it is the starting point for creating a link between stakeholder expectations and product requirements. It is formalized in the so-called Quality Plan. This is the document that describes the processes and activities that will be set up to understand if the deliverables produced are complete and correct and therefore guarantee an adequate level of quality.
A good Quality Management Plan includes at least the following information:

- Roles and responsibilities. Description of the different roles that will deal with the quality of the project. The project manager has overall responsibility, but there may be other roles that assist him. These can be quality auditors, third party testers, inspectors, etc.
- Completeness and correctness criteria. The purpose of the completeness and correctness criteria is to interface in advance with the customer, to define together the rules according to which a deliverable can be considered complete and correct. In other words, set the values with which the customer must be satisfied.
- Process of quality requirements. Description of the process that will be used to discover and agree on the customer's quality expectations. Generally, it is part of the initial process of gathering requirements at the bargaining stage.
- Quality assurance activities. Detailed definition of the quality assurance activities, i.e. the processes to be used to verify that the quality system is conducted correctly, to prevent the onset of defects upstream. These activities are often managed at a high level by a functional manager, sponsor or third party auditor.
- Quality control activities. Detailed definition of the quality control activities, i.e. the activities that are continuously performed throughout the project to verify that the deliverables are of adequate quality and do not present defects, as well as the necessary corrective measures.
- Quality Standards. List all the standards that the PM, as an agreement with the customer, has previously decided to follow for the project.
- Quality tools. List of quality-related tools that the PM intends to use.

Quality assurance is a quality macroprocess whose goal is to define the standards of a process by improving its efficiency, in order to ensure the requirements of the project deliverables as established by the customer. All this is aimed at proactively preventing product defects before they arise. Quality assurance therefore provides for the verification of compliance of products and processes with the rules drawn up by the various national and international regulatory bodies (for example the ISO). It is therefore the reference process for the inspections carried out by the control bodies and authorities, as well as for the audits requested by the customer. Considering that audits and statistical process controls often generate huge amounts of data, the PM, in the context of quality assurance, has the duty to collect them, analyse them and produce reports that give an account, both to his company and to other subjects involved, the results and possible improvement programs.

Quality control is the macroprocess that is dedicated to verifying the result in terms of product or service and therefore verifies whether or not the deliverables are acceptable for the standards established in the quality plan. It can be seen as a discipline that focuses on particular controls (such as, for example, software tests) and that seeks the match between product output and customer and company specifications, constantly looking for errors or anomalies. Furthermore, good quality control should include reactive, timely and effective interventions to bring failed processes or outputs back into the right quality ranges.

6.4 Tools and Best Practices

The list of best practices can be easily divided according to the three fundamental processes:

Planning

Cost-benefit analysis

Cost-benefit analysis (CBA) is an analysis technique aimed at comparing the efficiency of different alternatives that can be used in a given context, in this case a project, to achieve a well-defined goal. The CBA, in the quality field, checks whether the benefits that the prevention, research and correction of defects are greater than the related costs (quality costs). An option is considered desirable if the comparison between the total benefits (savings due to a lower probability of replacing the defective material or penalties following inspection, etc.) and the total costs results in a prevalence of the former, which is equivalent to argue that the project as a whole receives a net benefit from its implementation. In the presence of alternative intervention options, the option in which the prevalence of benefits over costs is greater is considered preferable.

Benchmarking

Benchmarking is a valid quality tool that helps companies and Project Managers to continuously improve their processes by learning from the experience of others. First, it is necessary to evaluate the operational processes to identify the strengths and weaknesses of the project; it is then necessary to identify the leading organizations that operate with particular efficiency and to discuss with them, in order to obtain useful information and consolidated practices to improve the performance.

Flowchart

One of the most suitable tools for quality planning through a schematic representation of the processes in a project is the flowchart. A flow chart is a pictorial or graphic representation of a process or a project, created according to some standard methods, to make it easier and more immediate to communicate and understand the process to all the people involved. With a flow chart you are able to schematically represent the components of a structure, the steps of a procedure or a chronology: in practice, any organizational process can be schematized in a diagram. The different steps of the process are displayed in the flow chart through different and pre-established geometric shapes, in fact:

- the circle indicates the beginning and end of the process;
- the rectangle contains brief descriptions of the various passages;
- the rhomboid contains synthetic descriptions of the different steps, which however are characterized by the interaction with other processes, incoming and / or outgoing;
- the rhombus does not contain a synthetic description, but a question, which presupposes the presence of two / three alternatives.

Representing a process through the flowchart means first of all representing what actually happens in stages. It is advisable to be as analytical as possible, trying to reach a high level of detail of the activities, as this allows to identify more easily what may be the possible weak links in the chain.

Design of experiments

The design of experiments (DOE) is a technique developed for the first time by R. A. Fisher in 1920 to identify the relationships that can exist between the characteristic variables of a project and the different products of the same project. In particular, this approach is applied in the quality management of a project when it is necessary to:

- formulate hypotheses on the reasons behind the trend of some critical variables;
- carry out some tests to verify these hypotheses;
- analyse the test results;
- identify the corrections to be applied;
- carry out further tests until a result considered reliable is achieved.

In order for the technique to produce its effects, the following six steps must be followed:

1. Clearly define the objectives of the tests to be carried out, thus avoiding too broadening the scope of the investigation with a consequent increase in costs.
2. Define the measures to be carried out on a quantitative basis, using specific metrics.
3. Replicate the tests several times by randomizing the test sequences, to achieve a certain robustness of the data and eliminate random fluctuations or deterministic factors of the measured values.
4. Identify and isolate possible sources of variations and sampling distortions. If some causes that produce certain systematic trends are known, it may be convenient to organize the experiments in blocks of sequences, to grasp the effects of the known causes separately.
5. Carry out the experiments sequentially, to evaluate the results of an experiment based on the next experiment.
6. Always check the results obtained from all the experiments carried out. At the end of a sequence, it is easy to assume that the results achieved are accurate. However, it is necessary not to be satisfied and carry out further checks also using other investigation tools.

The design of experiments is not just a way to verify whether the practical implementation of a new process / product actually meets the objectives established during the design. The design of experiments can in fact generate added value, not only if meant as a confirmation of what was initially foreseen, but also as a potential source of improvement initiatives that are not always intuitive a priori.

Assurance

Audit

The project audit is a formal type of project review, often designed to assess whether and how the quality standards required for project management are followed, through in-depth investigations and assessments. Audits are typically performed by a designated audit department, the Project Management Office, a licensed steering committee, or an external auditor.

A general auditing process consists of the following steps:

- Planning. The aim is to clarify how far the reviewer want to go in terms of control and duly inform all stakeholders interested in the review process.
- Collection. This is the core phase of the audit with the structured collection of data on the progress of the project, making use of the data made available by the monitoring and control process that the project manager has implemented up to that moment. Additionally, the reviewer can collect “ad hoc” data.
- Processing. Once the data has been collected, it must be processed through mathematical, statistical, visual or textual analysis in order to bring out clear and schematic information on the state of the work.

- Reporting and presentation. The relevant information must be included in a summary to provide a clear and broad overview of the progress of the project to all parties who need to know the results of the analysis carried out, from their team to key stakeholders. It is important that not only abnormal trends are highlighted, but also noteworthy positive situations.
- Action plan. Based on the information presented, develop an Action Plan that will help improve overall efficiency. People will therefore be involved by assigning them the corrective actions to be carried out and the relative deadlines.
- Follow up. The progress and results of the action plan will need to be monitored to make any improvements if things do not go exactly as planned.

Control

Control charts

Control charts are analysis tools used in the quality control of a project and are usually applied for the analysis of repetitive processes. They are a graphic representation of a process to check if this is stable and with a predictable trend. A process is considered out of control when a point on its track goes out of the set control limits or if there are at least 7 consecutive points on the track that are positioned below or above average (rule of seven). The horizontal axis of a control chart is generally made up of time while the vertical axis corresponds to the measured value of the sample.

The control charts consist of the following basic lines:

- a line indicating the upper tolerance range as per specifications (USL);
- a line indicating the upper limit (UCL) within which the data are considered acceptable;
- a central line indicating the average of the process data;
- a line indicating the lower control limit (LCL) within which the data are considered acceptable;
- a line indicating the lower tolerance range as per specifications (LSL).

The UCL and LCL control limits are set by the Project Manager in a conservative way, to highlight the values beyond which corrective actions will be undertaken in order to avoid exceeding the limits of the specifications. Points outside the UCL and LCL values indicate that the process is out of control and / or that it is not stable.

When a process falls within acceptable limits it is under control and does not need to be adjusted. On the contrary, when a process does not fall within acceptable limits, it must be adequate by identifying the causes that can be assigned to each of the situations highlighted and working to eliminate them or reduce their impact.

Pareto diagram

Pareto analysis is a supporting statistical technique to identify the significant subset of causes or actions that produces the highest percentage of effects. In the project context, Pareto analysis is used to guide corrective interventions and to help the project team to take action to solve those limited problems (20%) among the many under consideration, which cause the greatest number of defects (80%), which affect the quality of the deliverables and of the project as a whole.

The diagram is represented by a hybrid chart with bars and a line. Each factor is represented by vertical bars placed in descending order, which indicate the incidence of that factor with respect to the predetermined metric (e.g. number of defects caused). The line instead represents a cumulative

distribution (called Lorenz curve) of the incidences, which generally tends to flatten to the right, indicating, in fact, how the unitary contribution of the factors gradually disappears as we move away from the first block formed by 20% of the factors.
By allowing the detection of 20% of causes that generate 80% of problems, it allows to concentrate the efforts aimed at pursuing the most significant improvements.
The value of Pareto analysis for a Project Manager consists in favouring concentration on that 20% of essential factors and in managing with a lower level of priority the rest that has a minor importance in relation to the achievement of the set objectives.

Ishikawa diagram

The Ishikawa diagram also known as the cause-and-effect diagram or the fishbone diagram is based on the principle that identifying symptoms is the first step to solving a problem. It can therefore be defined as a form of graphic, logical and structured representation of the links existing between an effect and its causes.
The advantages of the Ishikawa Cause and Effect diagram are many, some of them being the following:

- Helps to search for the most important causes of the problem
- Relates effects to causes
- Represents all potential causes of the possible problem
- Helps discuss the problem by involving the team
- It remains a tool that is alive over time and is constantly updated by the team's feedback and possible solution hypotheses
- Its structure helps to think systematically
- Helps to analyze existing problems in order to initiate corrective actions
- Encourage the participation of group members to use common knowledge of the process
- Leads to the identification of areas where to collect data in order to implement further studies

7 Project Risk management

7.1 Introduction

In common language the term risk is almost always associated with negative events, for example: accidents, unexpected problems. In reality, the term risk includes both negative and positive events, since this term refers to both situations of uncertainty and ambiguous or unclear situations.

A sharp definition of risk is an uncertain event that can have a positive or negative impact in an economic context or on a project.

The ability to manage risk and make predictions about it is a key element of our economic system. Because profit is a premium for business risk and if you are not able to make risk assessments our economic system would not exist.

The ability to manage risk and make calculations about it has been the basis of the growth of our modern economic system. Before this there was a completely different world, even for the Catholic religion the loan of money for a fee was considered something unacceptable. Imagine what it could mean to ship goods from one end of the Mediterranean to the other end, while knowing that in the event of a storm or loss of cargo there would be a total loss of the goods without any possibility of recovering partly or completely the value of the goods. With the ability to manage the risk it was possible to insure the goods that were transported by establishing a price that was defined according to the probability of loss of the goods; in this way the economic system no longer depended on the will of God, but depended exclusively on the ability to define the probability of the occurrence of an event and associate this probability with an economic value.

Therefore a successful entrepreneur strongest ability is to make predictions about risk, while the ability to manage operational activities, has a secondary priority.

The risk is associated with the time factor, we could say that they are two sides of the same coin, if there is no future time there is no risk. Imagine what could happen in the future if at the birth of a person it could be established, with exact precision, all the diseases that the individual will face, including the date of death. In this context, the risk could not exist, because there would be no future time; the future from the human perspective is conceived only thanks to the uncertainty connected with time.

The time factor is of paramount importance when making irreversible decisions in a situation of great uncertainty. Often procrastinating decisions does not improve the quality of the same but worsens them since the options available will be reduced with the passage of time.

Peter L. Bernstein correctly pointed out that "The revolutionary idea that defines the boundary between modern times and the past is the mastery of risk: the notion that the future is more than a whim of the gods and that men and women are not passive before nature."

7.2 Objectives

In few words, the objectives of project risk management are to increase the probability and impact of positive events and decrease the probability and impact of negative events.

Projects drive change and innovation, therefore the exploration of unknown contests creates uncertainty which refers to the following factors:

- The identification of the customer's needs - often the definition of the customer's needs and requirements is vague and unclear, and this produces uncertainty.

- Knowledge of the domain and knowledge of technology – project activities take place in contexts where few people have full and in-depth knowledge of the domain. If we explore new contexts such as the space, there are large knowledge domains where there is little global knowledge and near zero hands on experience. The uncertainty is also due to the advancement of technology, in fact every time we use new technologies or apply existing ones to new contexts, we do not have a perfect knowledge of the results of the project activities or of any collateral impacts on other parts of the organization.
- The behavior of competitors is another factor of uncertainty in the performance of project activities, since competitors may decide to perform actions that can create partially predicted scenarios or totally unexpected scenarios. Both produce uncertainty and risks for the project.
- The nature and availability of resources is another element of uncertainty, since in organizations there is a shortage of resources, in particular the availability of personnel with a high degree of competence and leadership who are able to sponsor project activities This scarcity of resources reduces the quality time that can be dedicated to the sponsorship of projects and as a consequence produces risks with impacts on project results.

The uncertainty in a project belongs to three categories:

- **Unknown – Unknown**: What I do not know and I am not able to predict or imagine, within a reasonable time and at reasonable costs (e.g. earthquake, Covid-19)
- **Known – Unknown**: What could happen as a result of a trigger event with a probability (between 90% and 20%) that produces an impact on costs, time and quality. Project risk.
- **Known issue**, What I know, a problem that had an impact on the project. We must bear in mind that if an event has a high probability of occurrence (more than 90%) we can consider it a certain fact and therefore it is included in the baseline of the project.

These categories are adjacent to each other, contiguous, in some cases the border between each is blurred and uncertain. We can therefore describe risk as a continuous function of uncertainty where one can naturally move from no risk to a certain degree of uncertainty up to a complete risk.

Some risks connected with the project can be transferred to other companies while some risks, defined business risks, cannot be transferred to others, these risks include risk events for which the project does not deliver the expected benefits, for which we cannot get the expected revenues or for which the event is damaging the image of the company. These risks cannot be transferred in any way, having thousands of pages of contracts is not helping in managing business risks because the objective of a project is to complete the expected deliverables that will become capabilities that will become business value, collecting penalties from suppliers or winning trials does not deliver business value nor mitigate or remove business risks.

7.3 Processes

The key process that will help a project team to manage risks are:

- Develop the risk management methodology for the project (Risk Management Plan)
- Risk Identification
- Qualitative Risk Analysis
- Quantitative Risk Analysis
- Risk Response planning

- Risk monitoring and control

The risk management plan documents the methodology with which the risks for the project will be managed; typically, organizations have standardized risk management plans that are applied to a project depending on the level of perceived risk and linked to the project as a function of its economic value.
The plan is developed considering the following inputs: Project Charter, Project Management plan, scope statement, cost, schedule and communication management plan, stakeholder register, corporate environmental factors, factors related to the project context.
A risk management plan includes at least the following elements:

- Methodology: defines how risks will be identified, analyzed, managed and controlled.
- Roles and responsibilities: Who will do what with reference to risk management
- Budgeting: how the costs associated with risk management activities and contingency based on quantitative analysis will be managed in terms of budget.
- Timing: risk management activities to be carried out regularly.
- Risk categories: helps create a logical approach to risk management. The Risk Breakdown Structure (RBS) is a Work Break Down structure oriented to risks.
- Probability and Impact Matrix: the scale to be used for assessing the probability and impact of risks to the project
- Updated risk tolerances from stakeholders
- How to do risk reporting
- How to do risk tracking

The risk management plan can define risks levels for which the project team can only perform qualitative analysis and risks levels for which the quantitative analysis is mandatory.

During risk identification the project team, following the process documented in the risk management plan, brainstorms all events that can impact the project and these events are document in the risk register.
In order to identify project risks input can be collected from:

- Risk Management plan
- Cost Management plan
- Schedule Management plan
- Scope baseline
- Estimated Activity duration
- Stakeholder Register
- Quality Management plan
- Project artifacts
- Experience and knowledge of the organization

The project team should review all the project assumptions because if these might change will generate risks for the project and use the knowledge and experience of the organization to tap any lesson learned in previous projects.

During qualitative analysis the project team discusses all risks documented in the risk register and for each risk the team defines what is the probability of occurrence and what would be the impact to the project (cost, schedule).
Qualitative analysis can be performed very quickly and it requires a low investment of resources to generate tangible benefits, this is why often is the preferred method for projects.
Risks are assessed during a specific meeting and the success of the meeting requires that: a) all participants agree on the same definition of risks creating a matching between the language and numbers (Risk Matrix Impact Assessment, Probability of Occurrence Matrix, Risk Rating Scale) and b) Participants agree the decision making process to be followed in case of radically different opinions on risks
At the end of this meeting each risk will have a specific probability and impact with an overall risk rating, depending on the risk management plan some risks can be immediately move to the risk mitigation step while others might require a quantitative analysis.

Quantitative analysis requires an in-depth study of probability and impact in order to define the budget reserves to be used for project risk management.
Quantitative analysis must be done after the qualitative one has been completed, and it is an activity that is not carried out for all projects as it requires a considerable investment of time, financial and organizational resources.
The result of this analysis is extremely important because it provides an estimate of the overall probability that a project can achieve the objectives and therefore estimate the contingency (contingency) of the project, that is, the budget intended to face the risks of the same. In addition to the determination of the budget, a whole series of detailed actions can also be determined and then evaluated in the next phase.
For each risk the impact on the project is quantified as monetary value and the overall impact is defined as expected monetary value (EMV) which is computed by multiplying the probability of the risk with his monetary value. The EMV value is then used to determine what is the proper risk handling approach for each of the risks. See below an example.

Table 7.1 Example of EMV

Risk	**Probability**	**Impact in USD**	**Expected Monetary Value in USD**
Risk 1	60%	-22000	-13200
Risk 2	20%	-75000	-15000
Risk 3	10%	45000	4500
Risk 4	55%	-65000	-35750

Risk 5	85%	-75000	-63750
Risk 6	10%	-12000	-1200

Risk response planning aims at define an action plan for each event and associated risk by assigning a manager who will coordinate the actions established by the team. Planning of risk responses should be carried out for the most significant ones while those that have a lower probability of occurrence and a lower impact may be subject to a subsequent assessment.
Risk responses can be classified according to the following strategies:

- **Avoid a risk**, this strategy removes the risk trigger so that the project is executed in a different way. Possible risk response actions are:
  - Change Project Scope
  - Clarify requirements
  - Acquire more capabilities in the project team or in the organization
  - Change project plans
- **Transfer a risk,** this strategy moves the risk to a different organization. This strategy is very effective for managing financial risks but it is not transferring the project business risks which remains within the organization. Transferring risks requires the payment of fee to organization that accept the risk, when transferring risk it is critical to assess the ability of the organisation that takes the risk to really cope successfully with it. Possible risk response actions are:
  - Pay an insurance fee
  - Transfer the work for a project deliverable to a different company
- **Mitigate a risk,** this strategy reduces the impact and/or probability of a risk at an acceptable level for the organization. Possible risk response actions are:
  - Simplify the project processes
  - Make more tests
  - Create a prototype
- **Accept a risk,** this strategy applies to risk for which there is no action or the action is not justified in economic terms

Risk plans should be specific with action owners identified and detailed plan duly documented.

Risk monitoring and control aims at verifying the changes of the risks related to:

- The time, as some risks can disappear over time because the risk event cannot happen, but new risks can emerge
- The context of the project, because changes in this area can generate new risks for the project team
- The sensitivity of the project team and the stakeholders can change over time so that the perception of risk can change the probability and impact of risks.
- The scope of the project

On a regular basis the project team should review the risk register and check that no change has impacted the risk and if this happens take the most appropriate actions.
This process is facilitated by the trust and openness of the communications within the team and with the project stakeholders, so that anyone at any time can suggest that a new risk is emerged or disappeared from the project radar screen.

7.4 Tools and Best Practices

Risk register

The register is a list that includes at least the following elements:

- Identification number, to uniquely identify a risk
- Date and stage of the project when the risk was identified
- Name of the risk
- Positive event (opportunity) or negative (threat)
- Description of the SMART event (Specific, Measurable, Attributable, Relevant, Time-bound), the event that produces the risk must be specific, measurable, have a clear definition, must be relevant and connected with the time factor
- Trigger, the event at the occurrence of which the negative or positive event for the project is produced
- Probability
- Impact (Schedule, Cost), risk can impact time planning or costs
- Overall risk rating
- Potential response, the possible response to this type of risk
- Comments with the change log, which include an indication of any ratings. These help us to understand the evolution of risk over time
- Action, indicates who will do what and when, depending on this risk. This element of the risk register is produced as a result of the qualitative and/or quantitative analysis process

Risk Breakdown Structure

This is a WBS in which there is an indication of the possible risks sources which are typical for the knowledge domain and context in which the project is operating.
Example of software development from “Hillson, D. (2002). Use a risk breakdown structure (RBS) to understand your risks. Paper presented at Project Management Institute Annual Seminars & Symposium, San Antonio, TX. Newtown Square, PA: Project Management Institute.”

Table 7.2 Risk Breakdown Structure from Hillson, D. (2002)

LEVEL 0	LEVEL 1	LEVEL 2	LEVEL 3
Project risk	Management	Corporate	History/experience/culture
			Organisational stability
			Financial
			…etc…
		Customer & stakeholder	History/experience/culture
			Contractual
			Requirements definition & stability
			…etc…
	External	Natural environment	Physical environment
			Facilities/site
			Local services
			…etc…
		Cultural	Political
			Legal/regulatory
			Interest groups
			…etc…
		Economic	Labour market
			Labour conditions
			Financial market
			…etc…
	Technology	Requirements	Scope uncertainty
			Conditions of use
			Complexity
			…etc…
		Performance	Technology maturity
			Technology limits
			…etc…
		Application	Organisational experience
			Personnel skill sets & experience
			Physical resources
			…etc…

Risk Matrix Impact Assessment

Impact categories are described in detail to align risks assessors on the same language and approach, see the example from "Garvey, Paul; Landsdown, Zachary (1998). "Risk Matrix: An Approach for Identifying, Assessing and Ranking Program Risks". Air Force Journal of Logistics. DIANE Publishing. 22 (1): 18–21. ISBN 9781428990890."

Table 7.3 Risk Matrix Impact Assessment from Garvey and Landsdown (1998).

Impact Category	Definition
Critical (C)	An event that, if it occurred, would cause program failure (inability to achieve minimum acceptable requirements).
Serious (S)	An event that, if it occurred, would cause major cost/schedule increases. Secondary requirements may not be achieved.
Moderate (Mo)	An event that, if it occurred, would cause moderate cost/schedule increases, but important requirements would still be met.
Minor (Mi)	An event that, if it occurred, would cause only a small cost/schedule increase. Requirements would still be achieved.
Negligible (N)	An event that, if it occurred, would have no effect on the program.

Probability of occurrence

Probability ranges are also described in words to ensure that there is a common definition between risk assessors, see the example from "Garvey, Paul; Landsdown, Zachary (1998). "Risk Matrix: An Approach for Identifying, Assessing and Ranking Program Risks". Air Force Journal of Logistics. DIANE Publishing. 22 (1): 18–21. ISBN 9781428990890."

Table 7.4 Probability of occurrence from Garvey and Landsdown (1998)

Probability Range	Interpretation
0-10%	Very Unlikely to Occur
11-40%	Unlikely to Occur
41-60%	May Occur About Half of the Time
61-90%	Likely to Occur
91-100%	Very Likely to Occur

Risk rating scale

Probability and impact are defined in a specific table to facilitate the risk rating of a risk see the example from "Garvey, Paul; Landsdown, Zachary (1998). "Risk Matrix: An Approach for Identifying, Assessing and Ranking Program Risks". Air Force Journal of Logistics. DIANE Publishing. 22 (1): 18–21. ISBN 9781428990890."

Table 7.5 Risk rating scale from Garvey and Landsdown (1998)

	Negligible	Minor	Moderate	Serious	Critical
0-10%	Low	Low	Low	Medium	Medium
11-40%	Low	Low	Medium	Medium	High
41-60%	Low	Medium	Medium	Medium	High
61-90%	Medium	Medium	Medium	Medium	High
91-100%	Medium	High	High	High	High

Monte Carlo Simulation

Monte Carlo simulation is a computerized mathematical technique that gives to the project team a range of possible outcomes and the probabilities they will occur for any choice of action. This is very useful when there are multiple scenarios and it is important to determine what are the statistically correct outcomes for each scenario. The technique was first used while working on the atom bomb; it was named for Monte Carlo, the Monaco resort town renowned for its casinos.

The simulation requires that for each project activity that is in the glide path for the event of the risks there is an estimation of time and cost with a Pessimistic, Optimistic and Most Likely values documented.

A detailed explanation can be found on "Cook, M. S. (2001). Real-world Monte Carlo analysis. Paper presented at Project Management Institute Annual Seminars & Symposium, Nashville, TN. Newtown Square, PA: Project Management Institute."

8 Project resource and procurement management

8.1 Introduction

Procurement is that specific knowledge area of the Project that has the scope to provide the Project for the necessary contracts of materials, workforce and services acquisition.

There are some Projects, like large infrastructural installations, where the external costs spent for material, workforce and services can reach up to 90% (60% materials, 30% workforce and services) of the total value of the Project.

Procurement has role to select on the market the potential suppliers of material (vendors), workforce (subcontractors) and services. After selection, the Procurement role includes to call for bidding i.e. to ask the bidders to specifies the technical content of their proposals and provide for the relevant economical quotation. The bidding process is followed by the negotiation with the selected bidders and, finally, to award the contract.

Contracts in any Project shall cover any single activity that is necessary for the Project execution. We can have Vendor contracts for the supply of large items that may cost up to 10% - 20% of the main Project value, down to minor contracts like document translation or housekeeping services at the site.

Since a Project may include even hundreds activities, services and materials and since Procurement is the way for the Project Team to get the required contracts, this fact gives an idea about the key role of Procurement inside a Project. Procurement may became a critical bottleneck of the project if not properly staffed.

The Procurement activities need a specialist knowledge of the contracts and their implications from legal and commercial point of view. This specialist knowledge is not requested to the PM however, the PM should know the procurement processes as well as the critical clauses of the contract that may affect the Project performances. Examples of commercial clauses are the terms and conditions, guaranties, penalties, etc.

Moreover, the PM will be the major actor during the contract execution, therefore he has to know the payment conditions and the contract variations conditions.

The procurement activity is very sensitive for the project Stakeholder, hence the need for the PM to be always aware and updated about this issue.

8.2 Objectives

The objective of the procurement activity is to implement the project procurement plan or, in other words, to assign the supply, assembly and service contracts within the time schedule defined by the project manager in his project planning at costs not exceeding those defined in the project budget.

The contract award is the primary objective of the Procurement activity. As secondary objective, Procurement activity also includes the contracting of “change orders” i.e. the formalization of those variants to contracts that arise during the execution of the project.

It is important for the PM that suppliers selected and awarded during the Procurement activity are of an adequate technical level to ensure compliance with the required quality for the supply and have a level of commercial reliability sufficient to avoid litigation issues that could imply the assumption of additional risks for the PM.

The Procurement objectives often differ from those of the PM. In fact, Procurement will generally tend to widen the number of participants in the tender, because in this way it will be able to achieve prices that are more competitive. On the other hand, operating in this way, the Procurement lengthens the tender duration (more than in proportion to the number of participants), and also often increases the risk of awarding the order to some inexperienced and not particularly valid supplier. Obviously, this contrasts with the needs of the PM who, instead, aims to have technically and commercially viable companies in the project. The PM might even be keen to spend a little more than the minimum cost (if he remains within the budget limits) in order to save time in the tender and have greater reliability in the execution of the order.
Therefore an appropriate management of relationships between PM and Procurement is necessary.
The fiduciary relationship between PM and Procurement is also very important during the contract execution phase for the fast and fair solution of the contractual variants that are determined during the works.
In the case of change order, since the negotiation is restricted to only two counterparties, the leverage of competition cannot be exploited, so the trust relationship between PM and Procurement is important and involves the contractor too.
This part of the job covers a large portion of the Procurement and PM effort since, for some infrastructural projects, it is normal to have numerous change orders for a single contract during the Project execution.

8.3 Processes

Procurement activities have to be planned at the beginning of the Project in a coordinated way with the Project scheduling. Such a planning activity generates a document called “Procurement Plan” that has to be updated during the project life.
According to the organizational rules, some organizations require the approval of the Procurement Plan by the top management due to its strategic and cost impacting value.
During the Project life, each contract needs a process that starts with the selection of the potential bidders, the request for proposal that bidders will submit to the buyer, the negotiation with the selected bidder and the contract award. All this process should be monitored by the PM. The role of the PM is even more critical when, during the contract execution, there is the need of contract variation. In this case, the role of PM is essential and the relationship with procurement is critical.
During the Project life, all the several contracts foreseen in the Procurement Plan will be awarded according to the time needs of the Project. It is essential for the project success that the Procurement Plant will progress with the correct timing in order to keep the whole Project in time. Hence the process of Procurement Managing or Procurement Control.
Finally, there is the need to expedite the procurement activities as well as to manage the relationship with the procurement interfaces.
Therefore the main processes of Procurement Management are:

- Procurement Planning
- Procurement Execution or Conduct (Contract Awarding) and Variations Awarding
- Managing Procurement Relationship

described below.

Procurement Planning. The purpose of procurement planning is first to identify the entire purpose of the project to be bought from third parties and divide this purpose into different types of contracts, mainly:

- Supplies on site
- Assembly Works
- Services

The first kind of contract, supplies, are relevant to material supply by Vendors. The contract awarding requires well-defined technical specifications based on a project, even a preliminary one, and therefore allows the definition of a closed price payable into milestones.
The Assembly Works contracts essentially concern the provision of labor for works and assemblies whose details that are not still well defined at the time of the tender, therefore, generally, the contract is based on unit prices and the payments are regular based on the progress of the works.
A second step of the planning activity is, for each tender, to identify the list of possible competitors.
It may happen that, given the particular type and characteristics of the supply, it is not possible to proceed with a tender but it is necessary to decide for a “direct” order. In this case, it is necessary to have the necessary authorizations according to the organization standards.
Once the List of Tenders has been defined, it is necessary to schedule the sequence of the calls for tender. The schedule has to be coordinated with the project schedule. The result of the above steps is the Procurement Plan.
It should be noted that the orders cannot be anticipated excessively either because the input data would not be sufficiently clear or because otherwise the project costs would be excessively anticipated with the consequence of increasing the financial exposure of the project too much.
On the other hand, the order cannot be postponed too much. The timing of the award must take into account all the steps upstream of the order that require time and involve at least three actors: Procurement, Team (with particular involvement of the technical part for specifications) and competitors.
All the phases of the tender process (see later), for particularly complex supplies, can take up to a few months, therefore, if the planning has not been carried out correctly, there is a risk of serious delays with the project.
The Procurement plan and the relevant scheduled payments allows you to define the cost curve during the development of the project.
The PM, on the basis of the cost curve, will be able to assess that the latter is "covered" by the payments curve or that, in any case, there is no excessive financial exposure.
Many factors, including strategic ones, can enter into the definition of the procurement plan, such as, for example, that of reserving part of the work for local companies to contribute to the development of the local economy.
The Procurement plan cannot consists in a few orders since, as the merger of orders grows, part of the project margins are transferred to the suppliers. On the other hand, it cannot be too fragmented either as it would excessively increase the management costs of the plan and the interfaces between suppliers.

The Procurement plan has to be continuously updated during the project execution accordingly with the time schedule update. Each version of the plan must also include the planning of the change orders that inevitably arise during the execution of the project.

Procurement Execution and Variation awarding. As mentioned above, there are two types of contract award:

- First contract award
- Following change orders

The first award involves the following steps (may change according the organization rules and Project type):

- Request for Tender from the team to the Procurement containing the general data of the Scope to buy on the market
- Issuance by Procurement of the preliminary notice of tender to the market
- Preparation of the tender documentation and issuing of the tender
- Receipt of technical offers
- Evaluation and alignment of technical offers
- Receipt of economic offers
- Negotiation
- Awarding
- Order completion

All these phases can take months and the coordinated work of various actors.
Also the change orders requires their formalization like for the first award. For each variation it is necessary to define the scope included in the variation, to prepare the technical documentation, to update the contractual documents valid before the variation, to define the amount of extra work to be paid and negotiate the value to be paid. This process takes time but it is necessary to keep it always consistent the Project with the contractual documentation.

Managing Procurement Relationship. The PM should monitor and manage the Procurement process in order to share and transfer part of the risk deriving from the main Project into the contracts awarded to third parties.
For example, the main contract usually includes commercial clauses relating to material guarantees (Warranties), performance guarantees (Guaranties), liquidated damages (Penalties) for delay or lack of performances, Insurance coverage, etc. All those clauses should be transferred into the major critical supply contracts that are part of the Project Scope.
This contractual architecture is called “back to back” in the sense that part of the risk of the main Project is transferred to the suppliers. Of course, everything is proportionate to the value of the project, therefore inevitably a part of the risk will remain within the main project.
A similar approach can be followed for payments: payment claimed by suppliers can be linked to payment received for the main contract of the project.

Also the services that are included into the scope of the main contract (reporting, scheduling, assistance on site, spare parts supply, etc.) should be fully replicated in the supply contracts.
This coherence between main contract and daughters contracts should be monitored by the PM.

8.4 Tools and Best Practices

The Procurement Plan is a key document for those projects, like large infrastructures, where the total value of the project depends on the cost of material and services bought by third parties. In these cases, the Procurement Plan is a strategic document that can decide the future success of the Project in terms of margin and time to completion. For this reason, the PM should submit it to the key Project Shareholders (i.e. the Project top management) for their approval.

Once the PM and the Project top management approve the Procurement Plan, then the PM should make sure that Procurement staff is adequate for the relevant workload. Procurement knowledge area should staff all the specialist area for all contractual areas: supplies, works and services.
The Procurement Plan cannot include neither too many tenders nor too few.

Similarly, each tender should be limited to the minimum qualified bidders sufficient to assure the competition conditions (usually 3 are sufficient). The excess of bidders will cause a very long bid evaluation times especially due to the bid scope alignment of the offers.

The coordination between PM and Procurement area is essential since it is necessary to find a compromise between different needs: the PM gives priority to time, cost, and reliability, flexibility whereas Procurement gives priority to transparency, consensus, and fairness of the competition. If the tender process is unfair, it may generates claims from competitors and problems for the buyers.
The PM should identify, within the Procurement Plan those contracts that, due their value and long delivery time are critical for the Project. The PM should “tailor” the critical contract with specific agreements including the possibly to transfer in that contracts part of the project risks.
For long-term supply contracts, the “tailoring” may include the possibility to anticipate part of the scope (i.e. design) even before that the Project would start.

Some large Companies, involved in recurrent projects, uses to perform the preliminary qualification of potential suppliers to be invited in the call for tender. They also use to create a vendor-rating list that includes those suppliers and contractors that have already collaborated in previous projects.
The qualification of suppliers must aim at evaluating both technical and commercial skills. The qualification should not neglect the ability of the supplier as regards their skill for providing the services related to the supply (document management, warehouse management, surveillance, tests, inspections, etc.).

The PM should verify that contracts include the right flexibility in timing to avoid that any project delay having repercussions in contractual variations. Similarly, in order to simplify the management of change orders, it is useful to include in the supply contract, if possible, some quotations for extra supplies or extra services.

The PM and the Procurement management should be coordinated in managing the suppliers and subcontractors both during the negotiations for the first award of the contract and in the subsequent negotiations for change orders in a fair way. If the contractor has to accept unfair conditions like too low prices, then the Project might have problems later on because the supplier might have lost his interest and motivations to execute the contract. This policy should be agreed and shared as common PM and Procurement behavior provided the fulfillment of the Project Budget.

9 Project Stakeholder and Communication management

9.1 Introduction

The Project Management Institute (PMI®) in 1996 defines stakeholders as: "individuals and organizations who are actively involved in the project, or whose interests may be positively or negatively affected as a result of project execution or successful project completion". In this definition, it is clear that stakeholders can be both individuals who can be involved in project activities and who may have interests that are positively or negatively affected by the execution or progress of the project and who, by reacting to this event, in turn influence the progress of the project.

The actual definition provided by Project Management Institute about stakeholders is: "Stakeholders are individuals, groups, or organizations that can influence, be influenced by, or feel influenced by a decision, activity, or outcome of a project". This definition is similar to the one we have seen previously, but the new element is the emotional element, i.e. a stakeholder can be someone who not only has really influenced but could have the feeling of being influenced by a project, and not only could be influenced not by a project in its entirety, but by one or more individual decisions made during the course of project activities.

Stakeholders play a very important role in the success of a project activity, because in some situations a strong negative reaction to the project can bring serious consequences to the project itself.

These can be people, groups or sectors of an organization that are impacted in various ways by a project or that may have some direct or indirect form of interest for the result or for some of the expected deliverables. Not all are the same. Everyone has their own needs and expectations that need to be met.

An example of this situation is given by the Turin-Lyon railway which is a project that theoretically had a sound objective from an economic and environmental point of view, the objective was to reduce truck traffic and use rail transport, but despite this, the project has been subject to strong criticism from a number of communities, and at present, due to a mismanagement of communication and relations with these stakeholders, the situation has degenerated to the point where it is no longer clear what are the real facts of the matter, what are the reasons for the dispute, but now it has become a frontal battle in which none of the parties can withdraw without having to admit their defeat.

The events of the Turin-Lyon railway help us to understand how stakeholders must not be managed but must be involved in project activities, this explains why the Project Management Institute in the PM body of knowledge sixth edition, has started to use the term stakeholder engagement to define the area of knowledge that covers project stakeholders.

It is therefore essential to understand who the stakeholders are and how to ensure that they have a positive and supportive attitude to the project.

9.2 Objectives

If we look at the life cycle of a project we can identify two categories of stakeholders: core stakeholders (critical stakeholders) and non-core stakeholders (non-critical stakeholders).

Core stakeholders refer to groups or individuals who have very high influence in the early stages of a project, in fact they may have conceived the project themselves by approving in the business case and recommending the transformation the creation of a project activity. These types of stakeholders, during the execution phase, become critical because they play an essential role in facilitating the execution of

the project activities, for example by removing technical and, above all, organizational barriers and obstacles. Finally, this group of stakeholders includes those who will say whether the project was a success from a business point of view because not only the benefits defined at the beginning of the activities were achieved but also with respect to the contribution of these benefits to the implementation of the organization's strategy.
Non-core stakeholders have little or no influence in the early stages of a project, during project conception or during project approval; in fact, they have no opportunity to influence the decision-making and approval process. They begin to have some influence during the execution phase because, as we have seen, they may react negatively both to decisions made by the project team and to results that the project team has planned to achieve. This type of stakeholder becomes essential when at the end of the project is the time to maximize the use of the outputs of the project itself, in this context a wrong involvement, a wrong communication, a series of negative emotions from these groups and subjects will have a series of percussion on the creation of real benefits as a result of the project.
Stakeholder management ensures that critical and non-critical stakeholders are appropriately involved, based on their own typology, in all aspects of the project, program or portfolio. The purposes of this involvement are:

- ensure that the views and behaviors of all stakeholders are understood
- influence stakeholders to support work wherever possible
- allow an in-depth understanding of the environment in which the project operates
- maximize the impact of favorable stakeholders and minimize the impact of opposing stakeholders.
- allow to learn from stakeholders, obtaining results in products and improvements in processes
- enable better risk management and increase reputation
- inform, educate and influence stakeholders and the external environment to improve their decision-making processes and actions that have an impact on the project
- build trust between a company, its project and its stakeholders
- lead to a more equitable and sustainable social development by giving those who have the right to be heard the opportunity to be involved in decision-making processes

9.3 Processes

The key process that will help a project team engage stakeholders are:

- Stakeholder Identification
- Stakeholder Planning
- Stakeholder Control
- Stakeholder Communication Management

Identifying stakeholders is an extremely important activity that must be started even before the charter project is approved, directly during the evaluation of the business case.
Possible stakeholders in a project could be:

- The sponsor, who provides the tangible (budget) and intangible resources (relationships) to the project team with the aim of obtaining one or more tangible or intangible benefits. The sponsor plays an extremely important role in defending the project compared to other projects or other

activities that use the same resources so that the project team has all the people, materials, and organizational resources required for the success of the project

- The customer, who represents the group or organization that purchases and uses the results of the project activity
- End users, who represent the users of the product and services delivered by the project team
- Suppliers, who carry out activities or create deliverables useful for achieving project objectives; suppliers have an interest in the project success because this means more business opportunities with our organization; at the same time we have an interest in having suppliers who meet their commitments rather than having suppliers who have very low prices but in the end are not able to meet their commitments, in essence the goal of the project group is not to collect any penalties that are paid by late suppliers or defaulting suppliers, the goal is to complete the project on time and in cost and with the expected quality
- Other business functions that can be directly or indirectly impacted by the project
- The functional managers of the resources that have been assigned to the project
- The project management Office and project team

There are so many stakeholders in a project, hence it is extremely important that the project leader together with the project team correctly manages relations with them.
Another route to identify stakeholders is to use the following approaches:

- Organizational approach, consists of carefully reading the project documentation and the Organization Charts to understand the roles and responsibilities of the organization. From this perspective we must carefully consider the behavior of senior management in relation to the project because if the project is really important it is likely that the best people of the organization will be assigned to the project and the senior management will invest significant time thus helping the project team achieve its goals. If the senior management shows little interest in the project probably our project is not important enough and we will certainly face a series of problems
- Proximity, which looks at those who are in close contact with the final results of the project
- Social and environmental, which looks at those who are impacted by side effects in the environment or social sphere as a result of design decisions and activities done within the project
- Cultural values, which looks at those who have specific religious or political moral interests in our project
- Legal, which includes those involved under laws and regulations

Sometimes there is no clear documentation that can help project manager in understanding the stakeholder context in which his/her project is moving. Therefore, project manager can use a practical approach to identify one or more stakeholders. It consists in answering the following 20 questions:

1. Who approves the budget for the project?
2. Who approves the functional requirements?
3. Who approves the technical requirements?
4. Who approves functional design decisions?
5. Who approves the changes in requirements?
6. Who approves the timing changes?
7. Who approves the cost changes?
8. Who will use the product or services produced by the project?

9. Who defines the objectives of the organization that made this project necessary?
10. Who will allocate resources to the project deciding how long they will work on the project itself?
11. Who approves contracts with external suppliers?
12. Who is the executive sponsoring this project? (An executive is able to remove organizational barriers)
13. Who represents the organizational policies that are impacted by the project?
14. Who represents laws and regulations that impact the project?
15. Who will have big changes to their work from the results of the project?
16. Who will have to change their work processes as a result of the project?
17. Who will benefit from the results of the project?
18. Who will work on the project? (Focus is on external suppliers and subcontractors)
19. Who will make the decisions at critical moments?
20. Who will decide that the project is a success?

Planning the engagement of stakeholders in the project can generate high dividends in the ways: a) facilitate the completion of project deliverables; b) generate the expected benefits and value for the project.

To ensure stakeholder involvement that is in line with the objectives of the project, it is necessary that from the start of the project a series of plans and strategies are defined that have as their objective the involvement of stakeholders, and these plans and strategies must be documented in the stakeholder management plan.

We must remember that the expectations of the stakeholders arise not only when the project is actually started and approved, throughout the approval of the project charter, but the expectations and desires are created already in the phase of conception of the project, typically during the preparation and approval of the business case. In essence, these expectations must be managed in the best possible way even before the start of the project activities, this means that one of the first activities that the project leader must carry out is preparing the list of stakeholders and the related management plan.

The stakeholder engagement plan is prepared using the following inputs:

- The project charter that contains all the summary elements of the project as well as a first indication of the stakeholders who have already been identified during the preparation and approval phase of the business case
- the register of assumptions and project hypotheses, in the conception and planning phase of a project there are a whole series of assumptions and hypotheses that are the basis of many of the estimates that are made in the project itself, in some cases some of these assumptions hypothesize that one or more stakeholders provide resources, or maintain certain behaviors, for this it is possible to identify potential stakeholders
- The register of constraints indicates a series of constraints to which the project will have to obey, and in some cases these constraints are associated with one or more subjects that can be immediately included in the stakeholder register and for which it is necessary to prepare the appropriate involvement plans

- The requirements register contains all the requirements that have been officially documented by the project group by the project leader, in the requirements register are indicated the stakeholders for whom one plus the requirements are considered critical
- The benefit register normally contains not only the key performance indicators of the benefits but also indicates those who will be responsible for the effective maintenance of the benefits by the organization that receives the results of the project activities, these inevitably must be considered as stakeholders of the project
- the risk register must be analyzed to identify any stakeholders
- the list of project suppliers is an excellent starting point to identify one or more project stakeholders
- The "Organization charts" from which we can deduce functional relationships or hierarchical relationships relating to the members of the project team, or relating to already identified stakeholders that can lead us to identify additional stakeholders

The stakeholder engagement management plan shall be prepared from the start-up phase of the project and shall be reviewed multiple times during the project. For example when a new project phase begins, because typically it could change the organizational or environmental context in which this new phase of the project happens and this will automatically produce new project stakeholders; or when there are changes in functional organizations or client organizations of the results of project activities; or when groups or individuals become/cease to be stakeholders.
The stakeholder engagement management plan must include for each stakeholder at least the following elements:

- Engagement strategies, which indicates what is the relational and communication approach that will be used with this stakeholder
- Methods of communication, such as by e-mail or formal meetings or informal meetings
- The frequency with which the communication is to be made
- The type of communication, which could be defined according to a series of detailed statuses that must be predefined and pre-approved, as an alternative and possible to send periodic communications such as newsletters
- Any problems or "issues" that are open and that impact this stakeholder or that have been reported by this stakeholder

The control of stakeholder engagement has as its fundamental objective to ensure a continuous and lasting involvement over time, this result is essentially achieved with the following activities:

- Managing project communication in its various phases with the aim of obtaining, maintaining, and possibly amplifying renewing the lost stakeholder engagement and success of the project, this means ideas identifying "win-win" opportunities between the wishes of the stakeholder objectives and the project deliverables
- Managing the expectations of the stakeholders through negotiation, in fact some of the expectations of the stakeholders can be met through the results already foreseen by the comma project in some cases, but this will not be possible therefore necessary to carry out a negotiation and persuasion activity that helps the stakeholders to remain engaged in the activities of the

project even if they are aware that not all of their desires will be satisfied during the execution of the project activities

- Manage doubts and uncertainties with respect to the project objectives, one of the fundamental problems in carrying out the project activities and that as you go forward in the project you can create a disconnect between what has actually been assigned as a comma design objective and the results that are expected implicitly or explicitly by stakeholders, it is important to proactively manage these situations because dubious uncertainties that are not properly managed can create strong friction and possibly potentially permanently damage relationships by creating potential enemies of the project
- Inform appropriately if one or more project risks emerge

A series of critical skills are useful to obtain the right level of involvement by project stakeholders: conflict management, knowledge of cultural differences, negotiation, observation and communication skills, proactivity in issue resolution.

Communicating with stakeholder requires to understand what the customer is interested in. Stakeholders are interested in having information on the progress of project activities on a regular basis and with a frequency that has been agreed in advance, and with a predefined format as agreed with each stakeholder and according to the indications of the project communication plan and the stakeholder management plan.

In communication management the vision that each project team should define as a goal is to be able to make a presentation to senior management on the progress of the project with only 30 minutes notice. This time may seem extremely short and insufficient to make a series of effective reports, but this result can be achieved under the assumption that the work of the project team is organized not only to produce concrete results, not only to check all the activities carried out, not only to monitor the activities the project results, but also to measure the progress in a regular way. The idea is that to make a report on the progress of a project we can use a series of data and metrics provided in a continuous and truthful way by the project team.

Stakeholders also appreciate communications in which the complexity of the project activities is reported with few indicators and a clear perception of the progress, this means that all the details and all the explanations of the data must be put either as backup elements or provided only on request.

The principle to be used is the power of simplicity: if we have the ability to summarize in one or two slides the progress of a project this gives stakeholders an indicator of the clarity of ideas and our ability to control the project.

In planning the collection of data for the purpose of producing communications to stakeholders we must have an approach such that the cost of measurement is proportional to the cost of the project, this means that we cannot have excessively burdensome activities for medium or small projects because this would be a waste of resources, but if we had a project of large size and considerable complexity, obviously of the data collection procedures for the production of status will take more time and be more resource intensive.

Stakeholders and management do not like negative surprises, this means that any situations that may produce problems or increase the probability of occurrence of a risky event must be highlighted well in advance indicating the impact and what is the action to mitigate or avoid the situation.

Communications should address the following key questions:

- Is the project in line with time, costs and quality?
- What were the results produced since the last report and what were any significant contributions produced by the project team?
- What are the critical issues that could impact or are impacting the project and what are the alternative options?
- What are the risks of the project?
- What are the deliverables or concrete results expected for the next period?
- What are the decisions that the sponsor or stakeholders have to make?

9.4 Tools and Best Practices

Stakeholder register

A register of project stakeholders is a project-related document which contains all the information on the project stakeholders. This document identifies the people, groups and organisations that have an interest in the work, the project and its results.

The register (figure 1) includes at least the following elements:

- Name
- Organizational position
- Role with respect to the project
- Telephone and e-mail contacts
- Important requirements for this person or group
- Possible expectations
- An indication of the level of influence and interest on the project
- A classification of the stakeholder

STAKEHOLDER REGISTER

Project Title: _____ Date Prepared: _____

Name	Position	Role	Contact Information	Requirements	Expectations	Influence	Classification

Figure 9.1 Example of Stakeholder register

Stakeholder Power/Interest Matrix

Once identified, the stakeholders can be classified into four categories that are the result of two variables: power in the organization, and their level of interest in the project.

Depending on the placement of the stakeholder in the power of interest matrix, shown in figure two, a specific behaviour is suggested for each category:

- For stakeholders who have a high power but a low level of influence, an acceptable level of satisfaction with the project results should be ensured.
- For stakeholders who have a high power and a high level of influence on the results of the project it is necessary that there is a careful management both in terms of communication but also in terms of involvement and management of the relationship
- For stakeholders who have a low power at the bottom of interest it is necessary simply to allow them to control the situation but without having excessive involvement unless there is a specific request
- For the second and that they have a low power but a high interest it is suggested to properly manage communications to ensure that there is an adequate flow of information

There is no precise order to fill in the matrix: think to a stakeholder and then decide in which quadrant insert it according to its degree of power and its level of interest in the project. Placed the stakeholders in the matrix you will have a picture complete with key ones to manage carefully because have a high degree of power and interest in the project, those who need to be satisfied because for their power could compromise the project and those who are strongly affected but it is sufficient to keep them constantly informed on progress.

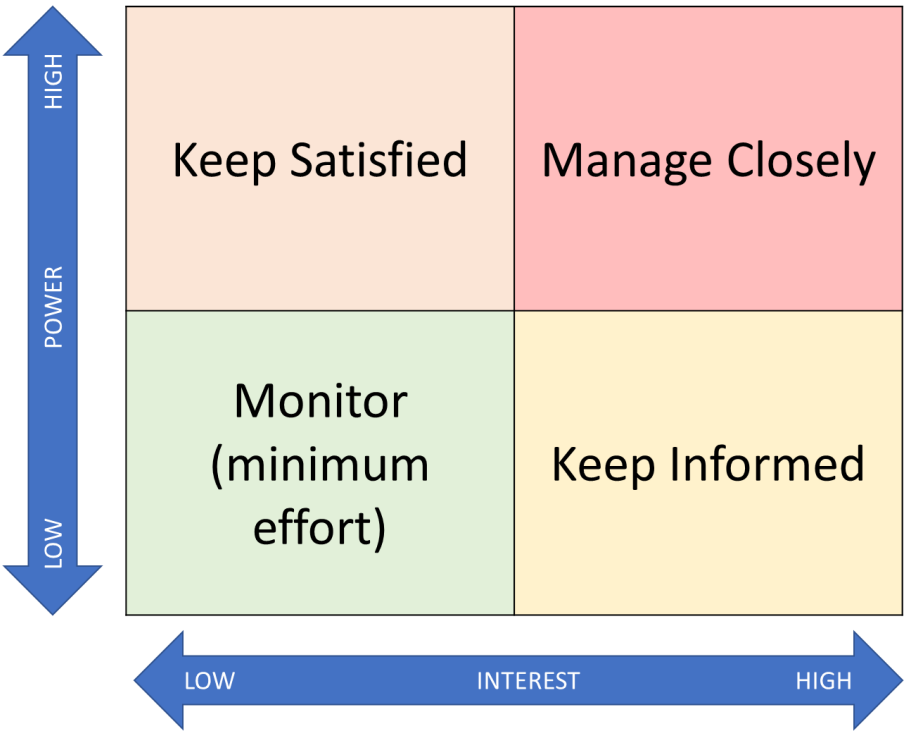

Figure 9.2 Power-Interest matrix

The Project Board

The project board is a committee in which some critical stakeholders for the success of the project are included, it can actually be considered a restricted group of stakeholders that has a very important function. In some complex projects it is advisable to provide for this figure within the project, because it helps the project team on two extremely important issues:

- Deciding on topics on which the team is not able to decide either because it does not have sufficient delegation to be able to make a decision in total autonomy or because the team has strongly discordant opinions, in this case having a select committee that follows the project with some attention and that knows well the problems connected with the project activities helps the project team in making comma decisions and we know how making decisions in a timely and effective manner often helps the project team to be proactive, because when we have more time available we can find better solutions to problems, yes instead we wait the last minute before deciding something before facing a problem typically these are not the best possible solutions but become in some cases a worsening of the problem
- Remove impediments to the performance of the project team, in some cases the project team may find obstacles in moving towards the goal and these obstacles can be caused by other stakeholders or other elements in the organizational context in which the team is moving, the ability and leadership useful to remove impediments is extremely useful for the success of the project

To decide which stakeholders should be involved in this committee, an excellent starting point can be the matrix of power and interest, because stakeholders who fall into the category keep informed or manage carefully should certainly participate in this committee with a representative who has sufficiently relevant proxies to perform the two functions indicated above.

The project board must certainly include the sponsor of the project and if the sponsor cannot participate or cannot devote sufficient quality time it is necessary that a person delegated by him participate and who had a full delegation, this means that this person will be able to make timely and immediate decisions but also to possibly influence other stakeholders who are part of the same committee or who are in any case part of the project stakeholders.

The meetings of this committee must be scheduled well in advance and with a regular frequency every two to three weeks, in this way we ensure that there is always a slot to be able to meet and have an exchange of quality communications between the project team and this committee.

Stakeholder Reporting

Project status reports are timely updates on project progress. They answer questions that stakeholders would like to ask based on their interests in the project. Written in a concise way, they offer in-depth information about a project, rather than about every detail. Creating regular status reports on a project is important, because they help keep all stakeholders up to date on the progress. In addition, a well-formulated and implemented reporting process will provide benefits to the project manager as this will receive far fewer questions and create fewer misunderstandings. Reports can show that a project is proceeding as planned and reassure all parties involved. If a project does not proceed according to plan, the report on its status will let others know what the delay is and what the PM is doing to solve any obstacles, allowing you to show a proactive approach to get things back on track.

10 Project Integration management

10.1 Introduction

Each project has its own life cycle that begins with the handover to the Project Manager (or Project Director) and finishes when the project team achieves the project scope.

During the project life, which can last up to some years, continuous reviews of the intermediate progress of the project are necessary (project monitoring). These are due to the need to verify if the intermediate actual progress of the project meets the planned one. If deviations like overtime or extra costs occur, it is necessary to decide on recovery actions to bring the project back on track (project control). The intermediate check of the project is also necessary to incorporate the scope changes that frequently occur during the project life. In this case, it is necessary to re-plan the project.

Such recurrent project checks imply the need to assure the temporal continuity (from the beginning to the conclusion of the project) that we could define as "horizontal" continuity because it crosses the entire time span of the project.

Furthermore, the project, which is typically based on teamwork, requires the collaboration of different actors, each with their own specialization: there are specialists in charge of preparing and managing the schedule, those in charge of managing the budget, those in charge of managing the costs, or the quality, etc. Additionally, it is to take into account that continuous interaction with the client(s) is relevant for the whole project and could entail revisions and changes to the original plan.

Such a multidisciplinary team and the interplays mentioned above imply the need to assure the consistency of different specializations from the beginning to the conclusion of the project that we could define as "vertical" coordination between the different functions that contribute to the execution of the project.

Integration management is that particular function within the project that ensures both the "horizontal" temporal continuity (project memory) and the "vertical" knowledge coordination of the project. By its nature, it is an "apical" function of the project team that is performed by the Project Manager (or the Project Director).

Due to its key role, the replacement of the Project Manager during the project progress is a very traumatic event for the project that creates problems for all external and internal interfaces.

PMBOK GUIDE 6th edition (the Guide) provides an exhaustive description of processes and activities relevant to Project Management. A large abstract of the Guide is reflected in the Standard for Project Management ANSI/PMI 99-01-2017.

10.2 Objectives

As already mentioned, the main objective of *Integration Management* consists in ensuring the temporal "continuity" of the project, and in particular, the consistency of periodic reviews, updates and corrective actions, and the coordination of the different specializations that cooperate inside the project team.

Given the "systemic" nature of the project, all functions must be aligned about the review needs in such a way that each function can act in a coordinated manner with the other ones.

To ensure continuity and coordination, the Project Manager has to develop his/her role internally and externally to the project:

- the internal role is the one of directing the project team to achieve the objectives (scope on time and budget);
- the external role is the one of maintaining the relationship with the project sponsor and evaluating those pieces of information about the project that can be given to third parties.

Among the tasks of Project Management Integration we can also list the following ones:

- the allocation of resources,
- the negotiation between the conflicting needs of the various functions,
- the study of different alternative solutions of specific problems,
- the customization of procedures to the specific project,
- the management of problems common to several disciplines.

In carrying out his role, the Project Manager will take into account the complexity of the project system. The complexity of the project derives from three main sources: 1) the systemic nature of the project in which each part is related to the other parts, 2) the role played by human agents (and their mental models), and 3) the ambiguity that derives from uncertainties, misunderstandings, and confusion.
An expert Project Manager will take this complexity of the project into account in certain phases and in particular contexts, trying to make his/her presence felt and helpful, and/or taking particular actions if and when necessary.

10.3 Processes

The sequential and recurrent phases through which the project is developed can be described as "processes".
Each process has to be repeated several times during the life of the project (with the exclusion of the closure process of the project that is just one) both to take into account the "external" variations as well as for aligning the project with the intermediate objectives (periodic monitoring and control).
The sequential processes or phases of the project are essentially the following ones:

- *Process of initiating the project*

This process entails developing the input document to the project, called Project Charter which is the equivalent of a contractual document that defines the purpose, the scheduled times, and the costs assigned to the project. In case of any significant project change due to external requests or internal needs, the project charter has to be updated. In this situation, the role of integration management is fundamental because it assures that all the functions involved in the project are aware of the change and can provide their contribution and the requested extra effort.

- *Process of planning the project*

This process consists of planning (or re-planning in case of a project change) the project. In particular, it includes the definition of the schedule. The initial planning defines the project Baseline. The approved project changes will cause the baseline to change according to the latest approved scope, scheduled times, and costs (approved baseline). The deviations of scheduled times and costs must be measured with respect to the last approved project baseline. Here the role of Integration Management consists in assuring that all the actors of the project provide their contribution to the re-plan following a change. During this phase, some functions could take advantage in order to recover a weak position, taking margins in excess. The Project Manager should carefully evaluate this possibility and share equally the extra effort.

- *Process of executing the project*

This process consists in leading the project team and managing the different specializations that are part of the team (disciplines and knowledge areas) in order to achieve the target. During this process, the project deliverables are generated according to the project plan.
This is the execution of the activities which requires to verify that every single discipline is performing at its maximum level, remove any possible bottleneck, suggest the ways to recover productivity, promote transparency in the communication, promote knowledge sharing, promote the improvement of operational skill and organizational learning of the project team.

- *Process of monitoring and control the project*

This process consists in monitoring the project progress in order to identify any deviation from the latest approved baseline and control the progress thereby implementing the corrective actions that keep the project on track.
The Project manager has to understand the status of the project based on the information given by the disciplines in a Status Report, find out the corrective actions and instruct the discipline leaders to act accordingly.
The main task of Integration Management is to keep the project team coordinated in the implementation of the recovery actions also promoting a proactive approach. This is important in particular when a project change has been approved.

- *Process of closing the project*

This process happens once during the project life and consists in closing the project.
This means finalizing all the activities and solving any commitment with the project sponsor as well as subcontractors. The project is closed when the scope has been achieved in terms of delivered material and achieved performances as well as the relevant Warranties and Guaranties have been fulfilled.
The final report and the lesson-learned report are issued. Project team members move to other projects.

10.4 Tools and Best Practices

The list of best practices can be divided at least into three groups in order to highlight the potentials of meetings and reports, formal and informal techniques, and system methodology techniques (namely Systems Thinking and System Dynamics).

Meetings and reports

Project Management is a teamwork therefore the coordination of the effort of every knowledge area is fundamental for its success.
In order to manage the integration of the Project Management Team, it is essential to call regular meetings where all the representatives of each knowledge area are involved. The *Integration Meetings* or *Project Progress Meetings* should be called on a regular basis. Usually, for large infrastructural projects, such regular frequency can be monthly. For small projects, the frequency can be daily or weekly.
Among best practices it is also essential the preparation and sharing of the Project Progress Report. The report can be anticipated to all the project functions involved in the project at least one day before the Project Progress Meeting.

All the knowledge areas involved in the project should cooperate in drafting the report. This is also essential to stimulate all the participants to the project to focus on their own targets.
One important factor for the success of integration of all the knowledge areas is to establish, during the meetings, a cooperative attitude thereby trying to avoid to look for one or more responsible of poor performances.
During the coordination meetings and the analysis of the progress report, the following topics have to be discussed:

- *Project Objectives.* All the knowledge areas should know the overall project objectives as well as their own objectives i.e. Scope, Scheduled Times, Costs, Resources, Risks, etc. Notably, single objectives can be revised according to the actual status of the project whereas the overall project objective cannot change unless a project variation occurs as per charter amendment.
- *Project Schedule.* All the people in charge of each knowledge area should know the Project Schedule at level of large WPs. In particular, the people in charge of the knowledge areas should know the project progress (actual vs. planned) from beginning up to the forecast closure (total job). They should also know the critical paths of the project, the requested deliverables, resources, etc. Cost and Time variance should be stressed during the Integration meeting in order to align the efforts of each knowledge area for closing the gaps. Notably, the plan has to reflect the latest contracts and subcontractors schedule, valid at the current date. For long lasting project it could be useful the analysis of the plan in the next future (i.e. three months look ahead) in order to focus the corrective actions in the next future in addition to the total job corrective actions.
- *Project Execution.* During project execution, it is necessary to check the deviations between the planned progress and the actual progress. Subsequently, it is necessary to analyze the causes underlying the deviation, if any, to discuss and coordinate the recovery actions needed to compensate the deviation. In particular, it is necessary to evaluate if changes to the project occurred and how they have to be solved. A typical recovery action has to be addressed to contractors and the performances of their allocated resources to the project. Any project variation has an impact on all the knowledge areas: scope (scope creep), cost, time, risk etc. Additionally, an important issue, in case of changes, is to evaluate if a Budget Recast is necessary (i.e., use budget reallocation from less expensive to more expensive budget area). Alternatively, it may be necessary the use of contingencies, if allocated.
- *Competing Scope.* Design is focused mainly on scope and quality (i.e. specifications); costs and scheduled times have lower priority. Design activity is iterative by nature. Procurement is focused mainly on scope and costs; quality and scheduled times have lower priority. Construction is focused mainly on scope and scheduled times; costs and quality have lower priority. Construction is deterministic by nature.

Integration management should balance all the different priorities mentioned above. Design is an upstream activity; if it is delayed then downstream activities have to recover. Pressure on Design activity leads to an increase of rework for construction. Rework means also redesign. This is a reinforcing disruptive loop. It generates pressure on design and construction with more and more mistakes due to people stress. Design mistakes generate contractor's claims. Claims means renegotiations of contractual cost and schedule. Since Design is requested for claim negotiation, this causes an additional project reinforcing loop that can lead to the project failure.

The Project Manager is the memory and coordinator of the project, and has to know how to avoid critical loops, avoid overloading the critical resources and lead the project in a stable and coordinated way.

Formal and informal techniques

As already mentioned, Integration project management involves various processes, systems, and strategies that bring them together. Project integration management is a collaboration with all the project elements (e.g., stakeholders, resources, and personnel) and, subsequently, it is also aimed at managing the conflicts between the different aspects of the project. Notably, project integration management is conceived with a "work practice" perspectives. This means that project integration management entails the development and use of a socially organized agenda where the project manager gets output. The project managers become proficient in particular areas such as project management, system analysis, system thinking, and design and redesign of a system, everything put in the context of a specific project. For these reasons, project managers are (or should be) familiar with an array of operating tools such as the work breakdown structure, Gantt diagrams, software, and operational system. Commonly, most of the actions and strategies involved in the work practices are related and needed to deal with the project objectives, schedules, execution, and scope.

To manage and overview project activities, the project manager can also rely on formal and informal techniques during the project to get information inside and outside the organization.

Among the main tools and techniques suggested by the literature we list the following ones.

- *Interviews (with operators and/or stakeholders),*

Interviews can be seen both as a formal and informal approach to get or discover information from the stakeholders by meeting or coordinate them directly. Usually, some interview questions are prepared before meeting the respondents and might entail recording their responses.

- *Focus group (target audience),*

Focused group refers to the expert in the area of project management that could be stakeholders, operators, and other general public. To get information from the focus group the project manager is involved in the discussion and may shape a dialogue one by one.

- *Organized workshops (within and out of the organization).*

Workshops are the primary technique to discover information among the public as well as from stakeholders since this technique creates an interactive environment and can build and foster relationship among the relevant actors involved in the project. The participants to the workshops may improve their communication as well as generate ideas and provide feedback on the project.

- *Group creativity techniques*.

To foster relationship among working bodies of the project, the project manager may use group creativity techniques, like brainstorming, priorities following techniques, expert questionnaires responses, idea mapping techniques, group model building, participatory modelling, diagram mapping and also case studies. All these techniques are meant to discover information that can be helpful for the completion of the project as well as to resolve discrepancies in it.

- *Group decision-making techniques.*

This technique is used to ensure the project development by unanimity, majority of voting members and, more in general, direct involvement of people.

- *Questionnaire and Survey to the general public*.

This technique uses written questionnaires and surveys that are distributed to the general public to gather quickly information that is subsequently sorted out by using statistical analysis.
In addition to these considerations it is to highlight that: 1) as we already mentioned (section 4.1.), several reports are used throughout the project; 2) in order to specifically address high levels of complexity in project integration, system methodology can be specifically recommended (see section 4.3).

Systems Methodology: Systems Thinking and Systems Dynamics

Among the best practices that can be mentioned to address the feature of complexity and understand change in and about economic-, environmental-, and social-related systems and projects, "systems methodology" (or the systems approach) is frequently used.
Systems methodology provides a set of conceptual and analytical methods, techniques, and tools used for systems thinking and dynamic modelling about complex and dynamic domains, such as the one related to project management. In this context, the fields of Systems Thinking and System Dynamics have acquired an increasing relevance over the last decades and are widely applied in a variety of fields and projects.
In contrast to the reductionist and analytical approach that quite frequently characterizes management studies, systems methodology and techniques adopt a systemic perspective applied for the analysis and understanding of complex domains and problems. In this regard, systems methodology provides more than a set of tools and can be seen from different perspectives: first, as a holistic approach to analyze how systems work and can be managed; second, as a set of techniques and tools that will support analysts, learners, and decision-makers in facing problem-solving tasks and complex issues; third, the ability to apply systems methodology can be even seen as a skill or even a "discipline" in itself.
Systems Thinking and System Dynamics are among the most recognized and applied system methodologies.

Systems Thinking

Systems Thinking (ST) supports analysts to inspect, analyze, and evaluate a specific problem in its domain (the "system" under investigation), thereby favoring the gain of policy insights and supporting learning as well as decision-making. Specifically, ST provides analysts, learners, and decision-makers with various tools and techniques that support them throughout the various stages of an intervention or a project.
In broad terms, key to the approach are the concepts of causal connections and feedback loops.
Among the most relevant tools we mention the following ones: causal loop diagrams (CLD), stock and flow diagrams (SFD), system archetypes, interactive learning environments (ILEs).
Figure 1 provides a simplified example of a causal loop diagram and a stock and flow diagram.

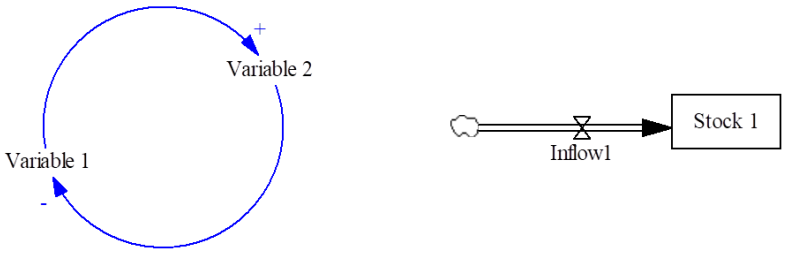

Figure 10.1 Simplified examples of a causal loop diagram and a stock and flow diagram.

The fundamental idea underlying ST tools is that the observed behavior of a system is generated by the structure of that system which is, in turn, influenced and governed by people's decisions. Hence, analyzing and representing the structure of the system is the key to make sense of what we experience and observe daily and to understand how people's mental models guide them in making decision and taking action subsequently (see Figure 2).

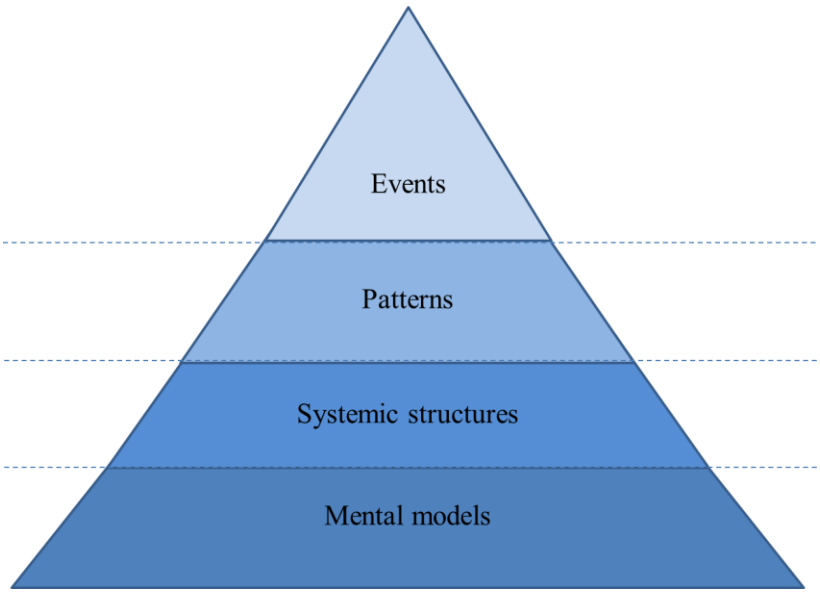

Figure 10.2 Four levels in Systems Thinking.

ST can be applied broadly and in a variety of fields, but is specifically recommended when the domain under analysis has some of the following characteristics

- the issue is relevant;
- several parts of the system interact (through cause-and-effect linkages) giving rise to the specific behavior (or problem) under analysis;
- parts of the system are not only linearly connected, but are also linked circularly thereby generating feedback loops:
- the problem to be faced is not easy to analyze, and might have been determined by causes distant in space and time (i.e., delays are relevant in the domains under analysis);

- trade-offs among possible solutions may exist;
- human agents and their behavior matter.

The development of an ST intervention usually involves five major phases, thereby guiding analysts and decision-making in applying ST theory and practice:

1. problem structuring;
2. causal loop modelling;
3. dynamic modelling;
4. scenario planning and modelling;
5. implementation and organizational learning.

Notably, an ST intervention does not imply to go through all the five phases mentioned above. Rather, these phases can be regarded as guidelines able to provide the basis for a systemic and structured analysis and critical thinking. This is fundamental also for integration management in the perspective of a project management intervention.

When the intervention requires to quantitatively model and simulate the behavior of the system (or problem) under investigation, it is recommended to move from pure System Thinking principles and tools to the domain of System Dynamics.

System Dynamics

System Dynamics (SD) is a computer-aided modelling and simulation approach to policy analysis and design that can be effectively applied to model and simulate dynamic problems arising in complex domains characterized by interdependence, mutual interaction, information feedback, and circular causality. As already mentioned previously, the main advantage in using this type of methodology (i.e., a systems methodology) is that it provides with a vision that considers many aspects inside a system as interconnected with each other, contrary to those approaches that adopt a reductionist approach to policy analysis, thereby considering factors and problems individually, in silos, or using a sectoral basis.

Overall, SD is based on four main concepts, as follows.

1. Systems are considered as a whole.
2. Emphasis is placed on the internal structure of the system as the cause of its dynamic behavior (in detail, the concept of feedback is a central notion).
3. Rather than considering relationships in a model as being linear, emphasis is placed on the non-linear character of many relationships.
4. Process delays (e.g. information delays) in social systems are considered important.

Notably, SD can be regarded as a complementary approach to ST, with the two of them that share most of the theoretical principles and some technical tools (e.g., CLDs and SFDs).

However, SD is specifically needed when a quantitative representation and simulation of the system/problem under investigation is required. The quantification is necessary and/or useful for several reasons; above all, building and using the computer model facilitate learning about complex dynamics and the development of managerial understanding and skills.

In principle, an SD intervention is usually structured as follows:

- articulate the problem that needs to be addressed;
- formulate a dynamic hypothesis or theory about the causes of the problem;
- build the simulation model to test the dynamic hypothesis;

- test the model; and
- design and evaluate policies, also with the support of ILEs.

From a technical point of view, any SD model contains a representation of the physical world relevant to the problem under analysis, and portrays the behaviour of the actors in the system, consequently embedding their decision-making rules. The modelling process eventually leads to a mathematical model that represents the system under analysis (and fits with historical data), and is subsequently used as a future-oriented tool (especially in the form of an ILE) to explore an entire range of feasible options, supporting policy analysis and scenario planning, and fostering learning.