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Project Management

turning change into success

This course outlines the nature and benefits of projects. Why is it beneficial to employ project management? The course starts with the explanation of the theoretical and practical foundations of project management and illustrates the role of project managers. How can they live up the expectations of companies aspiring to reap the benefits of change?

The content of this course follows the Project Management Body of Knowledge (PMBOK) developed by the Project Management Institute (PMI). The PMBOK categorizes the knowledge within the profession of project management along ten knowledge areas, ranging from integration and scope, cost and schedule management, over risk and quality management, to communication and stakeholder management. The course consequently structures its content along these knowledge areas.

A series of quizzes complete the course. These quizzes enables you to check your knowledge and provide you with hints where you could improve your knowledge.

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A Fundamentals

In this chapter, you learn the fundamentals of project management:

What is a project?

Why do we need project management?

The iron triangle of project management

Characteristics of the project life cycle

The organizational context of projects

What is program and portfolio management?

How are data, information, and reports managed in projects?

Decision making in projects

Roles, skills, responsibilities, and qualities of project managers

Leadership models and principles

Management process groups

Overview of the ten project management knowledge areas

1 What is a project and why do we do projects?

Projects have existed for hundreds of years. They exist in broad and small contexts. Some examples of projects are:

- The Acropolis in Athens
- The Eiffel Tour
- The new airport of Berlin
- The assassination plot against Hitler in July 1944
- Each volume of Harry Potter
- Your wedding reception
- Cleaning of your bathroom
- Repairing your car on your own
- The roll-out of a new database system in a company

The examples show that the outcome of a project can be a success or a failure. Think for a moment what all these projects might have in common.

Why do we do projects?

A project is about change. Independent of the nature, size, purpose, or success, projects mean change, they are about bringing change into our world.

The world is changing and so does the environment of our business. New fashion trends emerge, new technologies become available, new societal challenges and needs arise, posing threats and opportunities to the society and to business, too. New competitors appear on the market, existing competitors expand their market shares, and other ones go out of business. Companies that do not react to changes fall behind and jeopardize their existence. Taking up the challenge of change gives us the chance to capitalize on new opportunities.

Projects enable companies to venture into the changing world and to reap the benefits from the emergent opportunities.

Even though projects differ in many aspects, they have some essential traits in common:

- They have a goal that reflects an initial need
- There is a plan
- There are people involved assuming different roles
- There are resources required
- There are a clear start and end points
- There are outcomes produced
- There is a final result which can be a success or failure

"**A project is a temporary endeavor undertaken to create a unique product, service, or result**." [PMBOK Guide, p. 4]

There are two explicit and further three inherent characteristics [PMPBOK Guide p. 4-7]:

1. A project is a **temporary endeavor**, that is, a project has a definite beginning and end. The duration of the project can be long or short. More important it has a clear end point:
    - The objective of the project has been achieved
    - Its objective can no longer be met
    - The project runs out of money or other essential resources are no longer available.
    - The need for the project no longer exists
    - The project must be terminated for legal reasons
2. A project creates a **unique product, service, or result**. In other words, it produces one or more deliverables:
    - The product itself (a prototype of a new aircraft) or service itself (installation of a help desk for a particular new software)
    - One or more components for the improvement or enhancement of an existing product (a model for a new car dashboard design, one or more chapters of a book)
    - It can also be a unique combination of products, sub-products, and services.

A *deliverable* is something that can be delivered, such as a product, service, or result.

Each result may even be repetitive, like the construction of a prefabricated house. The construction itself may have its unique key characteristics (location, people involved, etc.)

The **inherent or implicit factor** for the project initiation are:

1. **Projects foster change**. Projects are undertaken to change situations of all kind (economic, environmental, political change to name a few). The change can be disruptive or a smooth transition to a desired future state.
2. **Projects enable value creation**. Projects help to produce benefits. That can be business value, contribution to achieve climate goals, societal progress, personal well-being and others. The benefits can tangible or intangible.

   The Project Management Triangle (or Iron Triangle) is a graphic metaphor to show the forces of the major constraints in project management: scope, schedule, and cost. Project Management's success is measured by the project team's ability to produce the expected results while managing schedule and cost.
3. **Projects respond to needs or requirements**. Projects are often a means of directly and indirectly achieving strategic objectives. The needs can be rooted in a market demand, customer request, social need, or other reasons:

Market demand	Volkswagen decided to build electric cars in response to its exhaust scandal
Strategic opportunity	The German railway company adds bus services to its regular service portfolio to increase revenues
Environmental consideration	Company providing a new service for electric car sharing to reduce pollution
Customer request	An electric utility company authorizing a project to build a new substation to serve a new IT park.
Technological advance	Cell phone manufacturer authorizing a new project to develop faster, cheaper and smaller phones

Legal requirements	A drug manufacturing company authorizes a project to establish guidelines for the handling of a new toxic material.
Social need	Housing project for handicapped people

Table 1: Categories and examples of reasons for the initiation of projects.

Why do we need project management?

Projects are about change. They bring benefit to business. Project management sets the scene for effectively and efficiently transforming change into benefits. It orchestrates the application of knowledge, skills, methods, techniques, and tools. This managerial framework empowers people to reap the benefits from change.

2 The project management triangle

The definition of a project covers

- its **scope**, its work to be performed to deliver the desired product, service, or result.
- the **quality** to be achieved as the inherent characteristics of the product, service, or result that fulfill the requirements derived from the project need.
- the **schedule** of the planned project activities reflecting the duration of the project, and
- the **cost** of the project reflecting the necessary funds to supply the project activities with the resources required to perform the project activities.

The *Project Management Triangle* (or *Iron Triangle*) is a graphic metaphor to show the forces of the major constraints in project management: scope, schedule, and cost.

Figure 1: Project Management Triangle (or "iron" triangle)

One side of the triangle cannot be changed without any impact on its other sides, if the size of area of the triangle shall remain the same.

If you want to maintain the level of quality (the area of the triangle), for instance, but you have to reduce the schedule, then you have to increase the costs or reduce the scope.

If you do not want to achieve any more all the desired requirements (the level of quality) then you can reduce the cost of the project, its duration, its scope, or all or two of these three parameters.

3 Project Life cycle

Projects are usually performed in phases. A series of phases describes the life cycle of the project from its start to its completion.

“Each project phase is the collection of logically related project activities that culminates in the completion of one or more deliverables.” [PMBOK Guide, p. 20] Each phase should be described in detail, mentioning its task, entrance and exit criteria, duration, and resource requirements.

Figure 2: Phases and phase gates of the project life cycle

Between the phases, there are phase gates (also called kill point, stage gate or phase review). At the phase gates, the progress of the project is evaluated and a decision is made whether to continue or cancel the project. This decision has the nature of a go/no-go decision.

The outcome of this decision can be

- “continue with/without modification”,
- “end of the project” or
- “repeat the whole phase or activities of it”.

Product life cycle. The product life cycle differs from the project life cycle as it describes phases that represent the evolution of the product, from concept through delivery, maturity, and retirement.

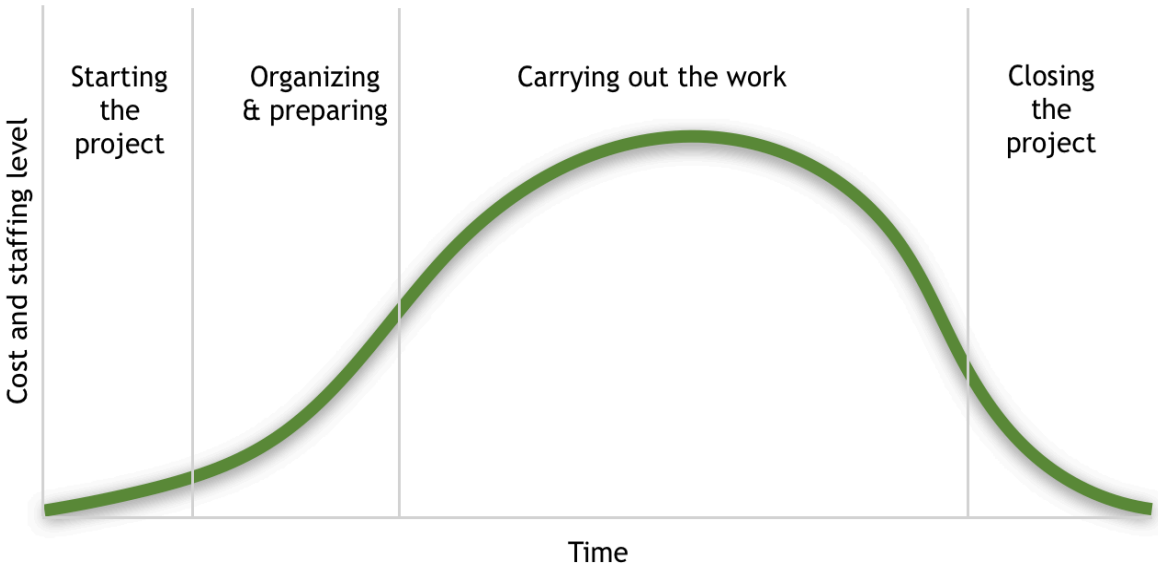


Figure 3: Distribution of effort levels over the project life cycle

Questo stava su una domanda!

Cost and staffing levels are low at the start, peak as the work is carried out, and drop rapidly as the project draws to a close.

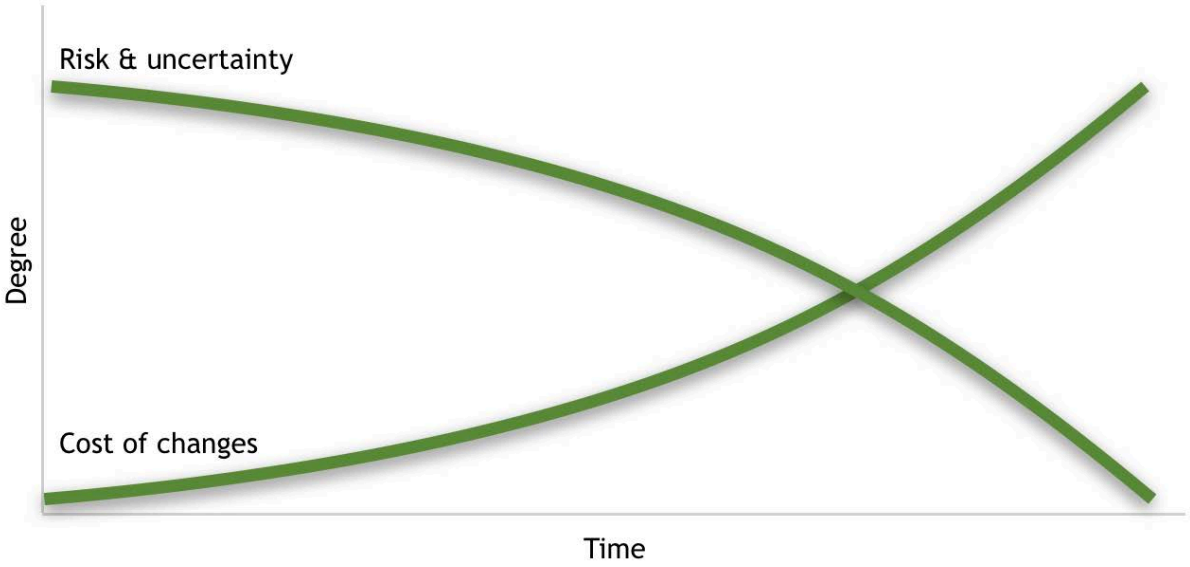


Figure 4: Typical development of risk and uncertainty and the costs of changes over the project life cycle.

Questo stava su una domanda!

The ability to influence the final characteristics of the project's product, without significantly impacting cost, is highest at the start of the project and decreases as the project progresses towards completion. The cost of making changes and correcting errors typically increases.

The project life cycle, that is, its series of phases can take different forms [PMBOK Guide, p. 19]:

- **Predictive life cycle**. Bulk of planning occurring upfront, then executing in sequential processes. The sequence of all phases are well defined at the beginning of the project. Each project phase usually follows the next one and no phase is repeated. Therefore, this cycle is also called waterfall cycle.
- **Iterative life cycle**. Allows feedback for unfinished work to improve and modify that work. In an iterative life cycle, a series of phases are repeated until a satisfactory result is achieved. Iterations may be necessary when additional knowledge is required that can be achieved through working on the tasks of the respective phases. New knowledge may be necessary for the continuous elaboration of requirements.
- **Incremental life cycle**. Provides finished deliverables that the customer may be able to use immediately. Through each iteration there is new functionality added to the product. The deliverable with the necessary and sufficient capability is considered complete only after the final iteration.
- **Agile life cycle**. It is both iterative and incremental to refine work items and deliver frequently. At each cycle the requirements are continuously reviewed, modified and reprioritized (usually in close cooperation with the stakeholder of the projects).

	Requirements	Activities	Delivery	Goal
Predictive	fixed	performed once for the entire project	single delivery	manage cost

	Requirements	Activities	Delivery	Goal
Iterative	dynamic	repeated until correct	single delivery	correctness of solution
Incremental	dynamic	performed once for a given document	frequent smaller deliveries	speed
Agile	dynamic	repeated until correct	frequent small deliveries	customer value via frequent deliveries and feedback

Table 2: Forms of the project life cycle

4 The Organizational Context

Projects are embedded in different organizational contexts depending on the size and importance of the project. Small projects are managed in a simple, functional, or weak matrix organization.

Organizational structure type	Project manager's authority	Project manager's role	Resource availability	Who manages the project budget
Organic or simple	Little or none	Coordinator; part-time	Little or none	Owner or operator
Functional	Little or none	Coordinator; part-time	Little or none	Functional manager
Weak matrix	Low	Coordinator; part-time	Low	Functional manager
Balanced matrix	Low to moderate	Coordinator; part-time	Low to moderate	Mixed
Strong matrix	Moderate to high	Full-time; designated job role	Moderate to high	Project manager
Project-oriented	High to almost total	Full-time; designated job role	High to almost total	Project manager

Table 3: Overview of organizational project contexts

Projects are typically undertaken in a divided approach in the functional organization type. For example, the IT department works on its portion of the project and then hand it off to the manufacturing department to complete its part, and so on.

The Weak matrix organization structure maintains many of the characteristics of a functional organization structure, and the role of the project manager is more of a coordinator. She or he cannot personally make or enforce decisions.

Matrix organization types have subtle differences, and it's important to understand their differences. The balanced matrix organization type recognizes the need for a project manager, but does not provide the project manager with the full authority over the project and project funding.

In the strong matrix organization type, project managers have the ability to strong-arm the functional managers into giving up their best resources for projects.

In the project-oriented organization type, team members are often collocated. The project has its own organization unit within the company. Virtual collaboration techniques are often used to accomplish the benefits of collocated teams.

5 Program Management

Projects usually do not exist in isolation. First of all, they are the manifestations of business value proposition and are thus deeply rooted in the environment of the project performing organization.

In many cases, there are interrelationships between and dependencies among projects. Several projects, for instance, may pursue a broader common objective. The development of a new aircraft may be split into projects addressing the wings, the fuselage, the landing gear, etc.

When the European Commission fosters research on particular topics, such as "Lifelong Learning" for instance, it groups complementary and partly even competing projects from different organizations and consortia together under one organizational framework.

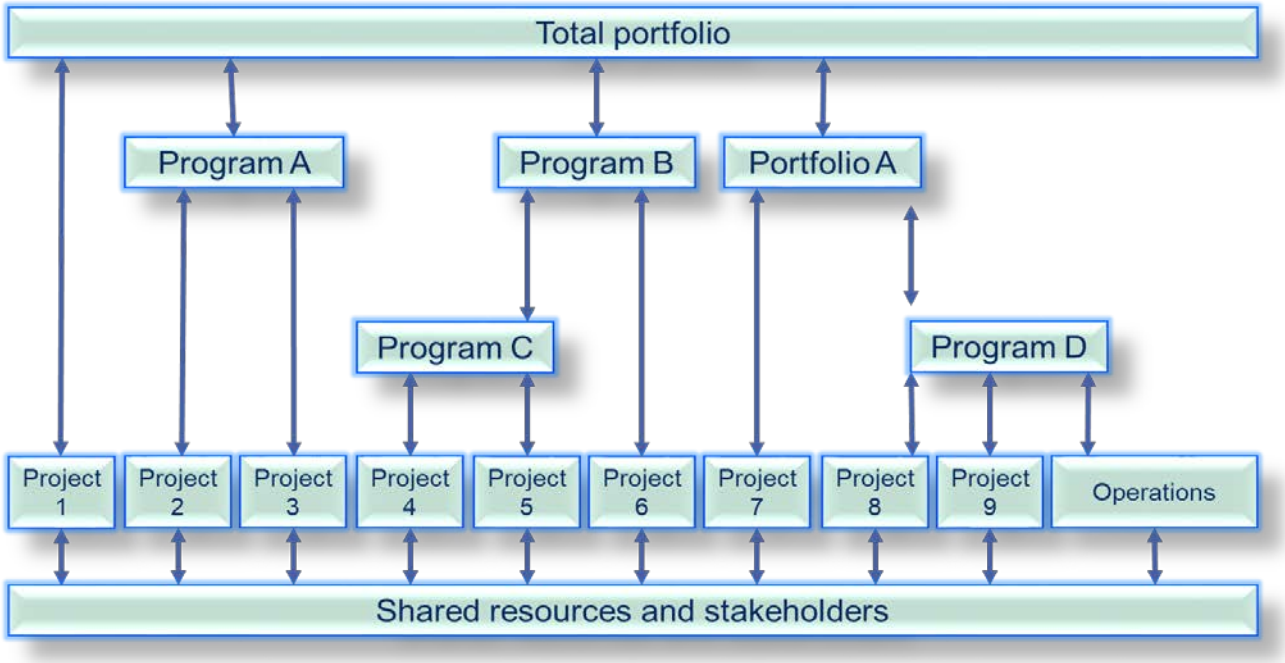


Figure 5: Example of a portfolio structure and its subdivision into programs, subprograms, projects, and further portfolios.

All these related projects are then managed as a program of projects. Programs can achieve more strategic goals and benefits that are out of reach when managing the projects individually. The expected success factors are thus measured on a more global level with the individual projects as contributing factors.

Programs consist of related projects and may also cover sub-programs that handle certain groups of related projects.

6 Portfolio Management

Program management focuses on related and complementary endeavors to achieve a common goal. Portfolio management, however, focuses on the management of all endeavors, not necessarily dependent or directly related, on project or program level of an organization.

Portfolio management's main goals are

- ensuring that the projects and programs of the portfolio are consistent with the organization's strategic objectives and
- optimizing resource allocation among all endeavors of the portfolio.

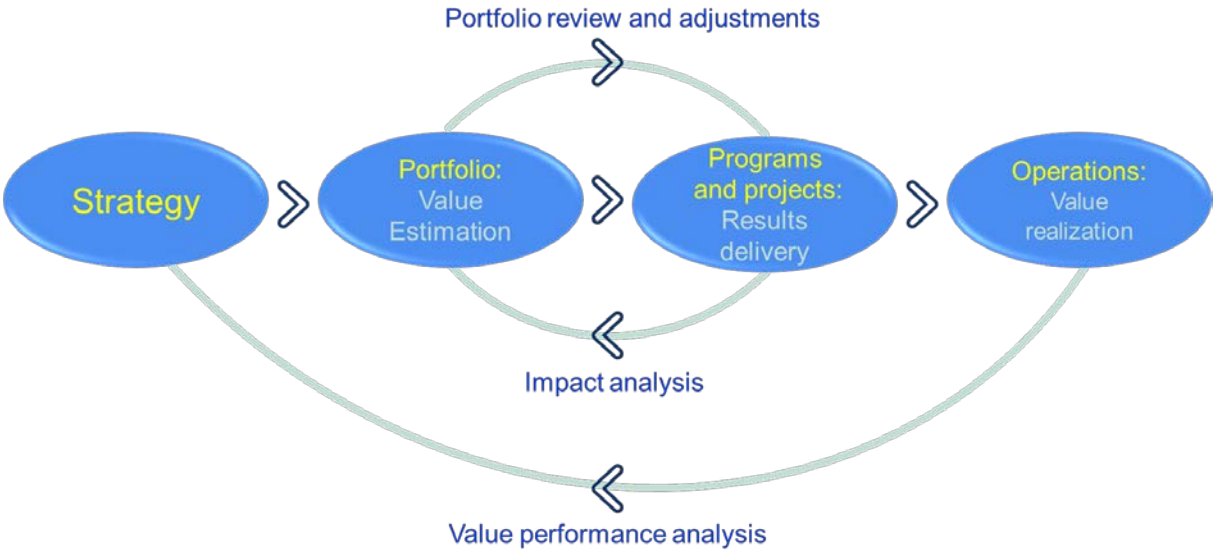


Figure 6: Strategic relationship between organizational strategy, portfolio, programs, projects and value performance.

7 Project Management Office

The Project Management Office (PMO) is a organization-wide institution that

- standardizes project-related governance processes and
- supports the sharing of resources, methodologies, tools, and techniques among projects.

The role of the PMO is consultative by supplying to projects useful templates and software, best practices, training, information, and lessons learned from other projects. It controls also the application of standards and best practices for good project governance. In some cases, it may even take control of projects and manage them directly.

8 Project Information Management

Throughout the life cycle of a project a significant amount of data is collected, analyzed, aggregated, and transformed to become project information. This information is communicated verbally or stored and distributed in various formats as reports.

8.1 Data, Information, Reports

Work performance data. Raw observations and measurements identified during activities performed to carry out the project work, e.g. work completed, key performance indicators (KPIs), quality measures, start and finish dates, number of change requests, actual costs, etc.

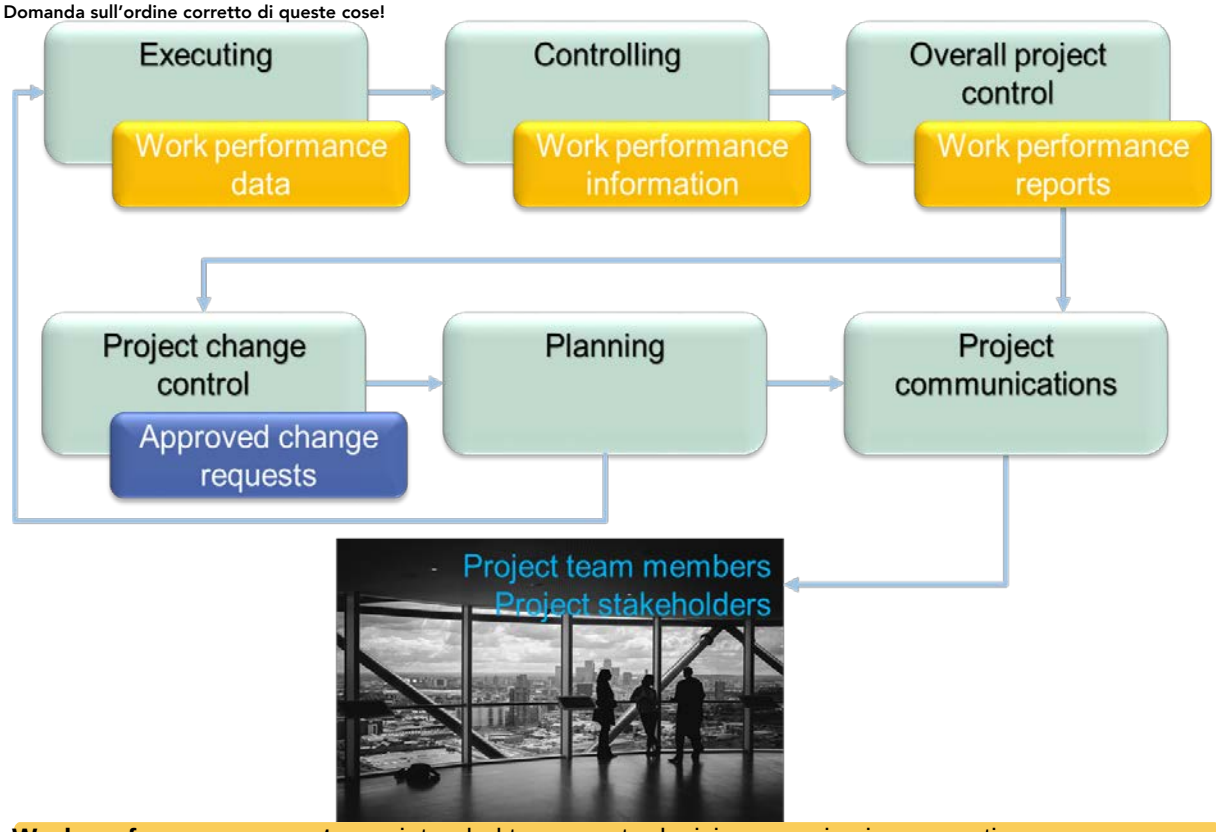
Work performance information. Performance data are analyzed in context and integrated based on relationships across areas, e.g. status of deliverables, implementation status of change requests, and forecasts estimates to complete.

Work performance reports. Physical or electronic representation of work performance information compiled in project documents, intended to generate decisions or raise issues, actions, or awareness, e.g. status reports, memos, justifications, information notes, electronic dashboards, recommendations, and updates.

Figure 7: Flow of information in a project

Work performance data are raw observations and measurements identified during activities performed to carry out the project work.

Work performance information is collected from various controlling processes.



Work performance reports are intended to generate decisions or raise issues, actions, or awareness.

8.2 Key Performance Indicators and Key Result Indicators

Key Performance Indicators (KPIs) are metrics that take the quantitative results of the *current* project and help the project manager and stakeholders to track the project's progress and performance. KPIs measure the actions and events leading to a result. They examine the present situation in the project and point towards the future. Project managers can study and analyze results and put in place corrective actions based on KPIs.

Key result indicators (KRIs), in turn, are metrics that measure and express past performances of projects. However, they can also be used as benchmarks to determine the project's overall success.

KPIs and KRIs do not specify which actions have resulted in success (or failure) and why, they are just benchmark business metrics that determine if a goal has been met. While KRIs can be financial or non-financial indicators, KPIs are non-financial indicators only. Additionally, although KPIs are a result of a single activities or single teams within the project, KRIs reflect more the performance of the entire project.

Further, while KPIs offer information for actions to take to improve project performance, KRIs provide just a snapshot or summary of the project. Because KRIs offer an overview, they provide good insight for project managers and stakeholders who are not involved in day-to-day operations.

Examples of KPIs are "Earned Value", "Cost Performance Index", and the like. KPIs will be discussed in detail in the chapters "schedule project management" and "cost project management".

KRIs are typically broken into two categories, financial related and non-financial related. *Examples of financial KRIs* include:

- Net or gross revenue.
- Net or gross profit before tax.
- Profit margins broken down by product, location, customer or segment.
- Return on capital.
- Market share.

All the non financial thing are correlated to the project and cannot be selled.

Examples of non-financial KRIs include:

- Number of customer complaints, returns or inquiries.
- Customer satisfaction
- Employee retention
- Number of defects
- Implementation or waiting times of a service.

8.3 Data and Information Gathering

Meetings. There are many different forms of **meetings** in project management. They help to produce information on the project's current status and its future progress. Meetings are a very good instrument to encourage conversation and interaction between people in order to foster the exchange of their implicit knowledge (experiences, insights, beliefs, etc.)

The *project kick-off meeting* is usually associated with the end of planning and the start of executing. Its purpose is to communicate the objectives of the project, gain the commitment of the team for the project, and explain the roles and responsibilities of each stakeholder. [PMBOK Guide, p. 86]

Daily stand-up meetings are held in agile environments, but increasingly also in more "traditional" project environments. A daily stand-up meeting is a short organizational meeting that is held each day. The meeting, generally limited to between five and fifteen minutes long, is sometimes referred to as a stand-up, a morning roll-call or a daily scrum. Each team member informs about her or his individual achievements of the past day, the plans of the actual day and the impediments and problems that may hamper the work of today.

Brainstorming is a technique used to spontaneously identify creative ideas and solutions. It is usually conducted in groups, but individual brainstorming is also possible. Brainstorming constitutes two phases: idea generation and analysis. It requires intensive, freewheeling discussion in which every member of

the group is encouraged to think aloud and suggest as many ideas as possible based on their diverse knowledge.

Brainstorming combines an informal approach to problem-solving with lateral thinking, which is a method for developing new concepts to solve problems by looking at them in innovative ways. Some of these ideas can be built into original, creative solutions to a problem, while others can generate additional ideas.

Mind Mapping consolidates ideas created through individual brainstorming sessions into a single map to reflect commonality and differences in understanding and to generate new ideas.

The ***Nominal Group Technique*** enhances brainstorming with a voting process to rank the most useful ideas. It is a structured meeting is held among the group members where they are required to find solutions to the problem identified for the discussion.

The meeting comprises the following four phases:

1. The facilitator briefs about the question or problem requiring decision. The participants are given time to *silently* write down their ideas that come to their minds in reference to the problem being discussed.
2. The facilitator writes down the ideas of each group member on the flip chart, thereby giving all the members the opportunity to share their ideas.
3. The members discuss their ideas to ensure a common and clear understanding.
4. Once all ideas are explained, the members are asked to prioritize the ideas (probably in several rounds), usually using a scale of 1 to 5. Eventually, the highest scoring ideas are selected.

Interviews are formal or informal techniques to elicit information. Prepared and/or spontaneous questions are answered by different stakeholders and their responses are recorded and later analyzed. Interviews can help to identify desired project features or problems with existing product deliverables and also with project performance.

Questionnaires and surveys are written (and standardized) sets of questions designed to quickly collect information from a large number of respondents. They are appropriate when a quick turnaround is needed, when respondents are geographically dispersed, and where statistical analysis is going to be applied.

Observation is a direct way of viewing individuals in their environment. It helps to learn how they perform their jobs or task. This can be particularly helpful to understand facts in a process that are difficult to articulate. It is mainly applied in requirements analysis when an observer views a user performing a task or job.

A **focus group** is a small and typically diverse panel of prequalified stakeholders and/or subject matter experts to learn about opinions and expectations on a given subject, product, service, or result. Focus groups are used to test the public response to a wide variety of subjects, including marketing, research, products, services, entertainment, propaganda and policies. Data gathered is considered a population sampling and used to predict a wider public response on the desired subject. Today, social media listening is often used in place of traditional focus groups.

Social media listening, also known as social media monitoring, is the process of identifying and assessing what is being said about a company, individual, product or brand on the Internet. Conversations on the Internet produce massive amounts of unstructured data. It's important, therefore, to define what the goals are for a social media listening initiative.

8.4 Data Analytics

Data analytics (DA) is the process of examining data sets in order to draw conclusions about the information they contain, increasingly with the aid of specialized systems and software. Data analytics

technologies and techniques are widely used in commercial industries to enable organizations to make more-informed business decisions and by scientists and researchers to verify or disprove scientific models, theories and hypotheses.

Data analysis techniques may include but are not limited to:

Alternative analysis is a planning and modeling technique used to yield various projections for some outcome based on selectively changing inputs. It is used to select the corrective actions or a combination of corrective and preventive actions to implement when a deviation occurs. It allows a business to respond to alternative situations more quickly and effectively because they have developed strategies to rely upon.

What-if scenario analysis (WISA) is the process of evaluating scenarios in order to predict their effect on project objectives. A ***scenario***, in this context, is a potential circumstance or combination of circumstances that could have a significant impact - whether good or bad - on an organization.

A business can use what if scenario analysis to see how a given outcome, such as project costs, might be affected by changes in particular variables, such as the late delivery of supplies or the unavailability of key personnel.

In project management, for example, WISA can help users see how changing data for specific dates and costs changes the completion date and/or total cost of the project.

Cost-benefit analysis (CBA) is an analytical tool for assessing and the pros and cons of moving forward with a project deviation or with a project idea or proposal. It helps to determine the best corrective action in terms of cost.

A formal CBA tallies all of the planned project costs, quantifies each of the tangible benefits and calculates key financial performance metrics such as return on investment (ROI), net present value (NPV), internal rate of return (IRR) and payback period. The costs associated with taking action are then subtracted from the benefits that would be gained. As a general rule, the costs should be less than 50 percent of the benefits and the payback period shouldn't exceed 12 months.

Earned value analysis provides information on the performance of the project and a perspective on scope, schedule, and cost performance. You learn more about it in the section “Cost Management”.

Root cause analysis is a way to identify reasons for problems occurred and to examine why, how and when the casual factors happened. When a system breaks or changes, investigation should be performed to have a full understanding of the event. Root cause analysis is a step beyond problem solving, which is corrective action taken when the event occurs. You learn more about it in the section “Quality Management”.

Trend analysis is used to forecast future performance based on past results. It looks ahead in the project for expected slippages and warns the project manager ahead of time that there may be problems later in the project if established trends persist. The results of trend analysis can be used to recommend preventive actions if necessary.

Variance analysis is a technique to analyze the differences between planned and actual performance. The information used may include duration estimates, cost estimates, resource utilization, resources rates, technical performance, and other metrics. It is mainly applied in process groups related to “Monitoring & Controlling”. Variance analysis allows for the appropriate preventive or corrective actions to be initiated.

Social analysis focuses mainly on the broad public as project stakeholder. It is the practice of systematically examining a social problem, issue or trend, often with the aim of prompting changes in the situation being analyzed.

A social problem is a situation that is viewed by a community as being undesirable. In a business context, examples of social problems include outsourcing jobs to another country, customer data privacy and wasting energy. Social analysis, which is topic-driven, can address such issues through qualitative

research or quantitative multivariate approaches. Multivariate analysis is a field of statistical analysis and data analytics that deals with variables and their relationships.

Social analysis frequently involves issues of equality and social justice, but it is also valuable to help organizations create business strategies and policies that are sensitive to particular social issues and likely to be perceived by customers as having a positive social impact or to avoid strategies and policies having a negative social impact. For example, after discovering through analysis of a customer survey that increased efforts to develop renewable energy would be viewed in a positive light, an oil company might decide to expand its investments in wind energy, geothermal energy and solar power research.

9 Project Management Information System

The Project Management Information System (PMIS) supports the management of information required for the successful execution of projects. It is a system consisting of the tools and techniques to gather, integrate, and disseminate the outputs of project management processes [PMBOK Guide, p. 716].

The PMIS usually addresses all project management knowledge areas. However, there is a huge variety of systems for all kind of industry and organization types, sizes, and domains. The optimum utilization of a PMIS depends heavily on the manner in which critical information is made available to all stakeholders and the level of process automation. A lot of emphasis is also placed on improving the accuracy of data based on which key performance indicators and reports are generated.

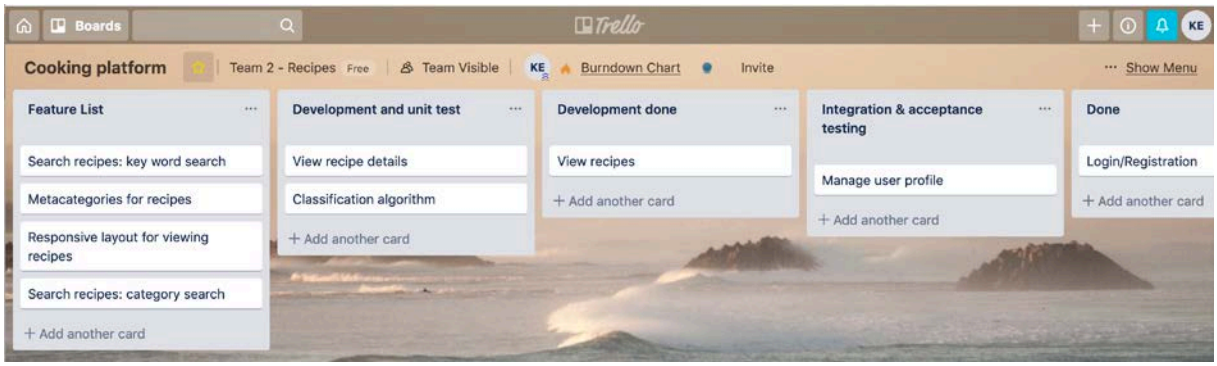


Figure 8: Example of a project management information system monitoring the development of a cooking platform.

The project management software market is characterized by fierce competition between Microsoft, Oracle, Autodesk, Aconex, Asana, Trello, and few others. While some organizations still rely on spreadsheet applications and basic electronic calendars, most organizations have invested in more robust applications to streamline their project management processes.

In agile environments it is quite widespread to use Kanban boards to visualize progress in the project.

A PMIS supports also the visualization of a series of key performance indicators (KPI) and other figures to illustrate the performance of the project.

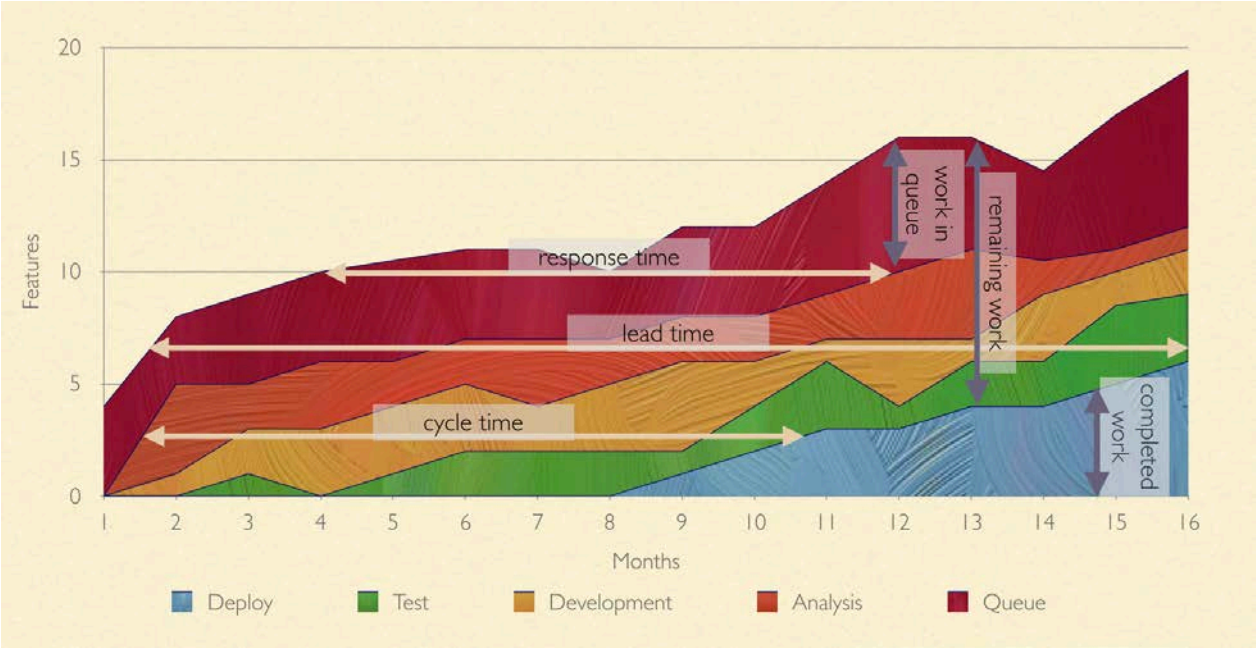


Figure 9: Example of the visualization of different indicators to measure project progress.

10 Decision Making

The decision-making process, in a business context, is a set of steps taken by managers to determine the planned path for business initiatives and to set specific actions in motion. Ideally, business decisions are based on an analysis of objective facts, aided by the use of analytics tools and methods.

There are many different decision-making methodologies, but most have at least five steps in common:

1) Identify a business problem.
2) Seek information about different possible decisions and their likely effect.
3) Evaluate the alternatives and choose one of them.
4) Implement the decision in business operations.
5) Monitor the situation, gather data about the decision's impact and make changes if necessary.

Decision-making techniques can be categorized along the following decision principles [PMBOK Guide, p. 144]:

Autocratic decision making. One individual takes responsibility for making the decision for the group.

Multi-criteria decision analysis is a technique based on a decision matrix that reflects the multiple conflicting criteria such as cost, quality, risk. Its main goal is to evaluate and rank ideas.

Voting is a collective decision-making technique addressing alternatives (various outcomes) of future actions. The goal is a prioritization of alternatives.

- *Unanimity*. A decision is reached when everyone agrees to a particular alternative.
- *Majority*. A decision is reached when more than 50% of the group members support a particular alternative.
- *Plurality*. A decision is reached when the largest block in a group opts for a particular alternative even if a majority is not achieved.

Design thinking is an iterative approach to come to a decision that intentionally seeks out people with different perspectives, knowledge, skills and experience and has them work together to create a practical solution for a real-world problem. It involves a series of steps that are carried out in a particular order to achieve a goal. The goal is to identify a solution that is capable of succeeding, can be carried out in a timely manner and is likely to be accepted by all stakeholders.

Empathize – This step involves interviewing stakeholders and asking open-ended questions. The goal is to learn more about the problem from multiple perspectives.

Define – This step involves synthesizing all the information that was gathered during the previous step and arriving at a group consensus that states what problem needs to be solved. The goal is to identify the scope and true nature of the problem.

Ideate – This step involves sharing ideas. The goal is to brainstorm solutions to the problem.

Prototype – This step involves creating a mock-up that conveys the essence of a proposed solution. An important goal of this step is to help the design team weed out unworkable or impractical solutions and focus attention on ideas that are likely to be approved by stakeholders.

Test – This step involves presenting the prototype to stakeholders. The goal is to solicit feedback that will let the design team know if they have successfully solved the problem or whether they need to go back to the drawing board and repeat steps.

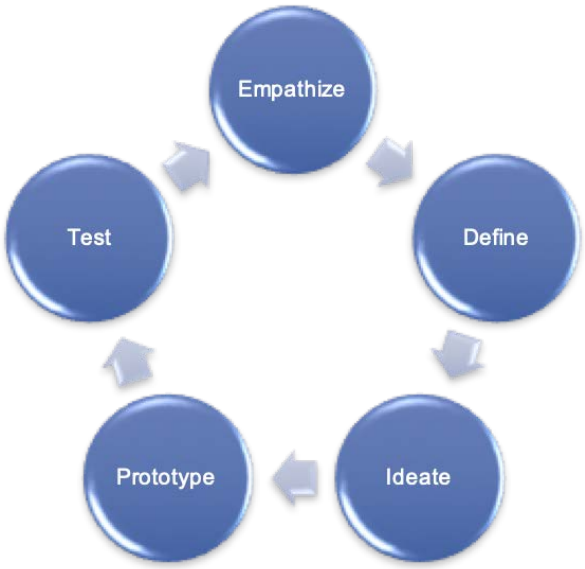


Figure 10: Iterative phases of Design Thinking

11 The Project Manager

The project manager is the "person assigned by the performing organization to lead the team that is responsible for achieving the project objectives". [PMBOK Guide, p. 716]

There is no "one-size-fits-all" description of the project manager and there are probably as many different roles as exist projects in the world.

Nevertheless, there are generic key roles each project manager is supposed to adhere to:

- The project manager is part of the project team and accompanies the project from its initiation through closing.
- The project manager leads the project team to project objectives and stakeholders' expectations and is responsible for what the project team produces.
- The project manager is expected to have management knowledge and skills, technical understanding, and experience.

Technical skills are core to project managers (and thus core to this course), but increasingly complex and competitive market and social challenges call for a broader focus on the project manager's skill set.

The project manager's competence emerges from a skill set that comprises three areas [PMBOK Guide, p. 56]:

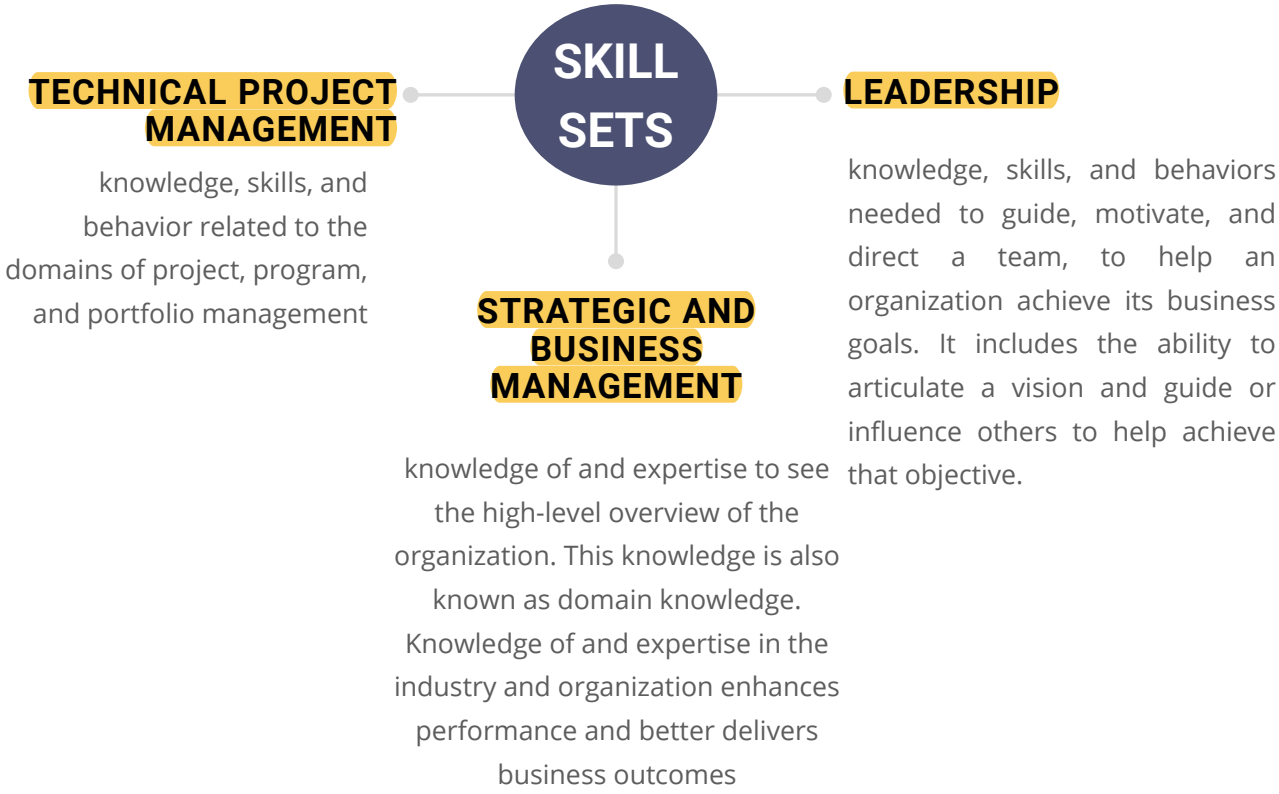


Figure 11: Competence areas of the project manager

12 Leadership

Leadership is crucial to the success of projects in organizations. The project manager deals with people with all their motivations and behaviors. She or he motivates and inspires while being concerned with the strategic vision of the project and the organization.

The project manager is manager and leader in one person. Managers are generally task-oriented and concerned with technical issues such as plans, controls, budgets, policies, and procedures.

Leadership skills are the strengths and abilities individuals demonstrate that help to oversee processes, guide initiatives and steer their employees toward the achievement of goals.

Leadership skills are an essential component in positioning executives to make thoughtful decisions about their organization's mission and goals, and properly allocate resources to achieve those directives. Valuable leadership skills include the ability to delegate, inspire and communicate effectively. Other leadership traits include honesty, confidence, commitment, creativity, and emotional intelligence.

Emotional intelligence (EI) is the area of cognitive ability that facilitates interpersonal behavior. EI emerges from five key factors:

- **Self-awareness**. A person has a healthy sense of emotional intelligence if they understand their own strengths and weaknesses, as well as how their actions affect others. A person with self-awareness is usually receptive to, and able to learn from, constructive criticism more than one who doesn't have emotional self-awareness.
- **Self-regulation**. A person with a high emotional intelligence has the ability to exercise restraint and control when expressing their emotions.

- **Motivation**. People with high emotional intelligence are self-motivated, resilient and driven by an inner ambition rather than being influenced by outside forces, such as money or prestige.
- **Empathy**. An empathetic person has compassion and is able to connect with other people on an emotional level, helping them respond genuinely to other people's concerns.
- **Social skills**. People who are emotionally intelligent are able to build trust with other people, and are able to quickly gain respect from the people they meet.

12.1 Leadership Styles

There exists a number of theories that can be helpful to draw for the development of a suitable leadership style:

- *Autocratic leaders* are essentially dictators.
- *Authentic leadership* is a type of management style in which people act in a real, genuine and sincere way that is true to who they are as individuals. Proponents of authentic leadership say this type of leader is best positioned to inspire trust, loyalty and strong performances from employees. An authentic leader rejects the idea that they have to adopt a persona different than their own. Authentic leaders also don't believe their professional self is different than their personal or private self. Instead, authentic leaders are self-aware and know their strengths and weaknesses. Above all, they possess a healthy amount of emotional intelligence and are empathetic to others' needs.
- *Laissez-faire* is the opposite of autocratic. The project manager allows the team to make their own decisions and establish their own goals.
- *Democratic-driven leaders* gather all the facts and ask for input from the team before making a decision.
- *Situational leadership*. It essentially means that the leadership style is adapted to the situation:
    - Directive is used when a team member needs to know the step-by-step procedures for the problem.
    - Coaching is used with team members who have limited experience with the task at hand.
    - Supporting is used with team members having completed the same types of tasks in the past and are able to complete the majority of the task at hand on their own.
    - Delegating is used when team members have performed the same tasks in the past and are capable of making decisions regarding unexpected issues that may occur.
- *Transactional leadership*, also known as managerial leadership, is a leadership style where the executive relies on rewards and punishments to achieve optimal job performance from his or her subordinates.
- *Transformational leaders* possess the ability to embrace change and lead their organization through such change by anticipating the impact it will have on the organization and perhaps on the entire industry. They also embody leadership traits such as emotional intelligence, willingness to collaborate and empathy. They may set ambitious goals, also call the 'moonshot goals', and get everybody inspired.
- *Charismatic leaders* are able to inspire, they are enthusiastic, self-confident and hold strong convictions.

- *Servant leaders* facilitate collaboration, support everyone's best thinking and work, and encourage the team's participation, understanding, and shared responsibility. Servant leaders change or remove organizational impediments. They focus on paving the way for the team to do its best work. There are ten attributes a servant leader should have:
    - **Listening**: While all leaders must possess superior communication and decision-making skills, the servant leader also must be willing to listen intently to others.
    - **Empathy**: A servant leader assumes the good intentions of co-workers and does not reject them as people.
    - **Healing**: Servant leaders understand part of their leadership responsibility is to "help make whole" employees whose sense of self is precarious or impaired.
    - **Awareness**: A servant leader is a disturber and an awakener.
    - **Persuasion**: Servant leaders rely on persuasion, not positional authority or coercion, to convince others.
    - **Conceptualization**: Seeing a problem from a "conceptualizing perspective" requires an ability to "think beyond day-to-day realities".
    - **Foresight**: Ability to understand the past and see the present clearly to predict how the future will unfold.
    - **Stewardship**: Staffs and trustees all have a responsibility to hold the institution "in trust" for the greater good of society.
    - **Commitment to the growth of people**: Believing in the intrinsic value of people, servant leaders feel a responsibility to nurture the growth of employees.
    - **Building community**: Large institutions tend diminish the sense of community people once had. The awareness of this loss propels servant leaders to find ways to build community in their institutions.

12.2 The Power of Leaders

Power is the ability to influence others. Power can be a positive manner or a negative one.

- **Punishment Power**. The employee is threatened with consequences if expectations are not met.
- **Expert Power** occurs when the person being influenced believes the manager is knowledgeable about the subject or has special abilities that make her an expert.
- **Legitimate Power** comes about as a result of the influencer's position (project manager, executive vice president, etc.)
- **Referent Power** is inferred to the influencer by their subordinates.

13 Project Management Process Groups

The Project Management Body of Knowledge (PMBOK) is a document containing standard terminology, best practices and process guidelines around project management as defined by the Project Management Institute (PMI).

The phases of a project constitute processes that can be grouped together into five logical groups [PMBOK Guide, p. 23]:

- **Initiating Process Group**. The processes of this group are performed to define the project and to authorize the start of the project.
- **Planning Process Group**. We perform these processes to establish the scope of the project, to refine the objectives and the course of the project in order to achieve its objectives.
- **Executing Process Group**. These processes are performed to complete the project work and to satisfy the project requirements.
- **Monitoring and Controlling Process Group**. The progress of the project needs to be tracked, reviewed, and approved. Necessary changes need to be planned and initiated.
- **Closing Process Group**. The processes of this group are performed to formally complete or close the project and all contracts (for procurement).

Figure 12: Project management process groups and their dependencies

Projects require management. We see needs and requirements for projects, devise project ideas, transform them into project proposals, formulate project descriptions and plans, perform the projects according to that plans, monitor and control the projects' progress, change the projects' paths and their plans, close the projects and measure their success. All these activities require to be managed carefully.

"Project management is the application of knowledge, skills, tools, and techniques to project activities to meet the project requirements" [PMBOK Guide p. 10]

Operations management is different from project management. It is the management of the ongoing production of goods and services. However, operations management interfaces with project management when the results of the project

- are input to mass production (the prototype is blueprint for a production series)
- improve processes or operations
- improve or enhance products or services of the ongoing business

[PMBOK Guide, p. 16]

13.1 Project Management Knowledge Areas

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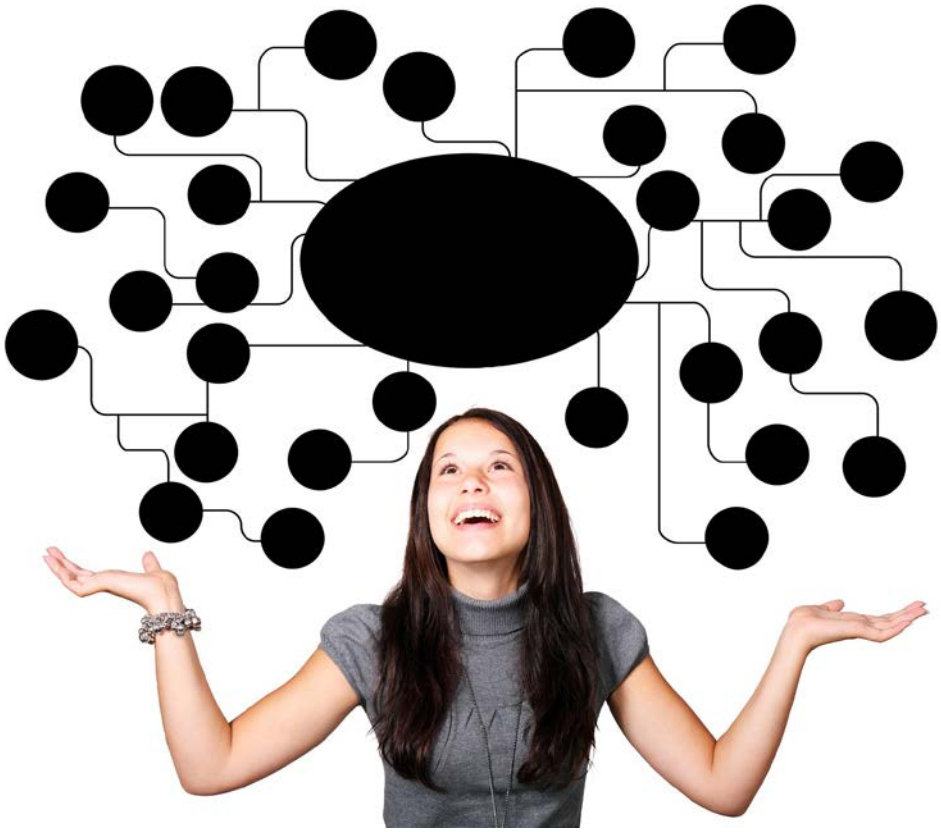
Figure 13: The ten knowledge areas of project management

The different processes of the project phases may require different knowledge depending on the things that need to be accomplished in these phases. In project management, this knowledge is separated along **ten management knowledge areas** [PMBOK Guide p. 23/24]:

- **Project Integration Management**: combination and coordination of the various processes across all knowledge areas.
- **Project Scope Management** addresses processes to ensure that the project includes all the work required, and only the work required, to complete the project successfully.
- **Project Schedule Management** includes the processes required to manage the timely completion of the project.
- **Project Costs Management** includes processes for planning, estimating, budgeting, financing, funding, managing, and controlling costs so the project can be completed within the approved budget.
- **Project Quality Management** includes the processes for planning, managing, and controlling project and product quality requirements, in order to meet stakeholder expectations.
- **Project Resource Management** includes the processes to identify, acquire, and manage the resources (includes human resources) needed for the successful completion of the project.
- **Project Communications Management** includes the processes required to ensure timely and appropriate collection, distribution, storage, and retrieval of project information.

- **Project Risk Management** includes the processes of identification and analysis of risks and planning and implementing risk responses.
- **Project Procurement Management** includes the processes necessary to purchase or acquire products or services from third parties outside the project team.
- **Project Stakeholder Management** includes the processes to identify stakeholders in the project and to analyze their expectations and impact on the project.



B Project Integration Management

In this chapter you learn

How to develop the project charter

How to manage the project management plan

How to direct the project work

How to manage project knowledge

How to monitor and control the project work

How to properly manage change control

How to close the project

Project Integration Management includes the processes and activities to identify, define, combine, unify, and coordinate the various processes and project management activities across all Project Management Process Groups, namely Initiating, Planning, Executing, Monitoring & Controlling, and Closing. [PMBOK Guide, p. 69]

This chapter addresses the processes of Project Integration Management are [PMBOK Guide, p. 70]:

- **Develop Project Charter**. The project charter is a document that states a project formally exists and provides the project manager with written authority to begin the project work and to apply organizational resources to the corresponding project activities.
- **Develop Project Management Plan**. The project management plan consolidates and integrates all management plans that are produced in the nine (subsequently described) knowledge areas, ranging from scope management, over schedule and cost management to procurement and stakeholder management.
- **Direct & Manage Project Work**. This process consists of leading and performing project work and implementing approved change requests.
- **Manage Project Knowledge**. Management of maintaining and expanding knowledge to achieve the project's objectives and contribute to organizational learning.
- **Monitor & Control Project Work**. This processes addresses tracking, reviewing, and reporting overall project work and progress to meet the project's performance objectives.
- **Perform Integrated Change Control**. All change requests need to be reviewed and approved. The changes have an impact on the direction of the project — on its quality, scope, duration, and cost — and may affect deliverables, project documents, and the project management plan. Finally, the approved changes must be communicated.
- **Close Project or Phase**. This process finalizes all activities of the project or phase, and all contracts.

1 Develop Project Charter

Develop Project Charter focuses on the development of a document that outlines the groundwork of the project, such as its objectives and vision, its success criteria, its key stakeholders, high-level description of the requirements addressed, its main deliverables, its risk, its sponsors and pre-approved financial resources, and the assigned project manager.

The project charter helps the project manager to communicate his authority and explain to project participants and stakeholders why the project is needed, who it involves, how long the project will take to complete, how much it will cost, what resources are needed and how successful completion of the project will help the organization. Once created, the document is rarely (if ever) amended.

Depending on a company's culture and management style, a charter may serve the same purpose as a business case.

Project charter templates often include the following components:

Project goal - documents the reasons for undertaking the project in clear, concise language.

Project participants - identifies what people need to be involved in the project and clearly states their roles.

Stakeholders - identifies other people who will be directly affected by the project and need to know about the project's progress.

Requirements - identifies what resources are required for the project's objectives to be achieved.

Constraints - documents potential roadblocks or bottlenecks.

Milestones - identifies start date and completion dates as well as dates for other important checkpoints.

Communication - specifies how the project manager will communicate with project owners, participants and stakeholders through the project.

Deliverables - documents what specific products, processes or services the project will provide upon completion.

2 Develop Project Management Plan

The Project Management Plan provides an integrative view on the entire project. It defines the work required to be performed to achieve the project's objectives, and outlines how the project work is executed, monitored and controlled, and finally completed.

The project management plan should be baselined, that is, it should contain baselines as project references for scope, time, and cost. The progress of the project will be measured against these references. Once baselined, the Project Management Plan can only be changed through the Perform Integrated Change Control process. Through change control the Project Management Plan is progressively elaborated by controlled and approved updates. [PMBOK Guide, p. 83]

The Project Management Plan includes subsidiary plans and baselines that are further described in the subsequent chapters [PMBOK Guide, p. 87]:

- *Scope Management Plan*. Definition and documentation of how the project scope is defined, monitored, controlled, and validated.
- *Requirements Management Plan*. Definition and documentation of how project requirements will be collected, analyzed, and managed.
- *Schedule Management Plan*. Definition and documentation of how the project schedule will be developed, structured, monitored and controlled.
- *Cost Management Plan*. Definition and documentation of how the project costs will be developed, structured, monitored and controlled.
- *Quality Management Plan*. Definition and documentation of how an organization's quality policies, methodologies, and standards will be implemented in the project.
- *Resource Management Plan*. Definition and documentation of how human resources and materials are allocated, managed, and released.

- *Communications Management Plan*. Definition and documentation of how, when, by whom, and to whom information about the project will be disseminated.
- *Risk Management Plan*. Definition and documentation of how risks and contingencies will be identified and handled.
- *Procurement Management Plan*. Definition and documentation of how the project acquires goods and services from outside the performing organization.
- *Stakeholder Management Plan*. Definition and documentation of how stakeholders will be engaged in project decisions, according to their needs, interests, and impact.
- *Scope Baseline*. It presents the actually approved version of the project scope statement, work breakdown structure (WBS), and its WBS dictionary as basis for comparison.
- *Schedule Baseline*. It presents the actually approved version of the project schedule as basis for comparison with actual project data.
- *Cost Baseline*. It presents the actually approved version of the project costs as basis for comparison with actual project data.

3 Direct and Manage Project Work

This process is responsible for leading and observing the project work as defined in the project management plan and implementing the approved changes to the project work.

The most important output of this process are the deliverables.

During the course of executing the project work, many data are produced that indicate the progress of the project and the performance of the project team. These work performance data (completion status of deliverables or activities, milestones achieved, etc.) are collected and processed. Analyzing these data yields work performance information about the performance of the project. This information is usually communicated to the project stakeholders and team members. It feeds also the documentation of the lessons learned to improve future project work. [PMBOK Guide, p. 92]

During the execution of the project work it is quite likely that issues and problems arise that lead to change request, which may modify the project scope, costs, budget, schedule, and/or quality of the project or product results.

A change request often arises when the client wants an addition or alteration to the agreed-upon deliverables for a project. Such a change may involve an additional feature or customization or an extension of service, among other things. Because change requests are beyond the scope of the agreement, they generally mean that the client will have to pay for the extra resources required to satisfy them.

One of the more challenging aspects of change management is ensuring that all details are sufficiently explicated and that all parties agree to what is expected. Explicit and detailed documentation makes it easier to identify when a change request must be submitted.

These changes must be handled very carefully. Otherwise the project risks feature creep. Feature creep (also known as scope creep) is a tendency for product or project requirements to increase during development beyond those originally foreseen. Feature creep may be driven by a client's growing "wish list" or by developers themselves as they see opportunities for improving the product. To control feature creep Perform Integrated Change Control is advocated.

Change requests can also originate externally. External change requests may have legal or contractual reasons.

Change requests can be classified as: [PMBOK Guide, p. 96]

Corrective Action. The performance of the project work is realigned with the originally planned performance.

Preventive Action. Measurements are taken to align the performance of future project work with the originally planned performance.

Defect Repair. Modification of a product or result to meet its required quality standards.

Updates. Updating of documents and plans to reflect modified or additional ideas or qualities.

4 Manage Project Knowledge

"Manage Project Knowledge" is the process of using existing knowledge and creating new knowledge to achieve the project's objectives and contribute to organizational learning." [PMBOK Guide, p. 98]

Knowledge is, to an enterprise or an individual, the possession of information or the ability to quickly locate it. This **explicit** knowledge is available on the internet, in books, manuals, tweets, videos, and the like. A further source of knowledge is company's accumulated business transactions and their related data. This knowledge inherent in these data but not readily visible needs to be discovered through *information or data mining*.

Knowledge in its **implicit** form connotes "know-how", that is knowledge that comes from experience, insights, beliefs or from innate reasoning ability.

Knowledge management is concerned with consciously and comprehensively gathering, mining, organizing, sharing, and analyzing knowledge. The challenge in knowledge management is to provide a common understanding of explicit knowledge and to support processes to turn implicit knowledge into explicit knowledge.

It is a common misconception that knowledge (including lessons learned at the end of the project) just need to be documented in order to share it. [PMBOK Guide, p. 100] Knowledge must be put into contexts that people use and understand in their everyday life. The contexts are essential when it comes to correctly understand and interpret explicit knowledge. *Explicit knowledge* needs to be codified and linked to a representation of contexts to ensure a proper sharing of knowledge.

Implicit knowledge resides in the mind of people. Project management has to encourage knowledge exchange through conversations and interactions between people *and* has to take care for an atmosphere of trust and respect so that people are willing and motivated to share their knowledge.

Some useful tools and techniques for knowledge management are: [PMBOK Guide, p. 103]

- Networking, face-to-face or through online forums that support open questions ("How can I …?").
- Special interest groups (including virtual groups) that meet to exchange knowledge.
- Meetings (face-to-face or virtual)
- Workshops (face-to-face or virtual)
- Storytelling to impart best practices
- Training with interaction between learners

5 Monitor and Control Project Work

This process is responsible for tracking, reviewing, and reporting of the project's progress and performance. **Monitoring** comprises observing the project, collecting all kind of project data that are useful to measure the project's progress and performance (*work performance data*), and assessing the current situation and trends in order to effect process improvements.

Work performance information is produced from work performance data by feeding actual and planned performance data into indicator models that express different aspects of project performance. There are indicators related to scope, schedule, costs, and quality. Variances from the plan may indicate problems or issues such as the project lagging behind the schedule or budget over-runs.

Controlling addresses means to identify the degree of variances from the plan, to compare these variances with agreed variance thresholds, to determine corrective or preventive actions or defect repairs, and to measure to what extend these actions resolved the performance problem or issue.

Monitor and Control Project Work is also responsible for producing and issuing work performance reports. They combine work performance information in a way to rise awareness, that is, to explain performance problems or issues and the corrective and preventive actions taken to resolve these problems or issues.

Work performance reports are communicated to project stakeholders through the communication processes as established in the communication management plan.

Examples of work performance reports are

- **Performance Scorecards** as graphical representation of the project progress over time. They monitor the progress of any project goal. The integral concepts of scorecards are targets and key performance indicators (KPIs). KPIs are metrics used to evaluate factors that are crucial to the parameters of the project success.
- Earned value graphs (see cost management).
- Defect histograms (see quality management).
- Risk reports (see risk management).

6 Perform Integrated Change Control

Perform Integrated Change Control implements Change Control in projects. It is responsible for reviewing change requests, approving changes and monitoring the implementation of the changes, and communicating the decisions on changes.

Change Control is a systematic approach to manage all changes made to the product, the deliverables, or the project. Changes can impact scope, cost, schedule, and quality of the project. The purpose is to ensure that no changes are made without proper consideration, that all changes are documented, that services are not unnecessarily disrupted and that resources are used efficiently.

Change control is the ultimate responsibility of the project manager. Change requests are stated by all kind of stakeholders in the project. In many cases, it is the customers that request changes emerging from their changed or expanded “wish list” comprising qualities of the desired product, service, or result.

The change control process is usually conducted as a sequence of steps proceeding from the submission of a change request. Typical IT change requests include the addition of features to software applications.

Change control can be implemented as a five-step process:

1) **Documenting** the change request and entering into the change management system: When the client requests the change, that request is categorized and recorded, along with informal assessments of the importance of that change and the difficulty of implementing it.
2) Impact **assessment**: Cost, schedule, quality and risk impact as well as benefits of making/not making the change are assessed against the project baselines.
3) **Decision**: If the change request is accepted, rejected, or deferred, that fact is documented and communicated to the stakeholders.

4) **Revision**: The team responsible for the change creates a detailed plan for its design and implementation, as well as a plan for rolling back the change should it be deemed unsuccessful. The plan includes revised cost estimates, activity sequences, schedule dates, resource requirements, and analysis of risk response alternatives.

5) **Approval**: In some cases, stakeholders and sponsors review and approve the change. Approved change requests are implemented through the Direct and Manage Work process. Deferred or rejected change requests are communicated to the person or group requesting the change. [PMBOK Guide, p. 120]

7 Close Project or Phase

This process constitutes the completion of all activities of the project, phase, or contract. This phase is responsible that project or phase information is archived, the planned work is completed, and team members and resources are released to pursue new endeavors.

The project manager reviews the completed and assesses that the project has met its objectives.

Activities of this phase target on ensuring that: [PMBOK Guide, p. 123]

- Documentation and deliverables are complete
- Project issues are resolved
- Deliverables are formally accepted by the customer
- Final project reports are written
- Personnel and resources are reallocated
- Lessons learned are documented and codified
- Project failure and success are audited
- The transfer of project results (products and/or services) to production or operation is properly installed.

The project manager finally summarizes the project results in a **final report**. It contains a brief description of the project, its product or service. It reflects the project's achievements against scope, cost, schedule, and quality objectives. It further explains the degree of the achievement of the expected benefits and gives recommendations for future benefit realization. Finally, it describes the risk and issues encountered in the course of the project.

C Project Scope Management

In this chapter you learn

How to identify and gather requirements

How to define the project scope

How to develop the work breakdown structure (WBS)

How to validate and control the project scope

Project Scope Management ensures that the project includes “all the work required, and only the work required, to complete the project success-fully” [PMBOK Guide, p. 129].

Project scope defines what is and what is not included in the project. The documentation of a project's scope, which is called project scope statement or statement of project work, explains the boundaries of the project, establishes responsibilities for each team member and sets up procedures for how completed work will be verified and approved.

During the project, this documentation helps the project team remain focused and on task. The scope statement also provides the project team with guidelines for making decisions about change requests during the project.

Changes cannot be avoided. It is natural for projects to change along the way, so the better the project has been "scoped" at the beginning, the better the project team will be able to manage change.

1 Project Scope vs. Product Scope

Project scope should not be confused with product scope. *Product scope* defines the features and functions of the end result of the project which can be a product or service.

Project leaders should create a product scope statement and they should use both the project scope and the product scope statements to support each other and establish for their organizations a clear understanding of what every project aims to achieve.

The *project scope* describes the work to be performed to deliver the product or service with the specified features and functions.

A *function* is a goal that can be accomplished with a product, service, process, practice, system, application, document, component, machine or environment (e.g. landing of an aircraft). A *feature* is a tool that helps to accomplish functions. For example, the wheels of an aircraft are features that support functions such as landing and taking off.

2 The Importance of the Project Scope Statement

The project scope statement

- articulates what the project comprises so that all stakeholders can understand what's involved;
- provides a roadmap that managers can use to assign tasks, schedule work and budget appropriately;
- helps focus team members on common objectives; and
- prevents projects, particularly complex ones, from expanding beyond the established vision.

Project Scope Management covers activities across the Project Management Process Groups Planning and Monitoring & Controlling. Its processes are [PMBOK Guide, p. 129]:

- **Plan Scope Management**. The scope management plan documents how the project and product scope will be defined, validated, and controlled.

- **Collect Requirements**. Stakeholder needs and requirements need to be documented and managed in order to meet project objectives.
- **Define Scope**. This process ensures that a detailed description of the project and product is provided.
- **Create WBS** (work breakdown structure). Project deliverables and project work is divided into smaller, more manageable components.
- **Validate Scope**. Formalizing acceptance of the completed project deliverables.
- **Control Scope**. Monitoring the status of the project and product scope and managing changes to the scope baseline.

3 Plan Scope Management

The scope management plan is part of the project management plan and describes the project scope is going to be defined, developed, monitored, controlled, and validated. The development of the scope management plan is mainly based on the information contained in the project charter. [PMBOK Guide, p. 135]

It also contains the *requirements management plan* that describes how project and product requirements will be analyzed, documented, and managed. [PMBOK Guide, p. 137]

4 Collect Requirements

The term "requirement" is defined as condition or capability that is required to be present in a product, service, or result to satisfy a particular need.

To determine a project scope, project managers must collect requirements for what the stakeholders need and expect from the project — this includes the project's objective or the project's deliverables, when the project needs to be completed, and how much they can pay for it.

The goal is to gather and record precise and accurate information during this process, so that the project scope effectively reflects all requirements and thus improves the chances for project leaders to deliver products that meet stakeholder expectations on time and on budget.

4.1 Requirements Documentation

Requirements documentation describes how individual requirements contribute to meet the objectives of the project. Requirements are defined on an abstract level first and are detailed more progressively as more information about each requirement is known.

Requirements can be categorized along business and technical requirements. Business requirements rather reflect stakeholder needs, while technical requirements manifest how their needs are going to be implemented.

Technical requirements may include functional and non-functional requirements.

Requirements documentation may also contain a description of quality requirements.

4.2 Requirements Traceability Matrix

The requirements traceability matrix is usually designed as table that links requirements to the deliverables that satisfy them. It helps to ensure that requirements are delivered at the end of the project.

Project ID		Project Name				Last Update	
Requirement ID	**Requirement Description**	**Requirements Category**	**Forward Traceability ID**	**Backward Traceability ID**	**Technical / System Test Case**	**User / Acceptance Test Case**	
101	Customer may view movies	Credentials	85, 86, 87		UT0101.41	AT0101.08, AT0101.09	
85	Registered, paying customers	Credentials		101	UT0085.16, UT0085.18	AT0085.02	
86	Guest customers	Credentials		101	UT0086.19	AT0086.03	
87	Registered, non-paying customers	Credentials		101	UT0087.09	AT0087.17	
...	...	...	...	...	...	...	

Figure 14: Example of a requirements traceability matrix

5 Define Scope

Based on the requirements defined and described in the previous process the project scope can be defined with greater specificity as more information about the project is known.

The scope is finally manifested in the project scope statement. This is a written document that includes all the required information for producing the project deliverables.

More detailed than a statement of work (as part of the project charter), the project scope statement helps the project team remain focused and on task. The scope statement also provides the project manager with guidelines for making decisions about change requests during the project. It includes acceptance criteria outlining the conditions to be met before deliverables get accepted.

This process can be iterative following **Rolling Wave Planning**. It may start with a high-level vision for the overall project that is further detailed in subsequent iterations. Work to be accomplished in the near term is planned in detail, while work in the future is planned at a higher level.

A well-articulated scope statement is considered a critical part of effective project management. Stakeholders for the project should have the opportunity to review the project scope statement, revise it as necessary and then approve it.

Once a project scope is completed and approved, the project managers can effectively allocate tasks and give their teams directions on what they each need to do to meet the target timelines and costs.

The project scope statement also establishes what is not included in the project. Objectives and tasks not listed in the project scope statement should be considered **out of scope**. Project managers can also list specific work that will not be part of the project.

When documenting a project's scope, stakeholders should be as specific as possible in order to avoid **scope creep**, a situation in which one or more parts of a project ends up requiring an uncontrolled expansion of work, time or effort because of poor planning or miscommunication. Scope creep is a tendency for product or project requirements to increase during development beyond those originally foreseen.

Gold plating is very similar to feature creep. Developers may add polish or features that weren't asked for, with the intention of adding value and impressing the client. Gold plating is generally seen as a poor

practice. Despite best intentions, the added work is often risky. Gold plating may take longer than anticipated, pushing a project past its due date. The additional changes can even have a negative effect on the existing functionality. However, even if it works out as intended, a client may not need or even like the added efforts. In addition to its other drawbacks, gold plating can also make it impossible to sell the client additional features after the agreed-upon scope has been met.

6 Create WBS

Project managers take projects requirements and map out what should happen (or not happen) and in what order those items need to occur. This generally leads to the creation of a work breakdown structure (WBS). As the name states, the work breakdown structure is a hierarchical decomposition of the totality of planned work into smaller portions and required tasks. The WBS specifies the work described in the project scope statement.

A WBS takes the form of a tree diagram with the "trunk" at the top and the "branches" below. The primary requirement or objective is shown at the top, with increasingly specific details shown as the one reads down. The planned work at the lowest level of the WBS is called **work package**. When completed, a well-structured WBS resembles a flowchart in which all elements are logically connected, redundancy is avoided and no critical elements are left out.

Work packages can be identified by a numbering system called Code of Account.

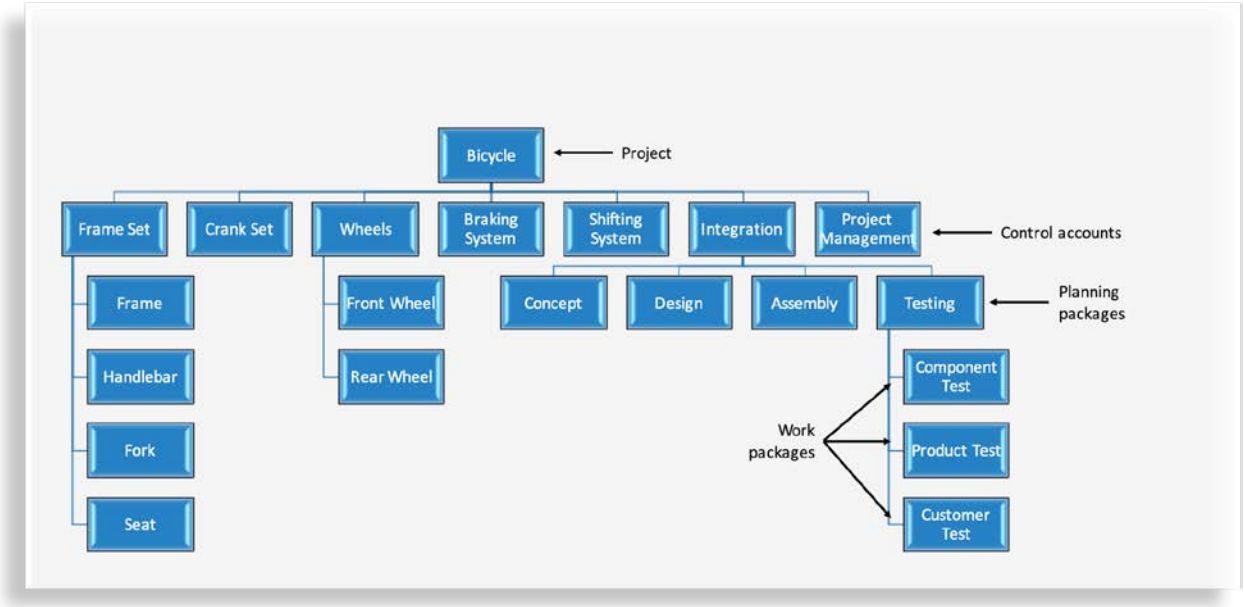


Figure 15: Example of a work breakdown structure (WBS)

Work packages are summarized in planning packages. On the next higher level, the planning packages are summarized into a **control account**. This is a management control point where scope, budget, and schedule are integrated and compared to the earned value for performance measurement.

The WBS is usually complemented by a **WBS dictionary**. It provides more information on deliverables and activities (or tasks) and their scheduling.

A well-organized, detailed WBS can assist the project manager in the effective allocation of resources, project budgeting, procurement management, scheduling, quality assurance, quality control, risk management, product delivery and service-oriented management.

The current version of the project structure and its WBS directory is recorded in the scope baseline.

7 Validate Scope

Validate scope is the process of formal acceptance of the completed deliverables. Verified deliverables are deliverables that have been checked and confirmed for correctness through the Control Quality process. Verified deliverables are deliverables that provide what had been specified in the project scope. They are, for example, well engineered, error-free, or the like.

Verification asks: Are we building the deliverables right?

Validated deliverables provide what has been expected by the customers or stakeholders. Verified deliverables are reviewed with the customers to ensure they meet and satisfy the customers' expectations. *Validation* asks: Are we building the right deliverables?

8 Control Scope

Control Scope is the process of monitoring the status of the project and product scope and managing changes to the scope baseline. [PMBOK Guide, p. 167]

Project managers should anticipate the need for changes as projects progress, carefully control what changes are made to the established project scope and document all changes made during the process. This requires strong project management skills. It also requires project managers and stakeholders to adhere to the project scope statement by recognizing what pieces are within the project scope and what requests are out of scope.

Project managers should rely on the Perform Integrated Change Control process that determines how change requests should be evaluated, recommended, and implemented by corrective or preventive actions.

The ability to distinguish between which requests are truly needed and which are out of scope allows organizations to avoid scope creep.

D Project Schedule Management

In this chapter you learn

How to determine project activities

How to sequence project activities

How to estimate the durations of the project activities

How to develop the project schedule

How to control the project schedule

“Project Schedule Management includes the processes required to manage the timely completion of the project.” [PMBOK Guide, p. 173]

The project schedule is a detailed plan that presents how the different activities (tasks) are scheduled in order to deliver the product, service, and results as defined in the project scope statement. It tracks the tasks, durations, planned dates, resources, dependencies, and constraints of the project.

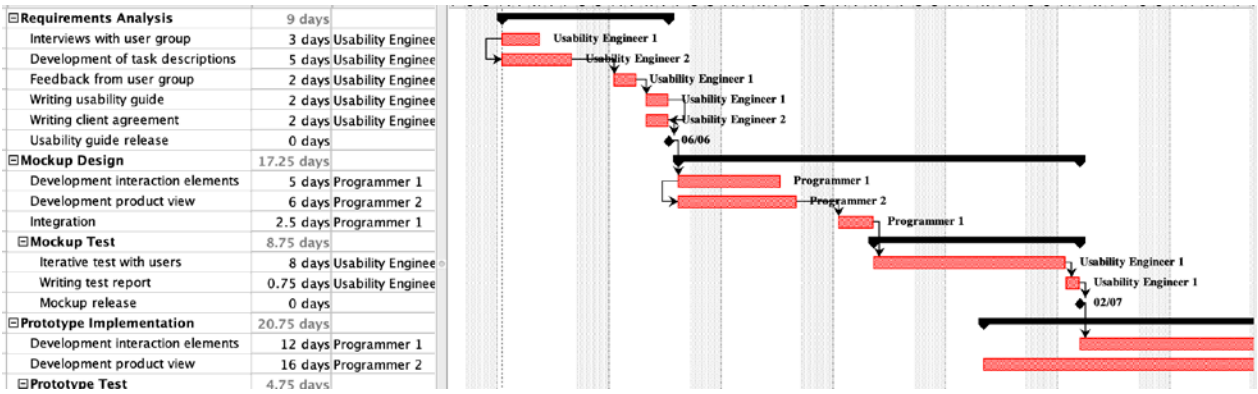


Figure 16: Example of a project schedule

Project Schedule Management covers project management activities across the Project Management Process Groups Planning and Monitoring & Controlling. Its processes are [PMBOK Guide, p. 173]:

- **Plan Schedule Management**. This process describes the policies, procedures, and documentation for planning, developing, managing, executing, and controlling the project schedule.
- **Define Activities**. Identifying and documenting the specific activities to be performed to produce the project deliverables.
- **Sequence Activities**. Identifying and documenting the relationships among activities.
- **Estimate Activity Durations**. Estimating the duration required to complete individual activities with the estimated resources.
- **Develop Schedule**. Analysis of activity sequences, durations, resource requirements, and schedule constraints to create the project schedule.
- **Control Schedule**. Monitoring the status of the project and manage changes to the schedule baseline.

1 Plan Schedule Management

Plan Schedule Management is the process of establishing the policies, procedures, and documentation for planning, developing, managing, executing, and controlling project schedule. [PMBOK Guide, p. 179]

The schedule management plan describes, among other things, which scheduling methods and tools will be used, when project schedules are released, the units of measure and control thresholds applied.

The control threshold indicates the agreed-upon amount of accepted variation before some action needs to be taken.

The schedule management plan also defines the rules of performance measurement and the formats and frequency for the schedule reports.

2 Define Activities

Define Activities focuses on the specific activities to be performed to produce the project deliverables.

The objective of this process is to produce a document listing all the required activities in a project.

Example of an **activity list**:

⊟ **Requirements Analysis**
Interviews with user group
Development of task descriptions
Feedback from user group
Writing usability guide
Writing client agreement
Usability guide release
⊟ **Mockup Design**
Development interaction elements
Development product view
Integration
⊟ **Mockup Test**
Iterative test with users
Writing test report
Mockup release
⊟ **Prototype Implementation**
Development interaction elements
Development product view
⊟ **Prototype Test**
Iterative testing
Writing test report
Prototype release

Figure 17: Example of an activity list

When *rolling wave planning* is applied, the activity list will be detailed as the project progresses. Future tasks are often indicated just as summary tasks.

The activity list is complemented by a **milestone list**. A milestone indicates a significant point or event in the project and has thus zero duration. A milestone is a synchronization point and can mark the transition of a project from one phase to another.

3 Sequence Activities

There are logical relationships between the activities in a project. These relationships must be managed in a way that allows to create a realistic and achievable project schedule. There are also leads and lags between tasks that should be taken into account. [PMBOK Guide, p. 188]

Sequence Activities is the process in charge with the management of these relationships.

3.1 Precedence Diagram

The **precedence diagramming method (PDM)** is a technique used for constructing a schedule model in which tasks are represented by nodes and are graphically linked by one or more logical relationships to show the sequence in which the tasks are performed.

There are four types of dependencies or logical relationships between predecessor activities and successor activities:

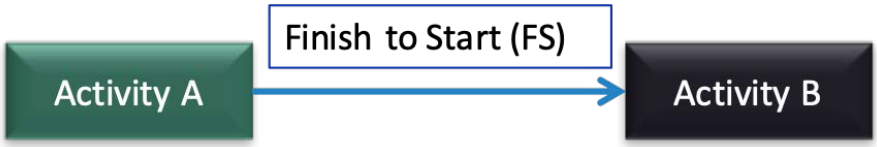


Figure 18: Finish-to-start sequence

This relationship "**finish-to-start**" indicates that a successor activity starts after the predecessor has completed. *Example*: Implementation of a user interface has to wait until its design is completed.

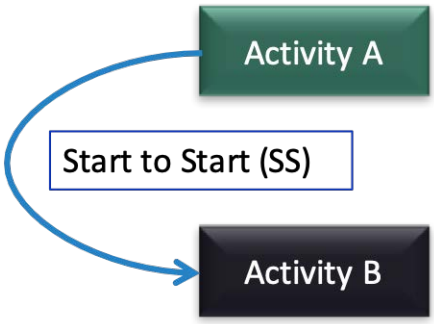


Figure 19: Start-to-start sequence

The relationship "**start-to-start**" indicates that both activities have to or can start at the same time. They may be executed in parallel. *Example*: When we have enough usability testers available, the user interface can be tested by different user groups in parallel. The tests may start at the same time.

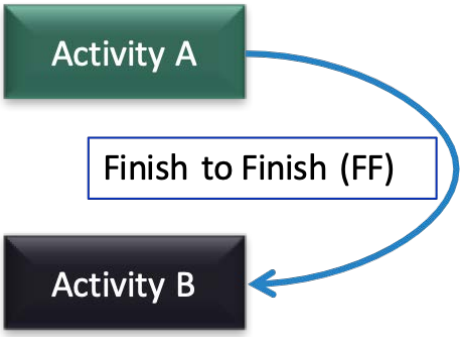


Figure 20: Finish-to-finish sequence

"**Finish-to-finish**" indicates that both activities can be executed in parallel, but should terminate at the same time. Example: Testing the user interface can be performed in parallel. The test may start at different dates but they all should terminate at the same date.

"Finish-to-start" is the most common used relationship. Theoretically, there is also a "start-to-finish" relationship. However, it is rarely used and usually expressed by a "finish-to-start" relationship.

3.2 Dependencies

There is always an underlying reason for a dependency between two activities. These dependencies can be classified as: [PMBOK Guide, p. 191/192]

- **Mandatory dependencies** are those that are legally or contractually required or inherent in the nature of the work. They are sometimes referred to as hard logic or hard dependencies. Example: The superstructure of a house cannot be built before its foundation is completed.
- **Discretionary dependencies** are sometimes referred to as preferred logic, preferential logic, or soft logic. They reflect sequences that are recommended following established (or preferred) procedures or best practices. Example: A user interface is tested with different user groups. It can be beneficial to test the user interface with one user group, update the interface in accordance with the test results, and continue with the next user group. However, it would also be possible to test the user interface in parallel with all user groups. Discretionary dependencies are thus good candidates when it comes to fast tracking.
- **External dependencies** involve a relationship between project activities and non-project activities. They are usually out of control of the project team. Example: A questionnaire is sent to the users asking them to evaluate the new user interface. The project team simply has to wait a certain amount of time until it receives a sufficient amount of responses.
- **Internal dependencies** involve a precedence relationship between project activities and are generally inside the project team's control. Example: Regression or integration testing cannot start until all modules to be integrated are completed.

3.3 Leads and Lags

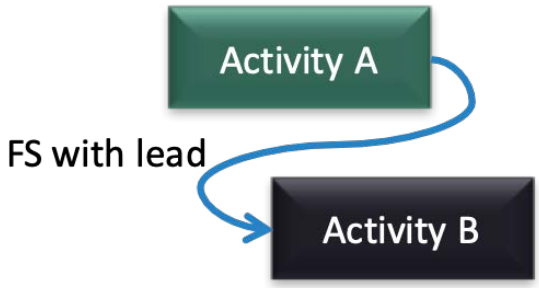


Figure 21: Sequence with lead

A **lead** is the amount of time a successor activity can be advanced with respect to a predecessor activity.

Example: You may not start with the distribution of a printed report in the company before all copies are completely printed.

Figure 22: Sequence with lag

A **lag** is the amount of time a successor activity will be delayed with respect to a predecessor activity.

Example: The second layer of paint can only be applied after the first layer is completely dry.

3.4 Project Schedule Network Diagram

A project schedule network diagram (PND) is a graphical representation of the logical relationships among the project schedule activities. It views activities, dependencies, and the critical path of a project. Boxes (or nodes) represent activities (with their required durations), and dependencies show up as lines that connect those boxes. When properly laid out, it is always laid in a left to right display to properly reflect the chronology of all project work.

Schedule network analysis is the process of factoring theoretical early and late start dates and theoretical early and late finish dates for each activity within the PND.

The early and late dates are not the expected schedule, but rather a potential schedule based on the project constraints, the likelihood of success, the availability of resources, and other constraints.

The most common approach to calculating when a project may finish is by using the **critical path method**. It uses a "forward" and "backward" pass to reveal which activities are considered critical. Activities on the critical path may not be delayed; otherwise, the project end date will be delayed.

The critical path is the path with the longest duration to completion.

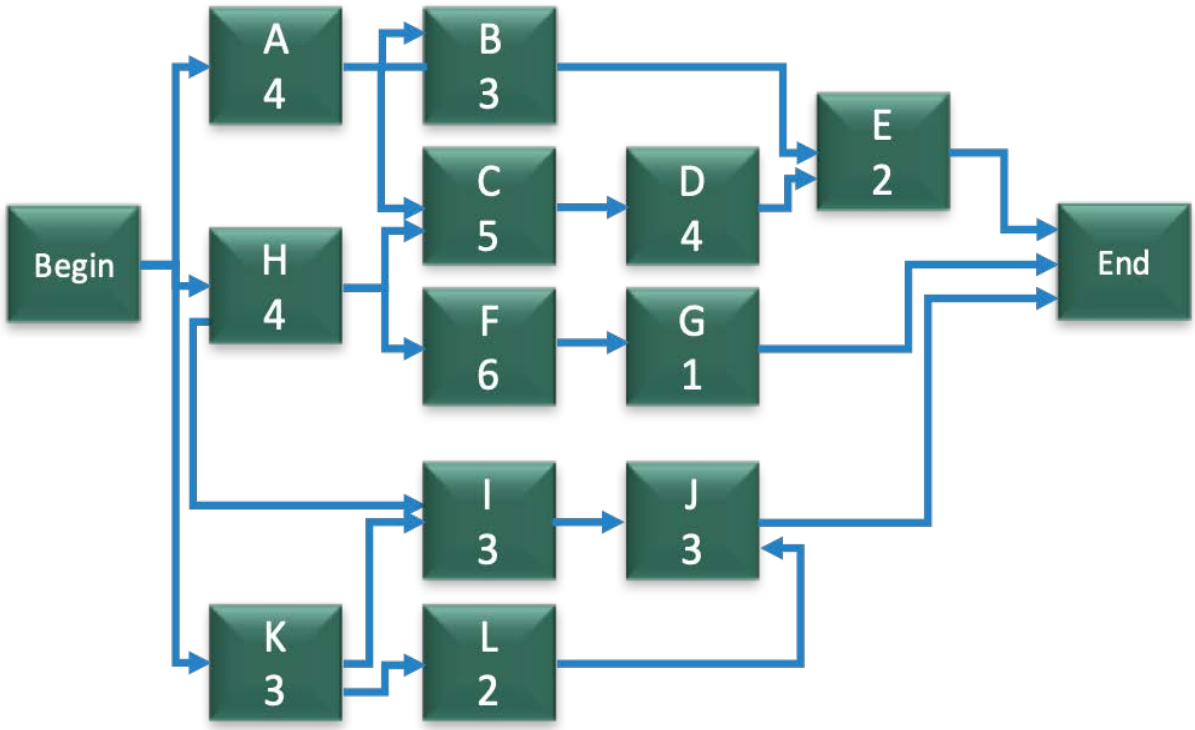


Figure 23: Example of a schedule network diagram (nodes are labelled with letters, the figures indicate the durations of the activities on the nodes).

Activities not on the critical path have some float (also called slack) that allows some amount of delay without delaying the project end date.

Float, or **slack**, is the **amount of time a task can be delayed without delaying the project's completion**. Technically, there are three different types of float.

- **Free float.** This is the total time a single activity can be delayed without delaying the early start of any successor activities.
- **Total slack.** This is the total time an activity can be delayed without delaying project completion.
- **Project slack.** This is the total time the project can be delayed without passing the customer-expected completion date.

4 Estimate Activity Durations

Estimate Activity Durations is the process of estimating the number of work periods needed to complete individual activities with estimated resources. [PMBOK Guide, p. 195]

This process estimates the amount of effort (time) required to complete the activity. Estimating activity durations takes into account required resource (type or skill level), quantity of the resource and its availability (from resource calendar). Duration estimates are progressively elaborated. The more detailed data on the activity and its required resources are available the more improves quality and accuracy of the duration estimates. [PMBOK Guide, p. 196/197]

4.1 Analogous Estimating

Analogous estimating is a technique for estimating the duration or cost of an activity or a project using historical data from a similar activity or project.

This is a gross value estimating approach, sometimes adjusted for known differences in project complexity.

Analogous estimating is generally less costly and less time-consuming than other techniques, but it is also less accurate.

[PMBOK Guide, p. 200]

4.1.1 Parametric Estimating

The estimates state a single value for the required resource. The estimation can be improved by considering uncertainty and risk.

Three-point estimating includes variations in the subjective judgment of a single estimate.

- **Most likely (tM)**. This estimate reflects the value a certain majority of persons (experts) estimates as quite likely.
- **Optimistic (tO)**. This estimate emerges from a best-case scenario or the optimistic assessment among the group of experts.
- **Pessimistic (tP)**. This estimate emerges from a worst-case scenario or the pessimistic assessment among the group of experts.

The estimate (tE) can be calculated by applying a simple formula for "*triangular distribution*".

$$tE = \frac{(tO + tM + tP)}{3}$$

The "*Beta distribution*" puts more weight on the most likely estimate.

$$tE = \frac{(tO + tM \cdot 4 + tP)}{6}$$

[PMBOK Guide, p. 201]

5 Develop Schedule

"Develop Schedule is the process of analyzing activity sequences, durations, resource requirements, and schedule constraints to create a schedule model for project execution and monitoring and controlling." [PMBOK Guide, p. 205]

The objective of this process is the development of an acceptable project schedule. It starts with all available information on the activities scheduled so far. The challenge is to review and analyze duration estimates, resource estimates, and schedule reserves and to possibly apply resource leveling to resolve schedule conflicts.

5.1 Critical Path Method

The critical path method (CPM) is used to estimate the minimum project duration and determine the amount of schedule flexibility on the logical network paths within the schedule model.

The critical path method is a step-by-step technique for process planning that defines critical and non-critical activities with the goal of preventing time-frame problems.

In applying the CPM, there are several steps that can be summarized as follows:

- Define the required activities and put them down in an ordered (sequenced) list.
- Create a flowchart or other diagram showing each task in relation to the others.
- Identify the critical and non-critical relationships (paths) among activities. The critical path is the sequence of activities that represents the longest path though a project, which determines the shortest possible project duration.
- Determine the expected completion or execution time for each activity.

- Locate or devise alternatives (backups) for the most critical paths.

Tasks that are not on the critical path have some float (also called slack) that allows for some delay of an activity without delaying the project's end date.

Thus, float or slack is the time that a task can be delayed without delaying the completion of the project. Technically, there are three different types of float times.

Free float. This is the total time that a single task can be delayed without delaying the earliest possible start of a successor task.

Total float. This is the total time that a task can be delayed without compromising the project completion date.

Project float. This is the total time that the project can be delayed without compromising the completion date expected by the customer.

The critical path method is used to calculate the critical paths and the height of the total and/or free buffers (margins) or schedule flexibility on the network paths within the schedule model. The early and late start and finish dates indicate the time periods within which the activity could be executed. On the critical path all activities have the same early and late start dates and the same early and late finish dates. Differing early and late dates indicate a free or total float.

The longest path has the least total float – usually zero. The critical path method is used to calculate the critical path(s) and the amount of total and free float or schedule flexibility on the logical network paths within the schedule model.

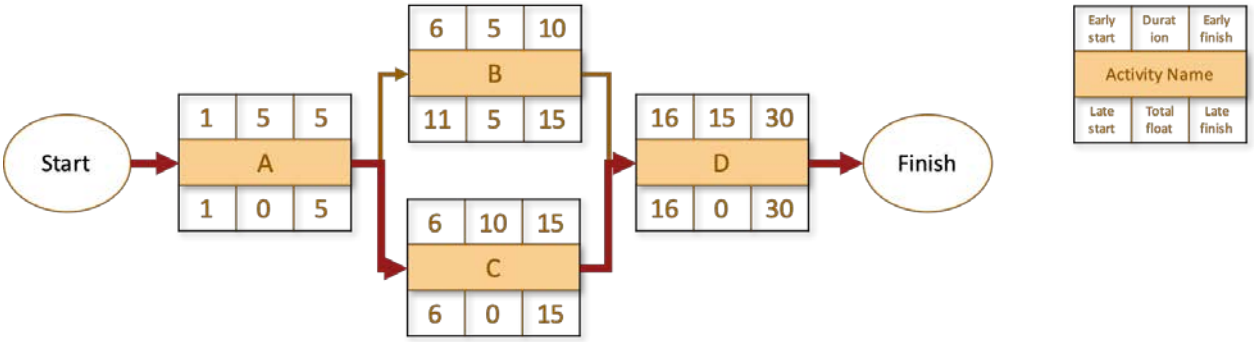


Figure 24: Example of a schedule network diagram. In this example, the critical path is the sequence A-C-D. The free float of activity B is 5 time units. This is also the total float.

[PMBOK Guide, p. 210/211]

5.2 Resource Optimization

Resource optimization is used to adjust the start and finish dates of activities to adjust planned resource use to be equal to or less than resource availability.

Resource leveling. A technique in which start and finish dates are adjusted based on resource constraints with the goal of balancing the demand for resources with the available supply. Resource leveling is required when resources are available only at certain times or in limiting quantities, or are over-allocated (e.g. a person is assigned with her or his full availability to two activities at the same time).

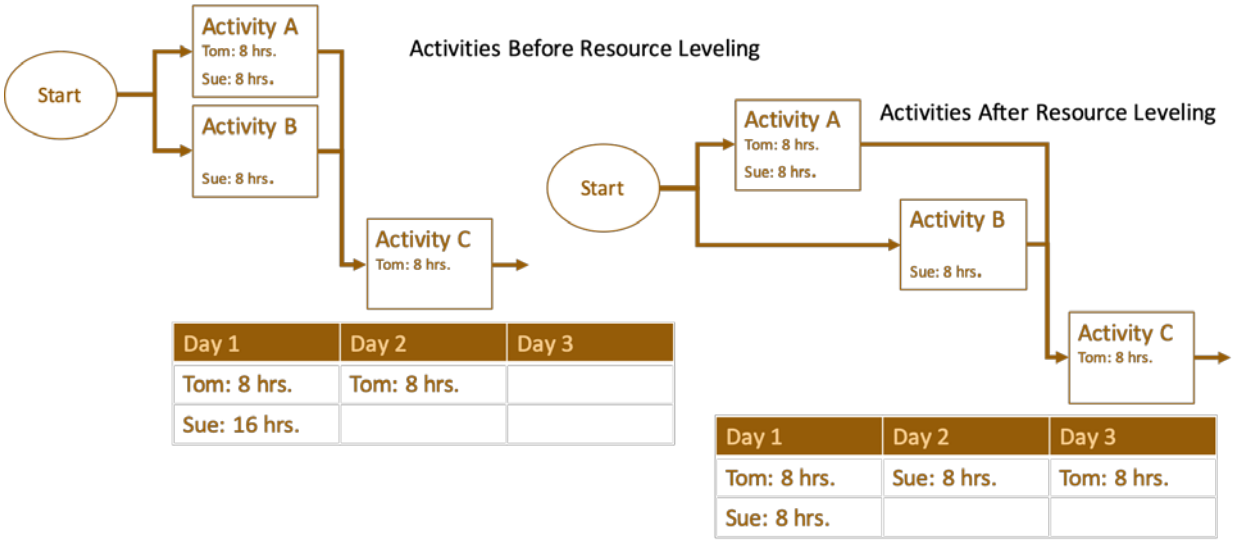
Resource smoothing. A technique that adjusts the activities of a schedule model such that the requirements for resources on the project do not exceed certain predefined resource limits. In resource smoothing, the project's critical path remains unchanged as resources are shifted between the activities while only increasing the duration of the activities with free and total float.

Figure 25: Example of resource leveling

[PMBOK Guide, p. 211/212]

5.3 Schedule Compression

Schedule compression techniques are used to shorten or accelerate the schedule duration without



reducing the project scope in order to meet schedule constraints, imposed dates, or other schedule objectives.

Fast tracking. A technique in which activities or phases normally done in sequence are *performed in parallel* for at least a portion of their duration. Fast tracking can be risky if the inherent dependencies between activities (in terms of produced results) are (partially) neglected.

Crashing. A technique used to shorten the schedule duration for the least incremental cost by *adding resources*. Crashing may result in increased costs.

[PMBOK Guide, p. 215]

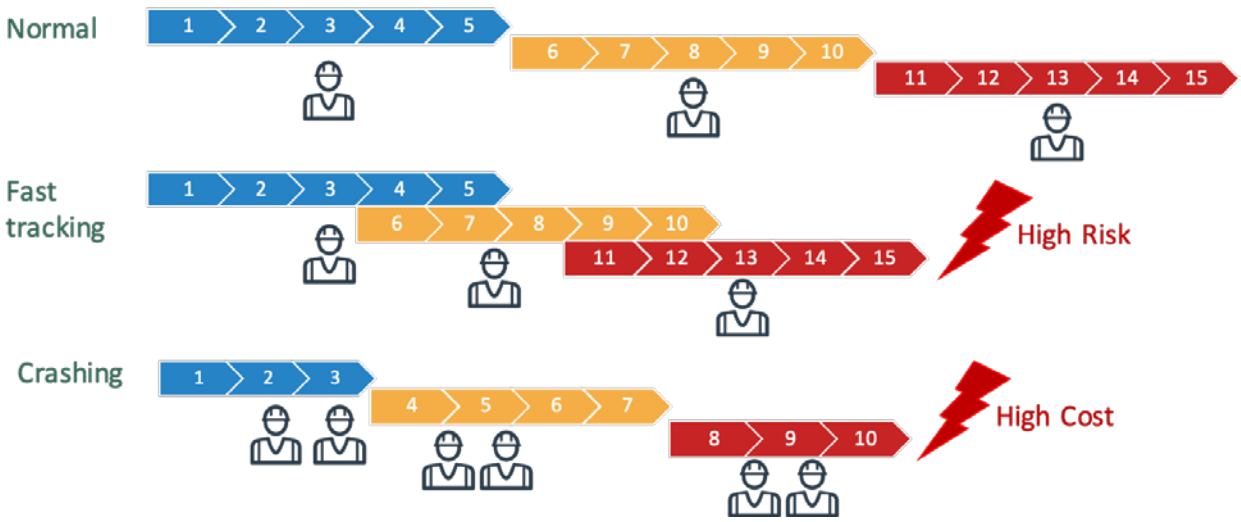


Figure 26: Possibilities of schedule compression

6 Control Schedule

"Control Scope is the process of monitoring the status of the project to update the project schedule and managing changes to the schedule baseline." [PMBOK Guide, p. 222]

The actual performance of the project may require schedule changes. Much like other changes, schedule changes go through the Perform Integrated Change Control process, too. Change control may include the following steps:

- Determining the current status of the project schedule,
- Influencing the factors that create schedule changes,
- Reconsidering necessary schedule reserves,
- Determining if the project scheduled has changed, and
- Managing the actual changes as they occur.

E Project Cost Management

In this chapter you learn

How to estimate costs

How to determine the project budget and its components

How to analyze and control costs

Cost management is the process of planning and controlling the budget of a project. It is a form of management accounting that enables the prediction of impending expenditures to help reduce the chance of going over budget.

Project Cost Management addresses planning, estimating, budgeting, financing, funding, managing, and controlling costs so that the project can be completed successfully within the approved budget. [PMBOK Guide, p. 231]

Expected costs are calculated while the project is still in the planning period and are approved beforehand. During the project, all expenses are recorded and monitored to make sure they stay in line with the cost management plan. After the project is finished, the predicted costs and actual costs can be compared and analyzed, helping future cost management predictions and budgets.

Project Cost Management covers project management activities across the Project Management Process Groups Planning and Monitoring & Controlling. Its processes are [PMBOK Guide, p. 231]:

- **Plan Cost Management**. Definition of how costs will be estimated, budgeted, managed, monitored, and controlled.
- **Estimate Costs**. Estimation of the monetary resources needed to complete project work.
- **Determine Budget**. Aggregating the estimated costs of individual activities or work packages to establish an authorized cost baseline.
- **Control Costs**. Monitoring the status of the project, updating project costs, and managing changes to the cost baseline.

1 Plan Cost Management

"Plan Cost Management is concerned with defining how the project costs will be estimated, budgeted, managed, monitored, and controlled." [PMBOK Guide, p. 235]

The only output of this process is the cost management plan. It describes how the project costs will be planned, structured, calculated and controlled.

The work breakdown structure (WBS) is the basis of the cost estimations. The component used for the project cost accounting is the control account. Each control account has a unique identifier (code or account number) that is linked to the organization's accounting system. The cost management plan documents this accounting system.

It also describes the control thresholds, that is, the agreed-upon cost variations to be allowed before some action needs to be taken.

Furthermore, it defines rules of performance measurement (when, which, and how earned values are calculated) and the formats and frequency of the cost reports to be disseminated.

[PMBOK Guide, p. 239]

2 Estimate Costs

Costs are assessed as the likely cost for the resources (people and materials) required to complete the different activities. They are predicted based on the information available at a specific point in time.

Cost assessment also includes considering resource alternatives and financing decision such as buy versus lease, make versus buy, or sharing of resources.

Cost estimating can be achieved by a variety of estimating techniques that resemble those in schedule management.

2.1 Analogous Estimating

Analogous estimating uses values, or attributes, of a previous project that are similar to the current project. Values and attributes of the projects may include: scope, cost budget, duration, and measure of scale.

[PMBOK Guide, p. 244]

2.2 Parametric Estimating

Parametric estimating uses a statistical relationship between relevant historical data, market prices, and other variables to calculate a cost estimate for project work (e.g. meters of cable at a price of X).

[PMBOK Guide, p. 244]

2.3 Three-Point Estimating

The estimates state a single value for the required resource. The estimation can be improved by considering uncertainty and risk.

Three-point estimating includes variations in the subjective judgment of a single estimate.

- **Most likely (cM)**. This estimate reflects the value a certain majority of persons (experts) estimates as quite likely.
- **Optimistic (cO)**. This estimate emerges from a best-case scenario or the optimistic assessment among the group of experts.
- **Pessimistic (cP)**. This estimate emerges from a worst-case scenario or the pessimistic assessment among the group of experts.

The estimate (cE) can be calculated by applying a simple formula for "*triangular distribution*".

$$cE = \frac{(cO + cM + cP)}{3}$$

The "*Beta distribution*" puts more weight on the most likely estimate.

$$cE = \frac{(cO + cM \cdot 4 + cP)}{6}$$

[PMBOK Guide, p. 244/245]

2.4 Alternatives and Reserve Analysis

Alternative analysis is used to evaluate identified options in order to select which options or approaches to use to execute and perform the work of the project. Alternative analysis may be applied, for examples, in decisions like buying versus leasing (or making). [PMBOK Guide, p. 245]

Reserve analysis addresses uncertainties. Contingency reserves are the budget within the cost baseline that is allocated for identified risks or work that is hardly to assess quantitatively, the so-called *known unknowns*.

The purpose of the contingency reserve is to compensate for the uncertainty inherent in cost (and time) estimates, as well as unpredictable risk exposure. When developing an application, for example, rework will be necessary. However, the amount of rework remains unknown beforehand.

A contingency is something that may or may not occur but that must be dealt with if it does. The word contingency implies that the potential of an event is foreseeable. In some situations, it is clear that some additional effort will occur, but the nature of this effort is unclear. These events are called *unknown unknowns*.

The quantitative assessment of all the costs required to complete the project work, including contingency reserves for known and unknown unknowns.

The costs include items like labor cost, materials, equipment, services, and rent for facilities, information technology, financing costs, and exchange rates.

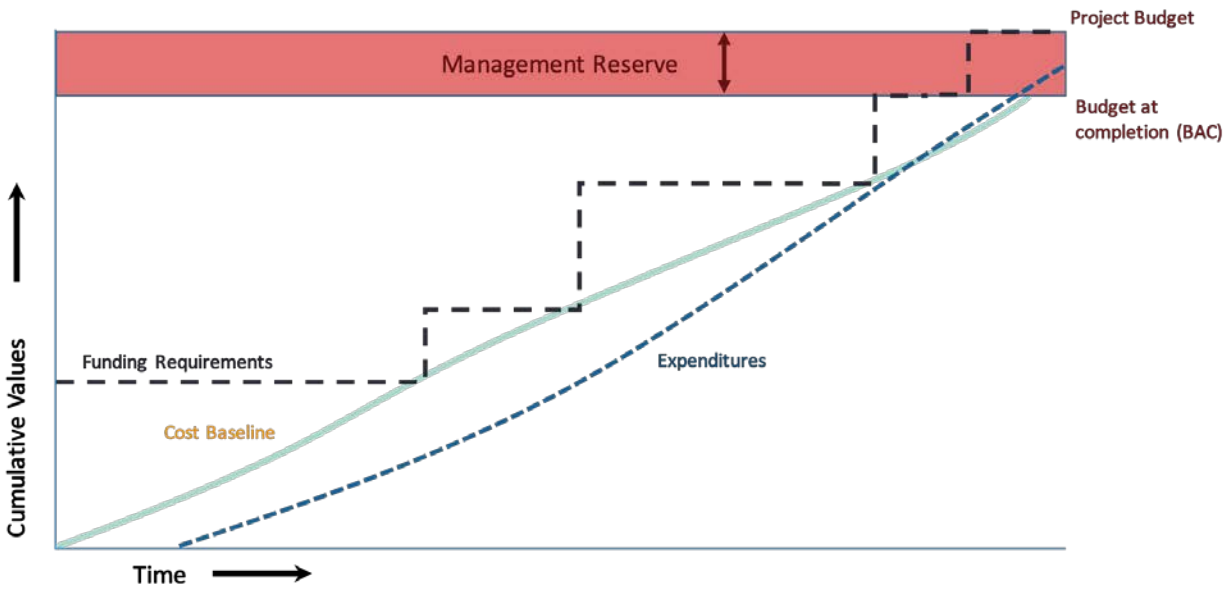
Indirect costs, if they are included in the project estimate, can be included at the activity level or at higher levels.

3 Determine Budget

"Determine Budget is the process of aggregating the estimated costs of individual activities or work packages to establish an authorized cost baseline." The project budget reflects all the funds authorized to execute the project work (including contingency reserves, but excluding the management reserve). [PMBOK Guide, p. 248]

Figure 27: Possible development of planned and actual costs, including funding requirements, project budget, and management reserve.

The cost baseline is the known state of the project budget. It is compared from time to time with the



actual project results.

The cost baseline can only be changed through formal change control procedures.

The cost estimates of the different activities and their corresponding contingency reserves are aggregated into the work package cost estimates. These estimates and the contingency reserves at work package level make up the control accounts. The summation of all control accounts yields the cost baseline.

The management reserve covers contingencies more on a global project level. When unforeseeable events at project level occur, change control may authorize the use of the management reserve. The corresponding funds are then added to the cost baseline.

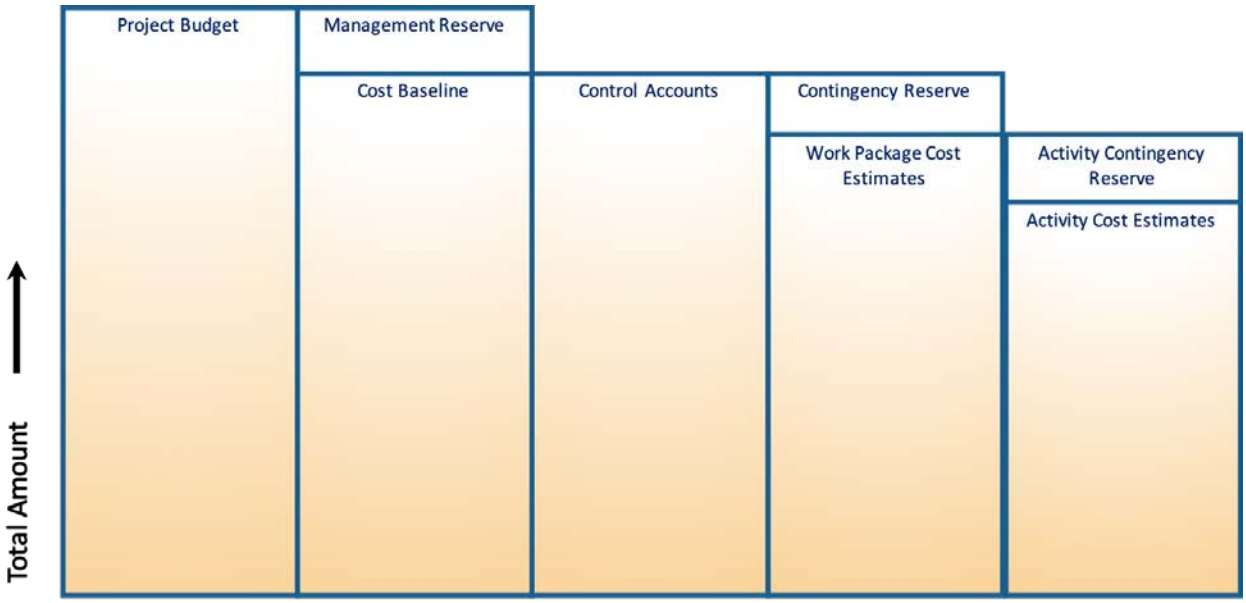


Figure 28: Components of the project budget

Cost estimates are directly tied to the scheduled activities. This enables a time-phased and cumulative view of the cost baseline.

Earned value management takes the cost baseline as its performance measurement baseline. The actual project performance is measured against this baseline.

[PMBOK Guide, p. 255]

4 Control Costs

Control Costs is the process of monitoring the status of the project to update the project costs and managing changes to the cost baseline.

Monitoring the expenditures should be linked with monitoring the work being accomplished for these expenditures. Cost control is managed based on the approved cost baseline.

[PMBOK Guide, p. 257/259]

The executing processes of the project yield work performance data that reflect the actual status and performance of the project. These data are compared with the planned costs. Deviations are analyzed and documented as work performance information. This information may entail recommendations for corrective or preventive actions to bring the project back on track.

Project performance is a composite assessment of how well a project team executes on its most important parameters, typically the financial performance. Project performance analysis is concerned with the "health" of the project, which has traditionally been measured in terms of financial performance.

The performance indicators are calculated based on a number of work performance and budget data:

Indicator	Definition	Purpose	Equation	Interpretation of Result
Planned Value (PV)	Authorized budget assigned to scheduled work	Amount of work planned to be completed at a certain point in time.		
Earned Value (EV)	Work performed expressed in terms of the budget authorized for that work.	Amount of work completed (earned) at a certain point in time.		
Actual Cost (AC)	Realized cost for the work performed during a specific period.	Amount of actual cost for all the work completed to a certain point in time.		
Budget at Completion (BAC)	The budget for the work to be performed.	Total amount of the planned work (project cost baseline)		
Cost variance (CV)	Deficit or surplus at a certain point in time.	Difference between the work completed (earned) and the actual costs at a certain point in time.	CV= EV - AC	*Positive*: under *Neutral*: on *Negative*: over planned cost
Schedule Variance (SV)	The amount of time the project is ahead or behind the schedule at a certain point in time.	Difference between the work completed (earned) and the work planned at a certain point in time.	SV = EV - PV	*Positive*: ahead of *Neutral*: on *Negative*: behind schedule
Estimate at Completion (EAC)	Expected total cost of completing all work expressed as all the actual costs at a certain point in time and the estimate to complete the remaining work.	If the CPI is expected to be the same for the remainder of the project	EAC = BAC/CPI	
		If future work will be accomplished at the planned rate	EAC = AC + BAC - EV	
		If CPI and SPI have an impact on future work	EAC = AC + (BAC-EV)/CPI*SPI	
Estimate to complete (ETC)	Expected cost to complete the remaining work	Assuming work is proceeding as planned	ETC=EAC-AC	
		Otherwise re-estimate remaining work from bottom-up	ETC= Re-estimate	
Variance at completion (VAC)	Budget deficit or surplus at completion.	Estimated difference in cost at the completion of the project	VAC = BAC - EAC	*Positive*: under *Neutral*: on *Negative*: over planned cost

Table 4: Overview on performance indicators

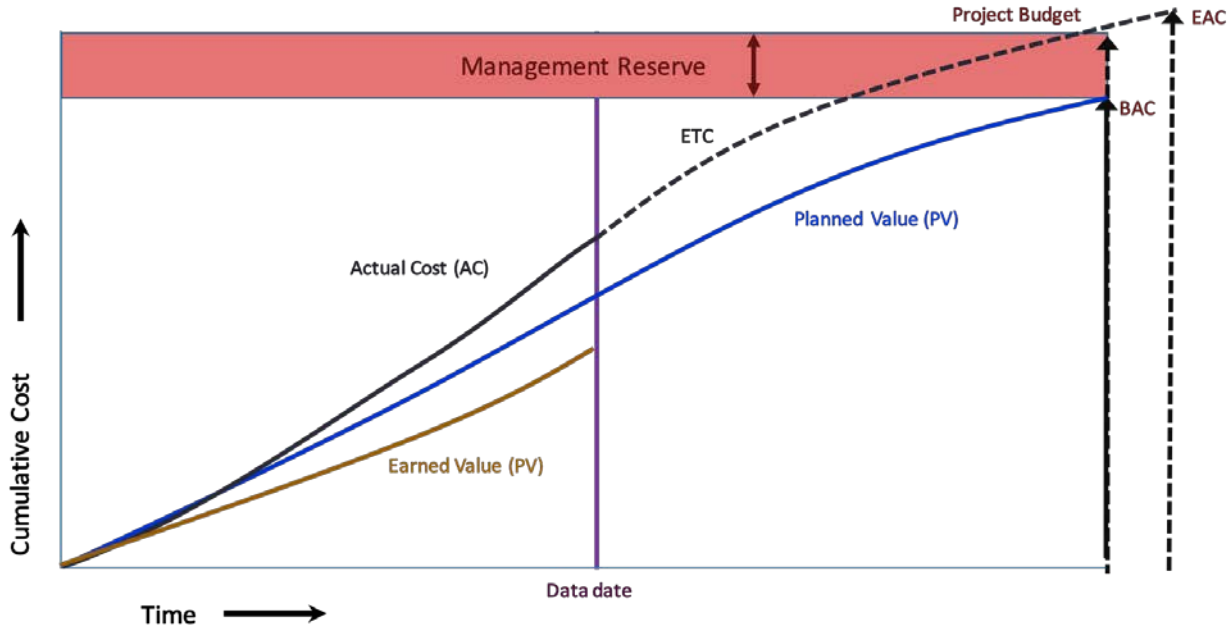
Key performance indicators (KPIs) are metrics used to track and analyze factors deemed crucial to the success of the project. In cost management, KPIs focus on the performance of the project (and project

team) for measuring progress toward meeting the project objectives and, in particular, the budget objectives.

In the context of cost management the most important KPIs are:

Schedule performance index (SPI) measuring the schedule efficiency expressed as the ratio of earned value to planned value. An SPI value less than 1.0 indicates that less work has been competed than indicated by the schedule baseline. An SPI above 1.0 indicates that more work than planned has been accomplished. When related to the critical path the SPI helps to estimate whether the project will finish ahead or after the planned completion date. [PMBOK Guide, p. 263]

Figure 29: Cumulative planned and actual cost and earned value including total costs, project budget, and management reserve

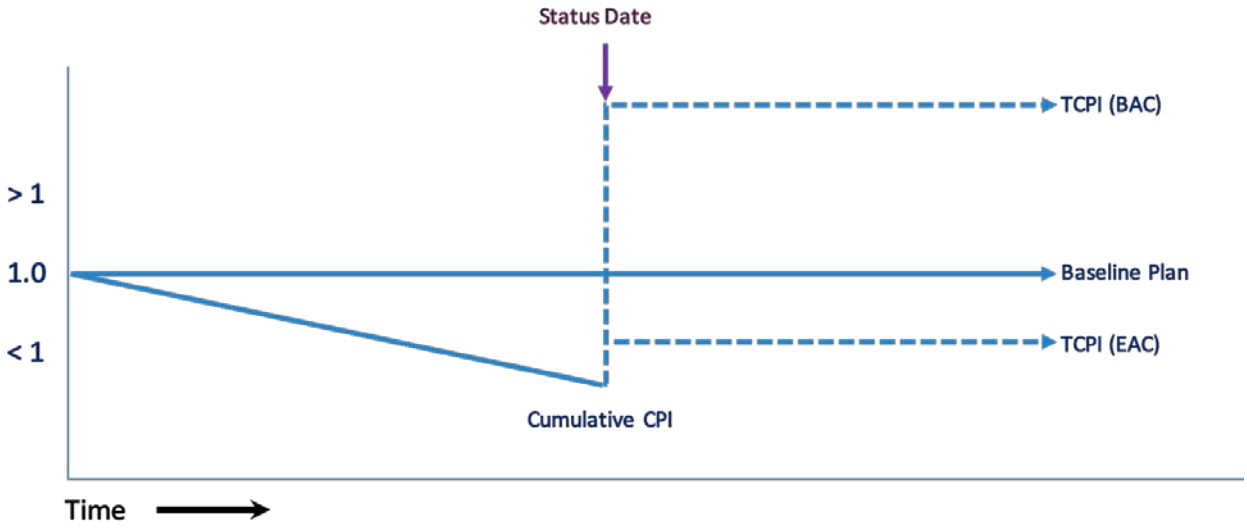


Cost performance index (CPI) measuring the cost efficiency expressed as the ration of earned value to actual cost. A CPI of less than 1.0 indicates a cost overrun for the work completed, while a CPI greater than 1.0 indicates that the project consumed less funds than originally planned for the work completed. [PMBOK Guide, p. 263]

To-Complete Performance Index (TCPI) measuring the cost performance that needs to be achieved with the remaining resources in order to meet a specific management goal. It is expressed as the ratio of the cost to finish the outstanding work to the remaining budget (budget at completion (BAC) or estimate at completion (EAC)). If it becomes obvious that the BAC is no longer viable, the project manager should consider the forecasted EAC.

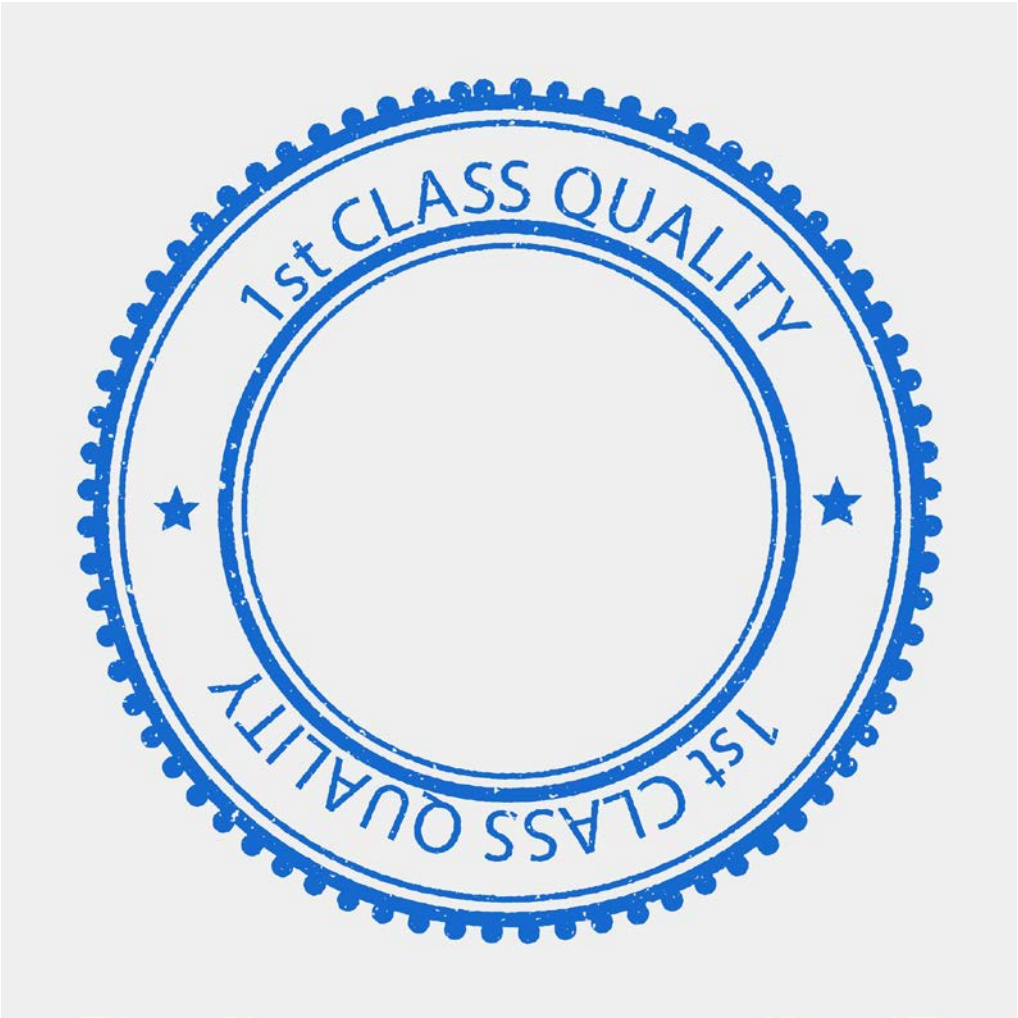
A TCPI value greater than 1.0 indicates that the project needs to increase its performance in order to stay within the authorized budget. A value less than 1.0 indicates that the project will quite likely stay within the authorized budget.

If the cumulative CPI falls below the baseline (as shown in the figure above) the project needs to perform in the range of the TCPI (BAC) to stay within the authorized budget. If BAC is replaced by the EAC the viable level of performance is indicated by the TCPI (EAC).



$$TCPI = \frac{Work\ remaining\ (BAC - EV)}{Funds\ remaining\ (BAC - AC)\ or\ (EAC - AC)}$$

Figure 30: Graphical representation of the To-Complete-Performance Index



F Project Quality Management

In this chapter you learn

Essentials about quality and quality costs

How to monitor and control quality

Project Quality Management incorporates the organization's quality policy regarding planning, managing, and controlling project and product quality requirements in order to meet stakeholder's objectives. It also supports continuous process improvement activities as undertaken on behalf of the performing organization.

Project Quality Management covers project management activities across the Project Management Process Groups Planning, Executing, and Monitoring & Controlling. Its processes are [PMBOK Guide, p. 271]:

- **Plan Quality Management**. Documentation of the processes of identifying quality requirements and standards and of demonstrating compliance with quality requirements and standards.
- **Manage Quality**. Implementing the quality management plan by quality activities along the organization's quality policies.
- **Control Quality**. Monitoring and recording the results of executing the quality management activities to assess performance and ensure the project results are complete and correct, and meet stakeholder expectations.

1 Quality vs. Grade

Quality

- Quality as a delivered performance or result is "the degree to which a set of inherent characteristics fulfill requirements" (ISO 9000).
- It may not be a problem if a suitable product is of low (i.e. it has only a limited number of features) but is of high quality (i.e. it has no obvious defects).

Grade

- Grade as design intent is a category assigned to deliverables having the same functional use but different technical characteristics.
- It may be a problem if a high-grade product (with numerous features) is of low quality (many defects).

Quality is sometimes defined as "meeting the requirements of the customer." The term quality assurance describes any systematic process for ensuring quality during the successive steps in developing a product or service. ISO 9000 is a standard for ensuring that a company's quality assurance system follows best industry practices.

Grade is related to the product's technical features. In other words, products can be graded based on their technical configurations or their features and capacities.

[PMBOK Guide, p. 274]

If a product has many features and capacities it doesn't say anything about the quality of the product and vice versa. Failing the quality level, i.e. failing to meet quality requirements, is always a problem, while failing the grade level is not necessarily a problem. A low-grade smartphone, for instance, with a

handful of features may even be desired by a certain user community and accepted if it has no obvious defects (high quality).

2 Cost of Quality

The cost of quality (COQ) includes all costs incurred over the life of the product by investment in preventing nonconformance to requirements, appraising the product or service for conformance to requirements, and failure costs.

Cost of Conformance

Money spent during the project **to avoid failures**

Cost of Nonconformance

Money spent during and after the project **because of failures**

Prevention Costs

Build a quality product: costs for training, document processes, equipment, time to do it right.

Internal Failure Costs

Failure found by the project: rework and scrap.

Appraisal Costs

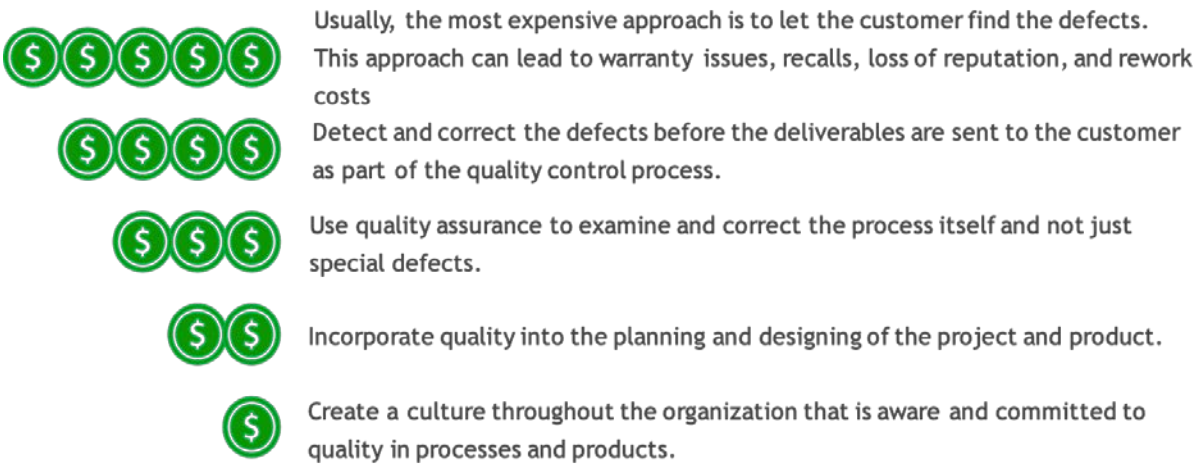
Assess the quality: testing, destructive testing loss, inspections

External Failure Costs

Failures found by the customer: liabilities, warranty work, lost business

Prevention is preferred over inspection. It is better to design quality into deliverables, rather than to find quality issues during inspection.

There are five levels of quality implementation:



[PMBOK Guide, p. 274/275]

Quality control requires a working knowledge of statistical control processes. These processes are designed around the following quality concepts:

[PMBOK Guide, p. 274]

3 Plan Quality Management

Plan Quality Management addresses design and documentation of the process of identifying quality requirements and standards for the project and its deliverables, and how the project will comply with quality requirements and standards.

The quality management plan may include the following descriptions:

- Quality standards to be followed by the project;
- Quality objectives to be achieved by the project;
- Project deliverables that are subject to quality review;
- Quality control and quality management activities (including corrective actions, continuous improvement, etc.)

[PMBOK Guide, p. 286]

4 Manage Quality

Manage Quality is the process of implementing the quality management plan yielding quality activities that incorporate the organization's quality policies into the project.

Manage Quality or Quality assurance (QA) is any systematic process of determining whether a product or service meets specified requirements.

It establishes and maintains set requirements for developing reliable products, services, or results. A QA system is meant to increase customer confidence and a company's credibility, while also improving work processes and efficiency.

The Manage Quality process implements a set of planned and systematic acts and processes that help to:

- Design an optimal and mature product by implementing specific design guidelines that address specific aspects of the product;
- Build confidence that a future output will be completed in a manner that meets the specified requirements and expectations through quality assurance tools and techniques such as quality audits and failure analysis;
- Confirm that the quality processes are used and that their use meets the quality objectives of the project; and
- Improve the efficiency and effectiveness of processes and activities to achieve better results and performance and enhance stakeholders' satisfaction.

[PMBOK Guide, p. 290]

After all data relevant for QA are gathered, data analysis is applied in order to detect quality problems or issues. Analysis may include:

Document analysis. Reports such as quality reports, test reports, performance reports, and variance analysis, can point to and focus on processes that may be out of control and may jeopardize meeting the specified requirements or stakeholder expectations.

Process analysis identifies problems and failures occurred in a process or opportunities for process improvements.

Root cause analysis (RCA) is an analytical technique used to determine the basic underlying reason(s) that causes a variance, defect, or risk.

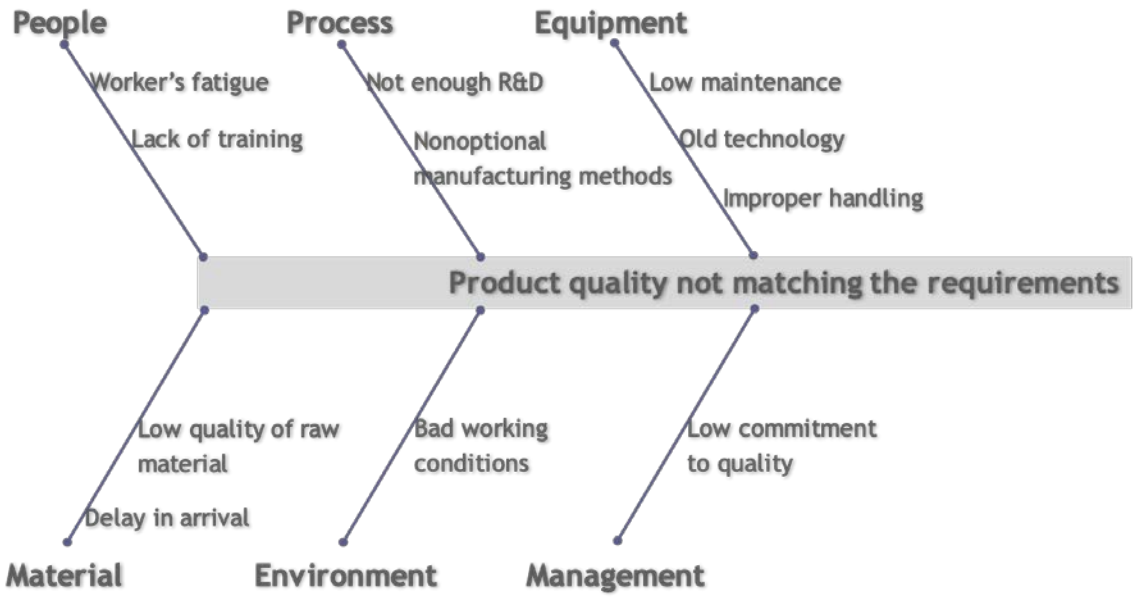
[PMBOK Guide, p. 292]

The results of the analysis are documented in the quality reports. They provide in-depth information on quality problems and issues. The reports can be used by other processes and departments to take corrective actions in order to achieve the project quality expectations and to meet quality standards.

There are a number of useful representation techniques for the visualization of quality problems and issues:

- **Affinity diagrams** can organize potential causes of defects into groups showing areas that should be focused.
- **Cause-and-effect diagrams** (or fishbone diagrams) break down the causes of a problem identified into discrete branches, helping to identify the main or root cause of the problem.
- **Flowcharts** show a series of steps that lead to a defect.

- **Histograms** can show the number of defects per deliverable, a ranking of the cause of defects, the number of times each process is noncompliant, or other representations of project or product defects.
- **Matrix diagrams** seek to show the strength of relationships among factors, causes, and objectives.
- A **scatter diagram** is a graph that shows the relationship between any element of a



process, environment, or activity and a quality defect.

Figure 31: Example of a cause-and-effect diagram

5 Control Quality

Quality control (QC) is a production-focused process and intended to ensure that the product or service adheres to a defined set of quality criteria or meets customer expectations.

Control Quality is the process of monitoring and recording results of executing the quality management activities in order to assess performance and ensure the project outputs are complete, correct and meet customer expectations. Control Quality determines if the project outputs do what they were intended to do.

[PMBOK Guide, p. 298]

In order to implement an effective QC, a project should adhere to the specific standards the product or service must meet (as stated in the quality management plan). Then the QC actions must be determined (for example, the percentage of units to be performed for each module). Next, real-world data must be collected (for example, the percentage of units that fail) and the results reported to the project team and stakeholders.

After this, corrective action must be decided upon and taken (for example, defective units must be repaired or rejected and poor service repeated at no charge until the customer is satisfied). If too many unit failures or instances of poor service occur, a plan must be devised to improve the production or service process and then that plan must be put into action. Finally, the QC must be ongoing to ensure that remedial efforts, if required, have produced satisfactory results and to immediately detect recurrences or new instances of quality problems or issues.

The main results of quality control are **verified deliverables**, **work performance information**, and **change requests**.

Quality control determines the correctness of deliverables. If verified, the deliverables become input to Validate Scope for formalized acceptance. If quality control identified deviations from quality standards it may trigger a change request or improvement.

Work performance information describers to what extend the evaluated results met quality standards, why work has been rejected, or where rework is required and lists the verified deliverables. It includes recommendations for corrective actions and process adjustments.

G Project Resource Management

In this chapter you learn

How to estimate the amount of resources required for the project activities

How to obtain these resources

How to sustainably develop a project team

How to check and manage team performance

How to control the resources assigned to the project

Project Resource Management serves for identifying, acquiring, and manage project resource and, in particular, recruiting, developing, and managing the project team. Resource Management is also responsible for creating, putting into effect and overseeing policies governing workers and the relationship of the project and organization with its employees.

Project Resource Management covers project management activities across the Project Management Process Groups Planning, Executing, and Monitoring & Controlling. Its processes are [PMBOK Guide, p. 307]:

- **Plan Resource Management**. Documentation of the processes of identifying, estimating, acquiring, employing, and managing team resources.
- **Estimate Activity Resources**. Identifying and estimating type and quantities of material, equipment, supplies, and personnel needed to perform the project work.
- **Acquire Resources**. Obtaining project personnel, facilities, equipment, materials, and supplies needed to complete the project work.
- **Develop Team**. Improving and enhancing individual team member skills and competencies and overall team performance.
- **Manage Team**. Tracking team and team member performance, providing feedback, resolving issues, and managing changes in the team to optimize team performance.
- **Control Resources**. Ensuring that the resources assigned and allocated to the project are available as planned, as well as monitoring the use of resources and team performance and prompting corrective actions as necessary.

1 Project Human Resource Management

The project team consists of individuals with assigned roles and responsibilities to work collectively in order to achieve a shared project goal [PMBOK Guide, p. 309] and to transform the project vision into a successful product or service. The project manager is thus expected to invest effort in recruiting, hiring, empowering, motivating, and managing the project's team members.

Project Human Resource Management (PHRM) is part of Project Resource Management as far as the project team is concerned. PHRM in this context is employee management with an emphasis on those employees as assets of the project.

Employees are sometimes referred to as human capital. As with other business assets, the goal is to make effective use of employees, reducing risk and maximizing return on investment (ROI).

The objectives of PHRM can be broken down into four categories:

Societal objectives: Measures put into place that respond to the ethical and social needs or challenges of the project and its team members. This includes legal issues such as equal opportunity and equal pay for equal work.

Organizational objectives: Actions taken that help to ensure the efficiency of the project team. This includes hiring the right amount of employees for a given task and maintaining high employee retention rates.

Functional objectives: Guidelines to ensure that human resources are being allocated to its full potential (adding expertise and strengthening commitment to the project) while retaining and improving team satisfaction and motivation.

Personal objectives: Resources used to support the personal goals of each employee. This includes proactively developing team skills and competencies.

2 Physical Project Resource Management

Physical project resource management (PPRM) is concentrated in allocating and using equipment, materials, facilities, and infrastructure needed for the successful completion of the project in an efficient and effective way.

Common failures in PPRM are

- Failing to secure critical equipment, facilities, and infrastructure on time resulting in delays.
- Ordering low-quality material causing low quality of or high defect rates in the project results which, in turn, may lead to a high rate of recalls or rework.
- Keeping too much inventory may result in high project costs. A low inventory, on the other hand, may results in project delays.

[PMBOK Guide, p. 310]

3 Plan Resource Management

This process documents how to estimate, acquire, manage, and use team and physical resources [PMBOK Guide, p. 312]. The result of this process is the resource management plan containing (among other things) the resource breakdown structure, description of roles and responsibilities, and the responsibility assignment matrix.

3.1 Resource Breakdown Structure (RBS)

Similar to the WBS, the RBS is a hierarchical list of team and physical resources categorized along resource types. Each lower level represents an increasingly detailed description of the resource.

3.2 Description of Roles and Responsibilities

The **role** is the *function assumed* by or *assigned* to a team member (e.g. scrum master, senior developer, business analyst, interviewer, etc.).

The **responsibility** cover the *assigned work and duties* of a project team member.

The team member's **competence** comprise the *hard and soft skills* required to complete assigned activities.

Hard skills comprise mastery and expertise within the individual to perform a specific task or series of tasks to complete a job. Proficiency in any hard skill is demonstrable and quantifiable (knowledge of programming in C++, typing, etc.). Certificates, diplomas, licenses and test scores are often used as

proof that an individual has achieved a certain level of proficiency for a particular hard skill or set of hard skills.

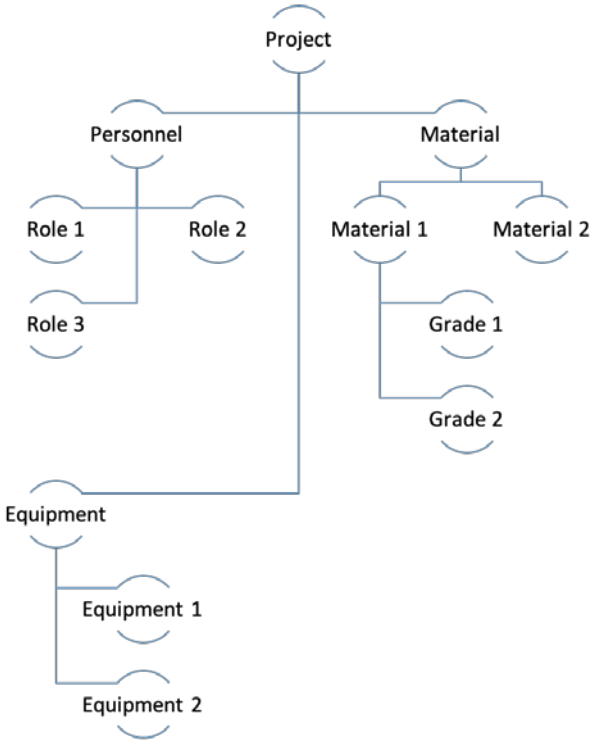


Figure 32: Example of a resource breakdown structure

A ***soft skill*** is a personal attribute that supports situational awareness and enhances an individual's ability to get a job done. The term soft skills is often used as a synonym for people skills or emotional intelligence. Examples are creativity, leadership, communication, collaboration, problem-solving, adaptability, time management, and the ability to be diplomatic and respectful, even during disagreements.

Authority summarizes the amount of rights to apply project resources, make decisions, sign approvals, accept deliverables, and influence others to carry out the work of the project. [PMBOK Guide, p. 318]

3.3 Responsibility Assignment Matrix

The Responsibility Assignment Matrix (RAM) is a broad concept to show the assignment of project resources to work packages or activities.

A wide-spread instance of a RAM is the so-called RACI chart. RACI stands for (responsible, accountable, consult, and inform). This type of charting is used to pin down who does what and who is responsible for certain work packages or activities.

[PMBOK Guide, p. 317]

Role	Definition
R - responsible	This role conducts the actual work/owns the problem.
A - accountable	This role approves the completed work and is held fully accountable for it.
C - consult	This role has the information and/or capability to complete the work.
I - inform	This role is to be informed of progress and results.

Table 5: Example of assignments of roles and responsibilities

Person / Activity	Ann	Ben	Carlos	Dina	Ed
Create charter	A	R	I	I	I
Collect requirements	I	A	R	C	C
Submit change request	I	A	R	R	C
Develop test plan	A	C	I	I	R

Table 6: Example of a RACI chart

4 Estimate Activity Resources

This process addresses estimating team resources and the type and quantities of physical project resources, such as materials, equipment, and supplies.

Based on the scope management plan and, in particular, the WBS, the resources required for each activity can be estimated.

5 Acquire Resources

Acquire resources is the process of obtaining human and physical project resources. The resources needed can be internal or external to the project-performing organization. Internal resources are acquired or assigned from functional or HR managers. External resources are acquired through the project procurement. [PMBOK Guide, p. 328/329]

Resources, in particular human resources, are acquired along the following main criteria:

- **Availability**. Resource calendars document the time periods when a required resource is available for the project.
- **Cost**. The cost of the required resources may be within the prescribed budget
- **Ability**. Human or physical resource must have the required capabilities.
- **Experience**. The team member has the necessary experience to contribute to the project.
- **Knowledge**. The team member should have relevant knowledge of similar projects or project activities, of the customer, and nuances of the project environment.
- **Skills**. The team member should have the hard and soft skills required in the context of her or his activities.

- **Attitude**: ability to work with other team members as a cohesive team.
- **International factors:** team member location, time zone, and language skills.

The result of this process manifests in the documentation of **physical and human resource assignments.**

[PMBOK Guide, p. 332]

Recruiting (acquiring human resources) is competitive, especially for those with high-demand technical skills. A **recruitment management system** (RMS) is a tool designed to manage the recruiting process.

Recruitment management systems have a range of functions. They include applicant tracking systems for managing job postings and applications, and functions to keep applicants connected and engaged. Routine tasks, such as scheduling phone calls and in-person interviews, comprise part of the work performed by these systems.

More advanced systems may look at incumbent employee performance reviews, resumes and other records to identify the characteristics of a firm's most successful employees.

For employers, online recruitment management systems manage job ads and provide a curated list of job applicants based on their own analysis. Features include an applicant tracking system capability and, often, the ability to integrate with their customer's existing applicant tracking system.

6 Develop Team

Develop Team or Team Building is responsible for improving competencies, team member interaction, and overall team environment to enhance project performance.

Project managers require skills to identify, build, maintain, motivate, lead, and inspire project teams to achieve the project’s mission and high team performance, and to reinforce the culture of the organization.

Members of the team represent a variety of professional and cultural backgrounds, including diverse industry experience, communicating in multiple languages, and cultural norms.

The project manager should develop and sustain a project team that works together independently in a climate of mutual trust.

Team collaboration emphasizes teamwork, innovative thinking and equal participation to achieve objectives. In the workplace, team collaboration also incorporates corporate culture and technology. Goals of team collaboration include completing projects quickly and efficiently, collectively brainstorming solutions and giving all team members a sense of accomplishment. The overall goal of Develop Team is to develop and sustain a team that collaborates.

Figure 33: The objectives of developing a project team

[PMBOK Guide, p. 338]

A wide-spread model for team building is called the "Tuckman ladder" (developed by Bruce Tuckman in 1965) that describes five development stages a team may go through:

1. **Forming**. The team learns about the project and their responsibilities and roles. Team members tend to behave independently. They do not know each other well enough to unconditionally trust one another.
2. **Storming**. The team starts to address the task suggesting ideas. Different ideas may compete for ascendancy and if badly managed this phase can be very destructive for the team. Relationships between team members will be made or broken in this phase and some may never recover. In extreme cases the team can become stuck in the Storming phase.
3. **Norming**. In this stage, the team develops harmonious working practices with teams agreeing on the rules and values by which they operate. Teams begin to trust themselves during this phase as they accept the vital contribution of each member to the team.
4. **Performing**. Performing teams are identified by high levels of independence, motivation, knowledge and competence. Decision making is collaborative and dissent is expected and encouraged as there will be a high level of respect in the communication between team members.
5. **Adjourning**. This final phase marks the end of the project and the break-up of the team. Often a celebratory event is organized at the end of a project and team members will undoubtedly leave the project with fond memories of their experience.

7 Manage Team

Manage Team constitutes tracking team member performance, providing feedback, resolving issues, and managing team changes to optimize project performance. Team management involves a

combination of skills with special emphasis on communication, conflict management, negotiation, and leadership. [PMBOK Guide, p. 345/346]

Successfully managed teams tend to produce benefits such as faster project turnaround times, more met deadlines and, as a result, less money spent. In addition, they enable to learn from each other, to solve problems more efficiently, to break down communication barriers, and to see the larger project mission.

Key elements of successful team management

Communication. Providing clear instructions, asking for clarification when necessary and listening to all members of the team. One aspect of proper communication might be implementing a team messenger tool that allows members to share files, make virtual calls and send updates in real time.

Conflict management. Conflicts are inevitable in projects. Effective team management may result in minimal conflicts, but a management strategy needs to be put in place if those issues arise. Conflict management could be handled individually with the team leader or as a group conversation.

If disagreements arise, team members need to be prepared to compromise for the best interest of the group. Choosing team members with a positive attitude that are willing to meet in the middle ensures that the entire team as a whole will be more successful. In this situation, the project manager should help *facilitate* a satisfactory resolution.

There are five patterns of approaches for conflict resolution:

Withdraw/avoid. Retreating from or postponing a conflict situation with the hope that the conflict will resolve itself.

Cases in which this technique can be used:

- When stakes are low.
- The stakeholders involved in the conflict are not important.
- The issue is not worth investing too much time.
- The conflict will disappear on its own after some time.
- When there is a heated argument among parties and giving them some cooling time is beneficial.
- When there is limited or no information available about the conflict.

Smooth/accommodate. Finding areas of agreement rather than areas of difference in order to smooth the situation. This technique prevents from indulging in tough discussions.

Cases in which this technique can be used:

- When the project team is very busy and has no time.
- A temporary solution to the problem can be beneficial.

Compromise/reconcile. Taking suggestions from all sides and trying to find a compromise.

Cases in which this technique can be used:

- All parties involved in the conflict need to win.
- Collaborative and forcing techniques do not work.
- There's need of a temporary solution to move forward quickly.

Force/direct. Agreeing on one viewpoint and enforce it. This is a win-lose situation and risks demoralizing team members.

Cases in which this technique can be used:

- Stakes are high and/or there's a need for an immediate solution.
- One party is likely right and the project team does not have time to investigate.
- The stakeholders involved in the conflict are not very important and/or the relationship with them is not essential.

Collaborate/problem solve. Discussing the issue with all parties to agree on a solution while considering multiple viewpoints and differing insights.

Cases in which this technique can be used:

- Incorporating multiple views is essential.
- The people involved in the conflict are very influential.
- Consensus is required.
- Distribution of the responsibility equally to all parties is desired.

8 Control Resources

Control Resources ensures that physical resources assigned and allocated to the project are available as planned, monitors the planned versus actual utilization of resources, and takes corrective action as necessary.

Control Resources is concerned with physical resources (equipment, materials, facilities, infrastructure, and the like); human resources are concerned in Manage Team.

Any changes in resource assignment and allocation impacting the schedule or cost baseline need to be approved through Perform Integrated Change Control.

[PMBOK Guide, p. 354]

H Project Communications Management

In this chapter you learn

Principles of communication

Management and Monitoring of project communication

Project Communications Management ensures that information needs of the project and its stakeholders are met through development and implementation of communication media and processes supporting effective information exchange.

Project Communications Management covers project management activities across the Project Management Process Groups Planning, Executing, and Monitoring & Controlling. Its processes are [PMBOK Guide, p. 359]:

- **Plan Communications Management**. Development of appropriate approaches and plans for project communication activities addressing the needs of the project and the project's stakeholders.
- **Manage Communications**. Timely and appropriate creation, collection, storage, retrieval, and dissemination of project information.
- **Monitor Communications**. Ensuring that information needs of the project and its stakeholders are met.

Communication serves the exchange of information addressing ideas, instructions, or emotions. The exchange can be in written or spoken form, formal or informal, through gestures or media, in meetings or presentations, or through project reports or documentation. Effective communication builds a bridge between diverse stakeholders of the project. Sending and receiving information takes place consciously or unconsciously through words, facial expressions, gestures, etc.

Successful project communication consists of

- a **communication strategy** addressing the needs of the project and the project stakeholders and
- the transformation of this strategy into **project communications** to ensure that the appropriate messages are communicated to stakeholders in an appropriate way. Project communications covers collection, creation, dissemination, storage, retrieval, management, tracking, and disposition of information.

[PMBOK Guide, p. 359-362]

Communication models emerge from a basic linear form covering sender and receiver with their personal, cultural, and situationally emotional background that influence the transmission and interpretation of messages.

The **acknowledgment** confirms the receipt of the message, but does not mean comprehension of or agreement with the message. The received message is decoded, interpreted, and understood. The

receiver then encodes thoughts and ideas into a message and transmits it to the sender. By receiving this **feedback** the communication has been completed successfully.

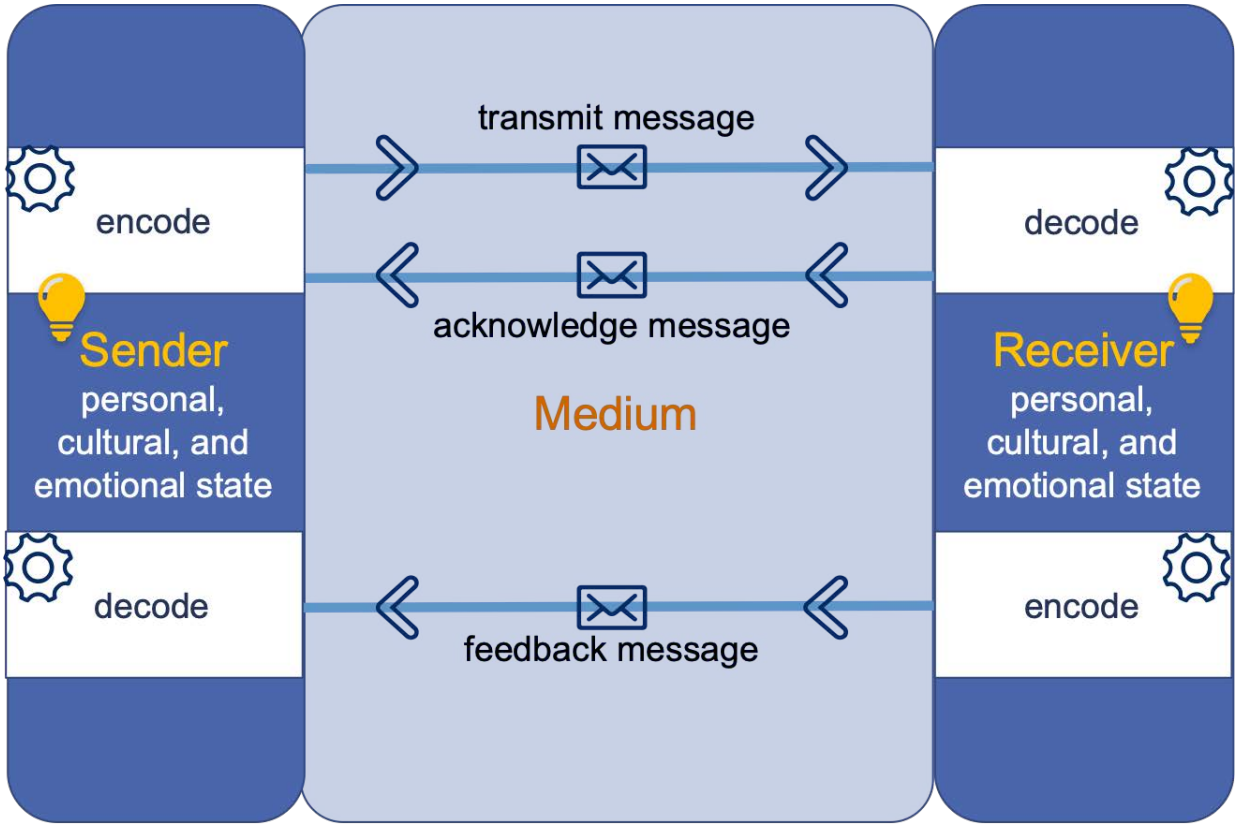


Figure 34: Schema of a communication model

[PMBOK Guide, p. 373]

1 Plan Communications Management

The Communications management plan recognizes the diverse information needs of project stakeholders. This plan is a policy-driven that formally defines who should be given specific information, when that information should be delivered and what communication channels will be used to deliver the information.

An effective communications management plan anticipates what information will need to be communicated to specific stakeholders and audiences. The plan should also address who has the authority to communicate confidential or sensitive information and how information should be disseminated (twitter, chat groups, websites, printed reports, and/or presentations). Finally, the plan should define what communication channels stakeholders will use to solicit feedback and how communication will be documented and archived.

The communications plan plays an important role in change management. An effective communication strategy can help break down resistance to change by getting everyone on the same page and helping stakeholders become engaged and endorse the need for change and the steps being taken to bring it about.

The communications plan should also address information dissemination in emergency situations.

2 Manage Communications

Manage Communications is in charge with the timely and appropriate collection, creating, distribution, storage, retrieval, and disposition of project information.

This process identifies all aspects of effective communication, including choice of tools, methods, and techniques. It goes beyond the pure dissemination of information by ensuring that the information being communicated has been appropriately generated and received by the target groups.

[PMBOK Guide, p. 379]

Manage Communications addresses, in general, the design and implementation of communication technology and communication methods and the communication skills.

Communication tools, like telephony, video conferencing, chat groups, facilitate real-time communication, called **synchronous or interactive** communication.

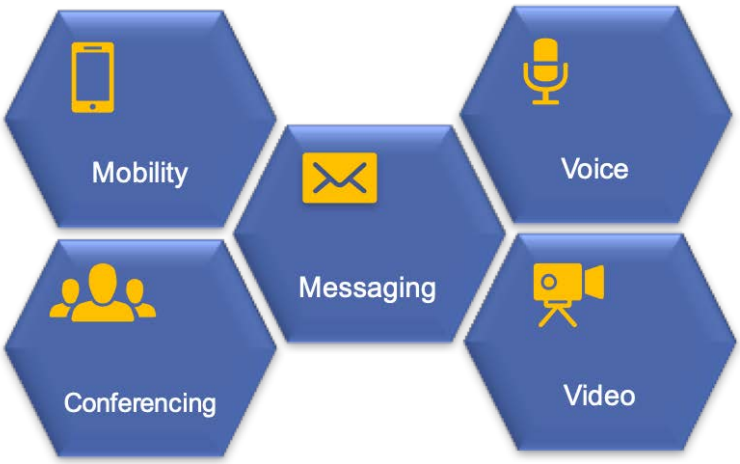
Other communication tools, like blogs, twitter or email, facilitate **asynchronous** communication that takes place at a person's convenience.

- Communication can have the nature of **push communication** (personal communication or communication addressing a small group—information distributed to recipients that need this information.
- Communication can also be designed as **pull communication** providing large and complex information for the broad public (mass communication) or specific groups (through social media, intranets, wikis, and the like).

Communication skills should include active listening, competence in conflict management, cultural and political awareness, networking (interacting with others to exchange information), and management of meetings.

Unified communications (UC) is a framework for integrating asynchronous and synchronous communication, with the goal of enhancing communication, collaboration and productivity. The goal of unified communications is to integrate the software that supports synchronous and asynchronous communication so the end user has easy access to all tools from whatever device is in use.

Figure 35: Components of unified communication



UC also supports users moving from one mode of communication to another within the same session. For example, a user may start communicating via email but then decide to escalate the interaction to real-time communication, transitioning the session to a voice call with one click and then to a video conference with another click without any disruption.

User-facing components of UC include the following technologies:

- Text-based tools, such as email, blogging, text messaging and chat
- Voice-based applications, such as telephony, voicemail and audio conferencing
- Video-based services, such as desktop video conferencing, room-based video conferencing and telepresence
- Web conferencing platforms, virtual meeting spaces and interactive whiteboards
- Enterprise social networking and collaboration platforms

3 Monitor Communications

Monitor communications ensures that information needs of the project and its stakeholders are met. It controls the effect of project communications on increasing or maintaining the support of the different stakeholders for the project and its results.

This process applies a variety of methods, such as collecting and analyzing customer comments and opinions on social media, customer satisfaction surveys, team observations, or evaluating changes in stakeholder engagements.

[PMBOK Guide, p. 388/389]

I Project Risk Management

- In this chapter, you learn:
- Definition of risk
- How to identify and document risks
- How to perform qualitative risk qnalysis
- How to perform quantitative risk analysis
- How to plan, monitor, and control risk responses

Risk management is the process of planning, organizing, leading, and controlling the activities of an organization in order to minimize the effects of risk on a project. It includes financial, strategic and operational risks, in addition to risks associated with accidental losses.

Reducing risk and developing a common risk management language requires an organization to:

- **Define scope**. Identify and prioritize critical business processes and their related risks.
- **Map risks. D**etermine which threats could jeopardize business objectives or critical strategy, share that information and set controls to offset these risks.
- **Develop an action plan.** Create a risk treatment plan to identify unacceptable risks and resolve risk gaps.
- **Monitor and measure.** Establish metrics to identify key control deficiencies. Evaluate how the risk management is progressing, how it varies from policy and the number of risk incidents.

Project Risk Management covers project management activities across the Project Management Process Groups Planning, Executing, and Monitoring & Controlling. Its processes are [PMBOK Guide, p. 395]:

- **Plan Risk Management**. Definition and documentation of how risk management activities are performed.
- **Identify Risks**. Individual project risks and sources of overall project risks are identified and documented.
- **Perform Qualitative Risk Analysis**. Prioritizing individual project risks for further analysis or action by assessing their probability of occurrence and impact.
- **Perform Quantitative Risk Analysis**. Numerically analyzing the combined effect of identified individual project risks and other sources of uncertainty on project objectives.
- **Plan Risk Responses**. Development of options, selection of strategies, and agreeing on actions to address project risk exposure and to treat individual project risks.
- **Implement Risk Responses**. Implementing agreed-upon risk response plans.
- **Monitor Risks**. Monitoring of the implementation of agreed-upon risk response plans, tracking identified risks, identifying and analyzing new risks, and evaluating risk process effectiveness.

1 Key Concepts of Risk Management

A **project risk** is an **uncertain event** or condition that, if it occurs, has a **positive or negative impact** on one or more project objectives such as scope, schedule, cost, and quality. [PMBOK Guide, p. 720]

Project risk management aims to exploit or enhance positive risks (opportunities) while avoiding or mitigating negative risks (threats). [PMBOK Guide, p. 397]

In order to manage risk effectively, the project team needs to know what level of risk exposure is acceptable in pursuit of the project objectives. The acceptable level depends on:

Risk appetite. The degree of uncertainty an entity is willing to take on in anticipation of a reward.

Risk tolerance. The degree, amount, or volume of risk that an organization or individual will withstand.

Risk threshold. The degree of acceptable variation around a project objective.

Project resilience. Project resilience is the ability a project has to quickly adapt to disruptions caused by unknown risks while maintaining overall project direction toward project goals. Some risks, the so-called unknowable unknowns, tend to occur in projects, but can only be recognized after they have occurred. These emergent risks can be tackled through developing project resilience.

- Including budget and schedule contingency for unknown risks in addition to a specific risk budget for known risks.
- Empowered project teams that has clear objectives and can tackle emerging unknown risks.
- Frequent review of early warning signs to identify emergent risks.
- Clear input from stakeholders to clarify areas where the project scope or strategy can be adjusted in response to emergent risks.

[PMBOK Guide, p. 399]

The emergence of an unknown risk is also called **black swan event**. A black swan event is an incident that occurs randomly and unexpectedly and has wide-spread ramifications. The event is usually followed with reflection and a flawed rationalization that it was inevitable. The phrase illustrates the frailty of inductive reasoning and the danger of making sweeping generalizations from limited observations.

The term came from the idea that if a man saw a thousand swans and they were all white, he might logically conclude that all swans are white. The flaw in his logic is that even when the premises are true, the conclusion can still be false. In other words, just because the man has never seen a black swan, it does not mean they do not exist.

2 Plan Risk Management

All risk management plans follow the same steps that combine to make up the overall risk management process:

Risk identification. The project identifies and defines potential risks that may negatively influence a specific project objective or the project as a whole.

Risks can be categorized along a risk breakdown structure (RBS)

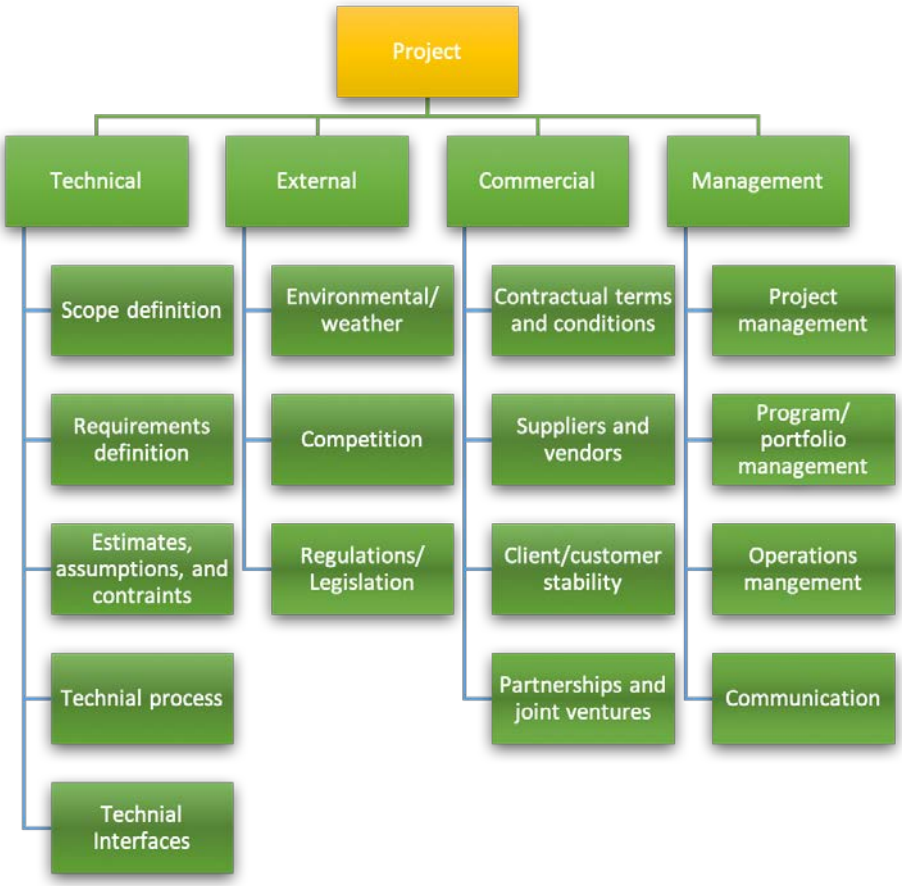


Figure 36: Example of a risk breakdown structure

[PMBOK Guide, p. 406]

Risk analysis. Once specific types of risk are identified, the project then determines the odds of it occurring, as well as its impact. The goal of the analysis is to further understand each specific instance of risk, and how it could influence the project objectives.

The risk management plan may also define a Probability and Impact Matrix for the project. This matrix is applied for threats *and* opportunities, while positive definitions indicate opportunities and negative definitions are used for threats.

Probability		Threats					Opportunities				
very high	.90	.05	.09	.18	.36	.72	.72	.36	.18	.09	.05
high	.70	.04	.07	.14	.28	.56	.56	.28	.14	.07	.04
medium	.50	.03	.05	.10	.20	.40	.40	.20	.10	.05	.03
low	.30	.02	.03	.06	.12	.24	.24	.12	.06	.03	.02
very low	.10	.01	.01	.02	.04	.08	.08	.04	.02	.01	.01
Probability		.05 very low	.10 low	.20 moderate	.40 high	.80 very high	.80 very high	.40 high	.20 moderate	.10 low	.05 very low
		Negative Impact					Positive Impact				

Table 7: Example Probability and Impact Matrix with Scoring Scheme

[PMBOK Guide, p. 408]

The numeric values are multiplied with the value of the threat or opportunity to calculate individual probability-impact scores for each risk. This score helps to priorities risks.

Risk assessment and evaluation. The risk is then further evaluated after determining the risk's overall likelihood of occurrence combined with its overall consequence. The project manager can then make decisions on whether the risk is acceptable and whether the project is willing to take it on based on its risk appetite.

Risk probability and impact levels are specific to the project context and reflect the risk appetite and thresholds of the project and its key stakeholders.

Scale	Probability	+/- Impact on Project Objectives		
		Time	Cost	Quality
very high	>70%	>6 months	>5M€	Very significant impact on overall performance
high	51-70%	3-6 months	1M€-5M€	Significant impact on overall performance
medium	31-50%	1-3 months	501k€-1M€	Some impact in performance of key components
low	11-30%	1-4 weeks	100k€-500k€	Minor impact on overall performance
very low	1-10%	1 week	<100k€	Minor impact on performance of secondary components
nil	<1%	no change	no change	no change in performance

Table 8: Example of definitions for probability and impact

[PMBOK Guide, p. 407]

Risk mitigation. During this step, risk management assesses highest-ranked risks and develops a plan to alleviate them using specific risk controls. These plans include risk mitigation processes, risk prevention tactics and contingency plans in the event the risk comes to fruition.

Risk monitoring. Part of the mitigation plan includes following up on both the risks and the overall plan to continuously monitor and track new and existing risks. The overall risk management process should also be reviewed and updated accordingly.

3 Identify Risks

Project risks need to be identified and documented. All members and stakeholders of the project are encouraged to contribute to this process. Special risk experts may also be invited to this process as well as other persons from outside the project that have experience in risk analysis and management.

3.1 Risk identification

To identify risks various data gathering methods (brainstorming, check lists, or interviews) and data analysis techniques (root cause analysis or SWOT analysis) can be applied. [PMBOK Guide, p. 414/415]

SWOT analysis (strengths, weaknesses, opportunities and threats analysis) is a framework for identifying and analyzing the internal and external factors that can have an impact on the objectives of the project.

The SWOT analysis examines four elements:

- **Strengths**: Internal attributes and resources that support a successful outcome.
- **Weaknesses**: Internal attributes and resources that work against a successful outcome.
- **Opportunities**: External factors that the entity can capitalize on or use to its advantage.
- **Threats**: External factors that could jeopardize the entity's success.

3.2 Risk register

The document produced in this process is the ***risk register***. It captures details of identified project risks. The following processes, Perform Qualitative Risk Analysis, Plan Risk Responses, Implement Risk Responses, and Monitor Risks complement the risk register. [PMBOK Guide, p. 417]

The risk register lists the identified risks as well as risk owners and preliminary risk responses if applicable. **Risk owners** for certain risks can be nominated. They are responsible for monitoring the risks assigned to them and for selecting and implementing appropriate risk response strategies. [PMBOK Guide, p. 411/721]

4 Perform Qualitative Risk Analysis

Qualitative risk analysis produces subjective results because it gathers data from participants in the risk analysis process based on their perceptions of the probability of a risk and the risk's likely consequences. Categorizing risks in this way helps project teams decide which risks can be considered low priority and which have to be actively managed to reduce the impact on the project objectives.

Project risks are prioritized for further analysis or action by assessing their probability of occurrence and impact. Risk perception introduces bias into the assessment of identified risks. Effective assessment requires a careful consideration of the risk attitudes of the key participants in this process. [PMBOK Guide, p. 419/420]

Data analysis techniques applied in this process are:

Risk data quality assessment. It evaluates the degree to which data about project risks are accurate and reliable as basis for qualitative risk analysis.

Risk probability and impact assessment. This assessment considers the likelihood that a specific risk will occur and the potential impact on one or more project objectives.

The results of Perform Qualitative Risk Analysis are recorded in the risk register. In addition, a **probability and impact matrix** can be used to present the probability of each risk occurrence and its impact on project objectives if that risk occurs.

If risks are categorized along more than two parameters, the probability and impact matrix cannot be used. In this case, a bubble chart displays three dimensions of data. Each risk and its impact is plotted as a disk or bubble. The two parameters assigned to the axis can be *detectability* and *proximity*. [PMBOK Guide, p. 425/426]

Proximity is the period of time before the risk might have an impact on one or more project objectives. A short period indicates high proximity.

Detectability is the ease with which results of the risk occurring can be detected and recognized.

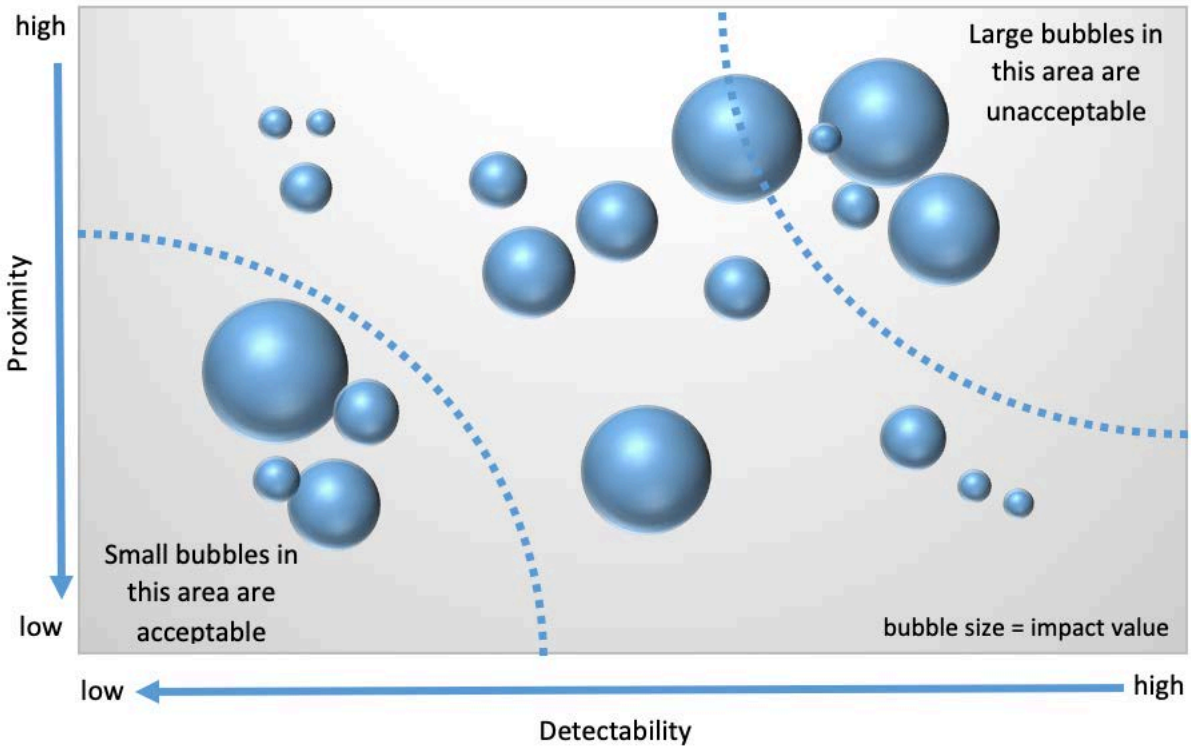


Figure 37: Example of definitions for probability and impact

Further useful parameters are:

Urgency it the period of time within which a risk response needs to be implemented in order to be effective. A short period indicates high urgency.

Dormancy is the period of time that may elapse after a risk has occurred before its impact is discovered.

Controllability is the degree to which the risk owner is able to control the risk's outcome. Where the outcome can be easily controlled, controllability is high.

Strategic impact is the potential of the risk to have positive or negative impact on the organization's strategic goals.

[PMBOK Guide, p. 424]

5 Perform Quantitative Risk Analysis

Quantitative risk analysis numerically analyzes the probability of each risk and its consequences. It attempts to assign a specific financial amount to threats, representing the potential cost to an organization if that risk actually occurs, as well as the likelihood that the risk will occur in a given year.

For example, if the anticipated cost of a significant cyberattack is $10 million and the likelihood of the attack occurring during the current year is 10%, the cost of that risk would be $1 million for the current year.

Quantitative analysis has to thoroughly address uncertainty when duration, cost, or resource requirement for a particular activity or other important parameters of the project may take a range of possible values.

Data analysis techniques applied here can be:

Simulation. A model that simulates the combined effects of project risks to evaluate their potential impact on achieving project objectives. Monte Carlo analysis is a wide-spread used simulation technique. The simulation uses, for instance, the project cost estimates.

Typical outputs include a histogram presenting a cumulative probability distribution (S-curve) of a particular outcome.

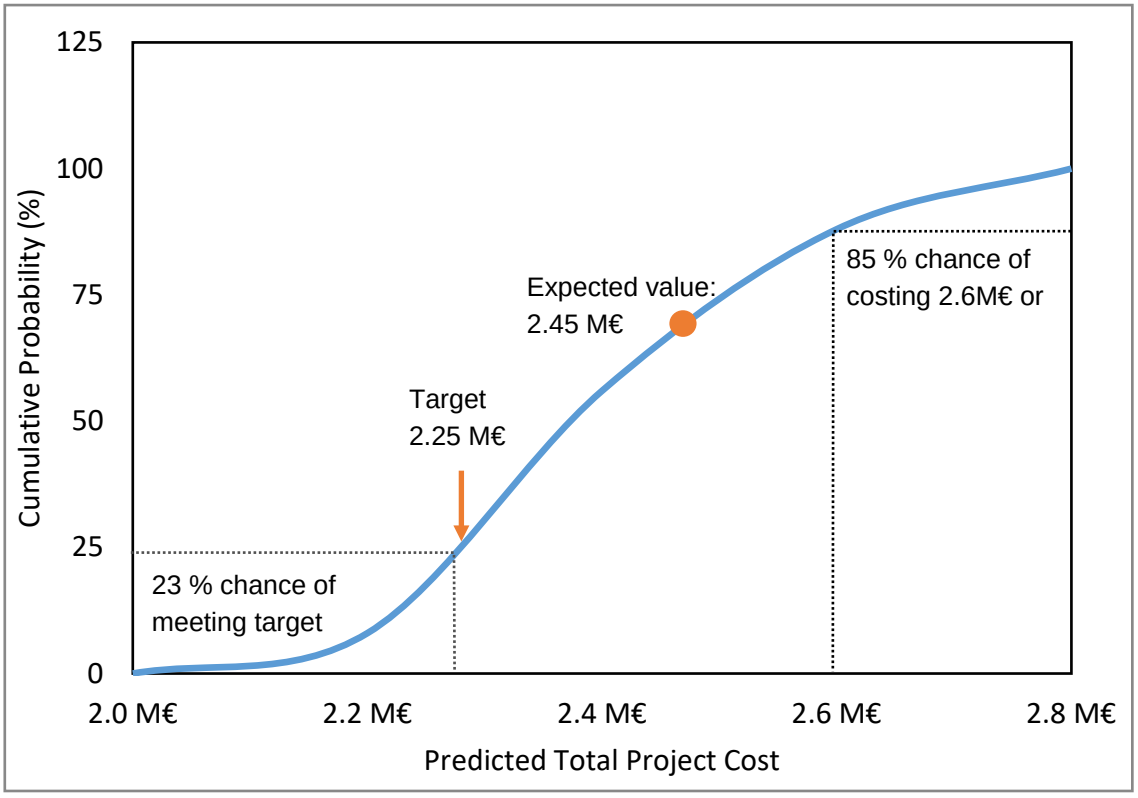


Figure 38: Example S-curve for quantitative cost risk analysis

[PMBOK Guide, p. 433]

Sensitivity analysis. This analysis helps to determine which project risks have the most potential impact on project outcomes. The tornado diagram presents the calculated correlation coefficient for each element of the quantitative risk analysis that can influence the project outcome.

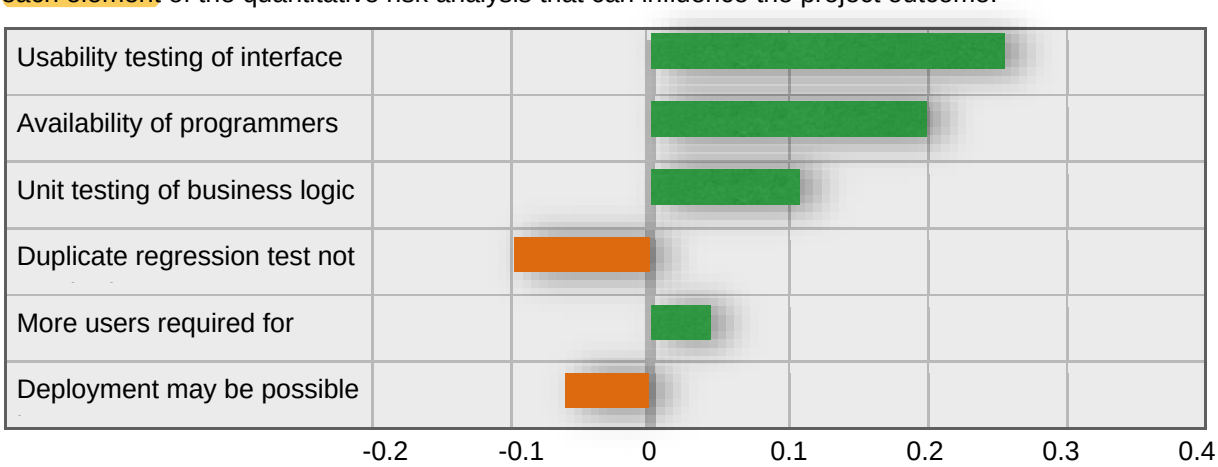


Figure 39: Example tornado diagram

[PMBOK Guide, p. 434]

Decision tree analysis. A decision tree uses a branching method to illustrate every possible outcome of a decision and supports the selection of the best of these outcomes. The end points of branches in the tree represent the outcome from that particular path.

Decision Definition	Decision Node	Chance Node	Net Path Value
Decision to be made	**Input**: Cost of each decision **Output**: Decision made	**Input**: Scenario probability, reward if occurs **Output**: Expected monetary value (EMV)	**Computed**: Payoffs minus costs along path

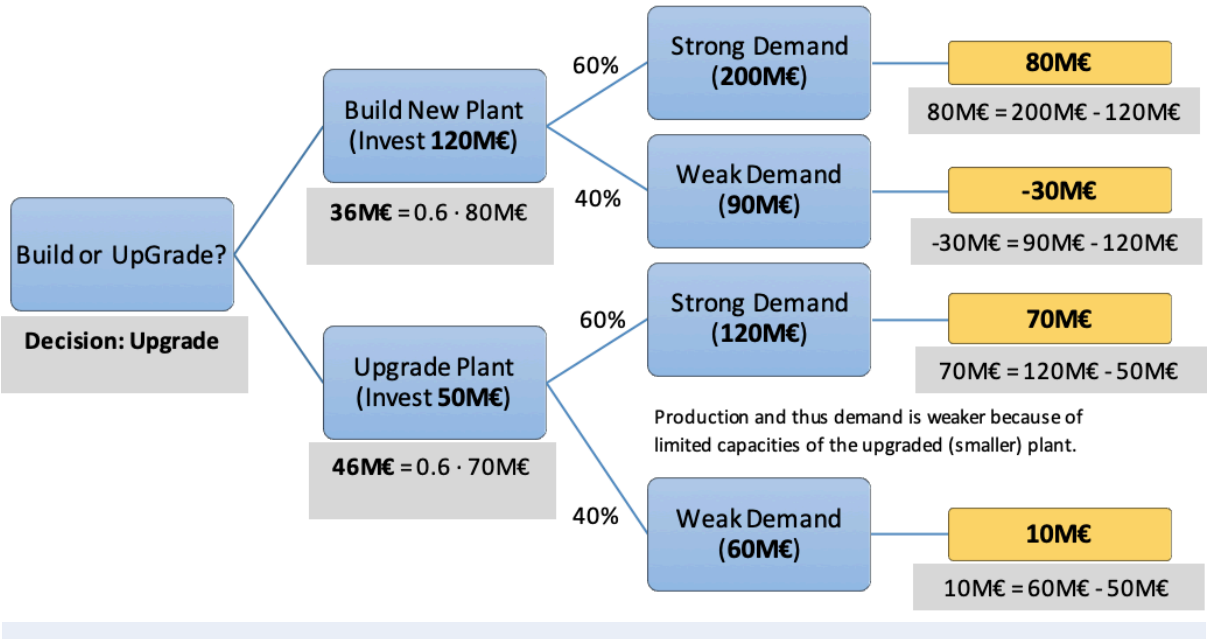


Figure 40: Example of a decision tree

[PMBOK Guide, p. 435]

The results of Perform Quantitative Risk Analysis complement the risk register.

6 Plan Risk Responses

This process is in charge with developing options, selecting strategies, and agreeing on actions to treat project risks.

Effective and appropriate risk responses can minimize threats and maximize opportunities. Once risks have been identified, analyzed, and prioritized, plans should be developed by the risk owner to address every project risk the project team considers important.

A contingency plan (or fallback plan) can be developed for implementation if the selected strategy turns out not to be fully effective or if an accepted risk occurs.

For ***dealing with threats,*** the following strategies can be considered:

- **Avoid**. While the complete elimination of all risk is rarely possible, a risk avoidance strategy is designed to deflect as many threats as possible in order to avoid the costly and disruptive consequences of a damaging event. A risk avoidance methodology attempts to minimize vulnerabilities, which can pose a threat.
- Examples of avoidance actions may include removing the cause of a threat, extending the schedule, or reducing the scope.

- **Escalate** or **Transfer**. The ownership of a threat can also be *escalated* to another department of the organization or *transferred* to a third party that handles the risk and bears the impact if the threat occurs. In both cases, the threat is outside the scope of the project. Risk transfer may involve payment of a risk premium to the party taking on the threat.
- **Mitigate**. This action is taken to reduce the probability of occurrence and/or the impact of a threat. Mitigation is more effective than trying to repair the damage after the threat has occurred.
- Examples are conducting more tests or incrementally developing technically critical or novel solution to gain insights into the technical approach carrying the risk.
- **Accept**. The risk is accepted and no proactive action is taken. Sometimes, projects decide to accept a risk and deal with any potential consequences. Projects will often accept a certain risk that cannot be addressed in a cost-effective way.

  A common active acceptance strategy is to establish a contingency reserve for time, money, or resources to handle the threat if it occurs.

[PMBOK Guide, p. 442/443]

For ***dealing with opportunities*** the following strategies can be considered:

Escalate. This strategy is beneficial when taking the opportunity is significantly outside the scope of the project or exceeds the project's capacities and/or the project manager's authority.

Exploit. Capitalizing on an opportunity means committing to this risk and capturing the benefits associated with. Example: A technical component you planned to produce on your own is suddenly available on the market at a much lower price. It is beneficial to change your make-or-buy decision.

Share. Sometimes, the consequences of an opportunity are shared with project's participants, business departments, or even third parties. Sharing can be beneficial when the opportunity can be better exploited with a partner external to the project. Examples include a joint-venture or a cooperation with a special-purpose company to reduce costs and risks in the development of a special technical component.

Enhance. Enhancing is about increasing the probability and/or impact of opportunity. The project takes measures to increase the chance of the risk happening. Examples of enhancing opportunities include adding more resources to activities when the expected benefits outweigh the costs.

Accept. Accepting an opportunity is simply capitalizing an emergent opportunity with or without taking proactive actions.

[PMBOK Guide, p. 444]

The risk strategies taken are documented in the risk register among other documents.

7 Implement Risk Responses

The risk responses agreed-upon in the previous process are now implemented. This process has to make sure that the planned proactive and corrective actions of the risk response plan are timely taken.

[PMBOK Guide, p. 449]

The actions taken are documented in the risk register and risk reports.

8 Monitor Risks

This process is responsible for monitoring the implementation of agreed-upon risk response plans, tracking identified risks, identifying new risks, and evaluating risk process effectiveness throughout the project.

Continuously monitoring for new, changing, and outdated project risks ensures that the project masters risks appropriately and key stakeholders are aware of the current level of risk exposure.

[PMBOK Guide, p. 453/454]

Monitoring risks may result in change requests to the scope, cost and schedule baseline. Change requests include recommended corrective and proactive actions. They are processed through Perform Integrated Change Control.

Results of this process are mainly documented in risk reports and the risk register.

[PMBOK Guide, p. 457/458]

J Project Procurement Management

In this chapter you learn

Various forms of contractual agreements

How to control procurement

Tools and techniques for procurement

Procurement management includes the processes necessary to purchase or acquire products, services, or results needed from **outside** the project team. It includes development and administration of agreements like contracts, purchase orders, memoranda of agreements (MOAs), or service level agreements (SLAs).

Procurement comes with significant legal obligations and penalties. The project manager is usually not an expert in procurement law. Signing legal agreements binding the organization is reserved to those who have the authority to do so. However, it is the project manager's responsibility to make sure that all procurements meet the specific needs of the project.

The legally binding contracts are usually subject to an extensive approval process, involving the legal department.

Procurement involves agreements that constitute the relationship between two parties—a buyer and a seller. The contract must adequately describe the products, services, or results that the seller is agreeing to provide, while being in compliance with the laws and regulations.

A contract should clearly state the deliverables and results expected, including knowledge transfer, terms and conditions, and probably a procurement statement of work (SOW) as the narrative description of products, services, or results to be delivered.

[PMBOK Guide, p. 461]

Project Procurement Management covers project management activities across the Project Management Process Groups Planning, Executing, and Monitoring & Controlling. Its processes are

[PMBOK Guide, p. 459]:

- **Plan Procurement Management**. Documentation of procurement processes and decisions.
- **Conduct Procurements**. Requesting and obtaining seller responses, selecting sellers, and awarding contracts.
- **Control Procurements**. Managing procurement relationships, monitoring provider performance, managing changes and corrections, and closing contracts.

1 Plan Procurement Management

The procurement management plan describes which goods and services are acquired from outside the project (from other departments of the performing organization or from external sources) and how and when they are acquired.

The plan may describe things like

- General procurement statement of work (SOW)
- Shortlist of qualified sellers
- Preparing and issuing of bid documents
- Performing the cost and quality evaluation of seller proposals
- Negotiating and signing contracts

[PMBOK Guide, p. 468]

Various types of **contractual agreements** are used in procurement management. They can be grouped along three different groups:

- **Fixed-price contract**. Sets a fixed total price for a defined product, service, or result to be provided. Under the fixed-price arrangement, buyers need to precisely specify the product or services being procured.
    - ***Firm Fixed Price Contract (FFP)***. The price for goods is set at the outset and not subject to change unless the scope of work changes. Any cost increase due to adverse performance is the responsibility of the seller.
    - ***Fixed Price Incentive Fee Contract (FPIF)***. Considers financial incentives tied to achieving agreed upon metrics. They are typically related to cost, schedule, or technical performance of the seller. A price ceiling is set. If the final costs are below the ceiling, cost savings a shared between buyer and seller. All costs above the ceiling are the responsibility of the seller.
    - ***Fixed Price with Economic Price Adjustment Contract (FP-EPA)*** is used whenever the seller's performance period spans a considerable period of years. It allows for pre-defined adjustments to the contract price due to changed conditions, such as inflation changes, or cost increases (or decreases) for specific commodities.
- **Cost-reimbursable contract**. It considers all legitimate actual costs incurred for completed work, plus a fee representing seller profit. It provides flexibility to redirect a seller whenever the scope of work cannot be precisely defined at the start and needs to be altered, or when high risks may exist in the effort.
    - ***Cost Plus Fixed Fee Contract (CPFF)***. The seller is reimbursed for all allowable costs for performing the contract work, and receives a fixed-fee payment calculated as a percentage of the initial estimated project costs.
    - ***Cost Plus Incentive Fee Contract (CPIF)***. The seller is reimbursed for all allowable costs for performing the contract work, and receives a predetermined incentive fee based upon achieving certain performance objectives as set forth in the contract. If the final costs are less or greater than the original estimated costs, then the buyer and seller share costs based upon a pre-negotiated formula, for example, an 60/40 spilt over/under target costs.
    - ***Cost Plus Award Fee Contract (CPAF)***. The seller is reimbursed for all legitimate costs, but the majority of the fee is earned only based on the satisfaction of certain broad subjective performance criteria defined and incorporated into the contract.
- **Time and Material Contract (T&M)**. T&M contracts are a hybrid type of contractual arrangement that contain aspects of both cost-reimbursable and fixed-price contracts. They are often used for staff augmentation, acquisition of experts, and any outside support when a precise statement of work cannot be quickly prescribed. Certain parameters can be specified in the contract, such as unit labor or material rates, seller profit, etc.

[PMBOK Guide, p. 471/472]

The procurement plan describes a general roadmap for soliciting services or products from prospective sellers. This includes documents such as bid, tender, or quotation when the seller selection is based on price, or proposal when technical capability or technical approach are the decisive factors.

Depending on the goods or services needed, the bidding documents can include:

- **Request for information (RFI)**. Requests information on the goods and services to be acquired from the sellers.

- **Request for quotation (RFQ)**. Requests information on how vendors satisfy requirements and/or how much it costs.
- **Request for proposal (RFR)**. Proposals address solutions that are not easy to determine.

The buyer structures procurement documents to facilitate an accurate and complete response from each perspective seller and to facilitate easy evaluation of the responses.

[PMBOK Guide, p. 477]

2 Conduct Procurements

Conduct procurements is in charge with requesting bids from sellers, obtaining seller responses, selecting a seller, and awarding a contract. Qualified sellers are selected and legal agreements for delivery are implemented.

Advertising is sometimes used to inform potential sellers about requested products, services, or result. This may extend existing list of preselected sellers if necessary.

Bidder conferences are scheduled when prospective bidders need a clear and common understanding of the procurement and no bidders receive preferential treatment.

3 Control Procurements

Contract performance needs to be monitored, changes and corrections are performed as appropriate, and finally the contracts are closed. Controlling procurements ensures that both the seller's and buyer's performance meet project requirements in accordance to the terms of the legal agreement.

Because of the legal aspect, many organizations treat contract administration as an organizational function that is separate from the project.

Control procurements may cover:

- Collection of data reflecting the physical and financial performance and establishment of procurement performance indicators;
- Refinement of procurement plans and schedules;
- Monitoring the procurement environment so that implementation or adjustments can be facilitated; and
- Payment of invoices.

The independence and credibility of procurement audits are critical to the reliability of the procurement. The organization's code of ethics, its legal counsel, and external legal advisory arrangements including anti-corruption initiatives complete proper procurement controls.

[PMBOK Guide, p. 492/494]

Effectively managing outside suppliers and spending by departments while keeping costs under control and maintaining open communications with employees can be difficult. Increasingly, business executives are using e-procurement software to streamline and automate transactions (with sellers) and create more openness.

3.1 Claims administration

Contested changes are changes where buyer and seller cannot reach an agreement on compensation for the change or cannot agree that a change has occurred. They are also called claims. When they cannot be resolved, they become disputes and finally appeals.

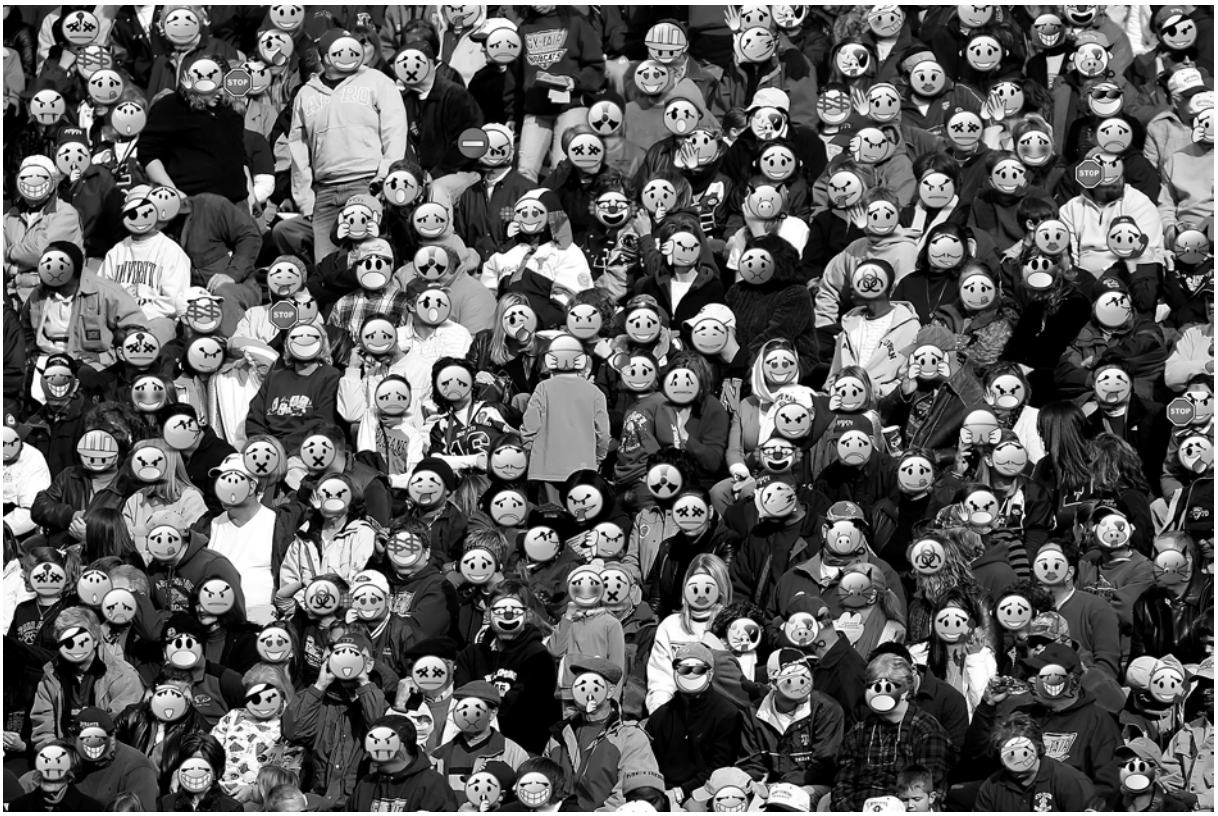
If the parties themselves do not resolve a claim, it may have to be handled in accordance with the alternative dispute resolution (ADR) procedures typically established in the contract. Settlement of all claims and disputes through negotiation is the preferred method.

[PMBOK Guide, p. 498]

3.2 Inspection

An inspection is a structured review of the work being performed by the contractor. Inspections may involve review of deliverables or walkthroughs (of the site of software, for instance) by both the buyer and the contractor to ensure mutual understanding of the work in progress.

[PMBOK Guide, p. 498]



K Project Stakeholder Management

In this chapter you learn

the essentials of stakeholder analysis

purpose and instruments of managing stakeholder engagement

Project Stakeholder Management studies the varying motives and concerns of stakeholders in order to cultivate positive relationships between the stakeholders and the project.

It is concerned with

- identifying people, groups, or organizations that could impact or be impacted by the project,
- analyzing stakeholder expectations and their impact on the project,
- and developing appropriate management strategies for effectively engaging stakeholders in project decisions and execution.

While some stakeholders may have a limited ability to influence the project (in a positive or negative way), others may have significant influence on the project and its expected outcomes. The ability of the project manager to correctly identify and manager these stakeholders in an appropriate manner can mean the difference between success and failure.

The key to effective stakeholder engagement is continuous communication with all stakeholders to understand their needs and expectations, address issues as they occur, manage conflicting interests, and foster appropriate participation of stakeholders in project decisions and activities.

[PMBOK Guide, p. 503-505]

Project Stakeholder Management covers project management activities across the Project Management Process Groups Initiating, Planning, Executing, and Monitoring & Controlling. Its processes are [PMBOK Guide, p. 503]:

- **Identify Stakeholders**. Identifying project stakeholders regularly and analyzing and documenting relevant information regarding their interests, involvement, relationships, influence, and potential impact on the success of the project.
- **Plan Stakeholder Engagement**. Developing strategies and actions to involve project stakeholders based on their needs, expectations, interests, and potential impact one the project.
- **Manage Stakeholder Engagement**. Communicating and working with stakeholders to meet their needs and expectations, address issues, and foster appropriate stakeholder participation.
- **Monitor Stakeholder Engagement**. Monitoring project stakeholder relationships and tailoring strategies for engaging stakeholders through the modification of engagement strategies and plans.

1 Identify Stakeholders

Process of identifying project stakeholders regularly and analyzing and documenting their interests, participation, relationships, influence, and impact on the project success.

A project stakeholder is a person or group who has an interest—vested or otherwise—in the outcome of the project and whose support is required for a project to be successful.

Stakeholders can be internal or external to the project. Internal stakeholders are those within a company whose interest stems from direct employment, ownership or investment. Internal stakeholders include employees, managers, board members, donors and investors.

External stakeholders are those outside of a company who are indirectly affected by the project's decisions and outcomes. External stakeholders include customers, suppliers, government agencies, creditors, labor unions, community groups, and the broad public.

1.1 Stakeholder Analysis

Stakeholder analysis is the process of weighing the demands and influence of stakeholders, then ranking which ones are most likely to influence or be influenced by the project's actions or deliverables. This information is then used to make more balanced and effective business decisions.

The "stakes" of a person can be one or a combination of the following qualities:

Interest. Stakeholders can be affected by the project or its outcomes.

Rights. Legal rights (occupational health and safety, for instance) or moral rights (environmental sustainability or protection of gender equality).

Ownership. Stakeholders that have a legal title to an asset or property related to the project.

Knowledge. Specialist knowledge the project can benefit from.

Contribution. Provision of funds or other resources, including human resources, or providing support for the project in more intangible ways, such as advocacy in the form of promoting the objectives of the project or acting as a buffer between the project and the power structures of the organization and its politics.

[PMBOK Guide, p. 512]

1.2 Stakeholder mapping

Stakeholder mapping is a method of representing stakeholders along various categories.

Power/interest grid, power/influence grid, or impact/influence grid. Each of these relationship parameters are used to depict the stakeholder's level of authority (power), level of concern about project outcomes (interest), ability to influence the project outcomes or the course of the project (influence). [PMBOK Guide, p. 512]

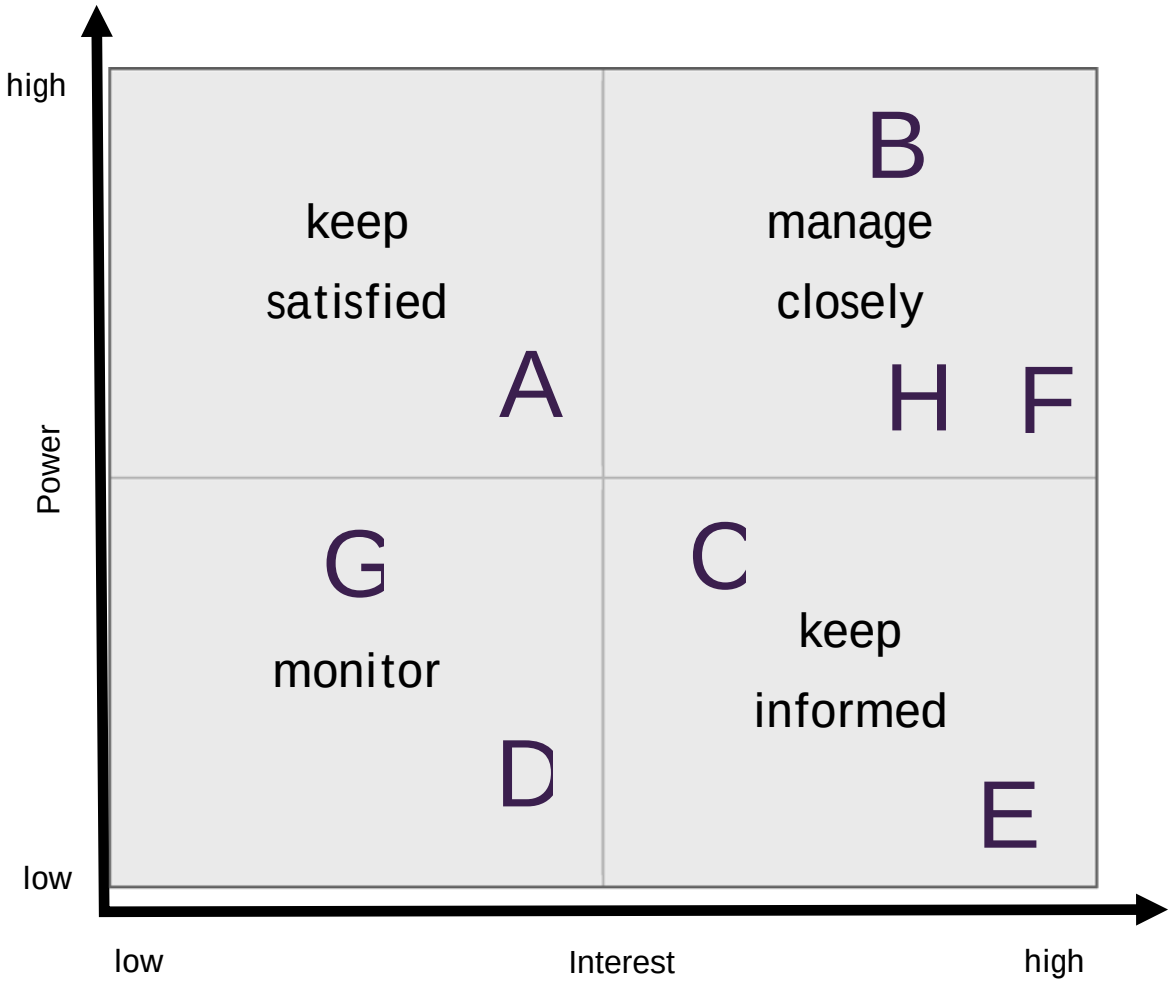


Figure 41: Example of a power/interest grid categorizing the stakeholders A through H.

The **low-power/low-interest** group is the group that the project manager is least concerned with. It shouldn't be completely ignored, but the project manager shouldn't spend too much time communicating with them.

Anyone with **high power** within the organization deserves attention and time, even if this group has **low interest** in the project. This can be a tricky group to deal with, because the project manager wants to ensure they are 'in the loop' while not getting tired of hearing from the project or annoyed by updates on something that just doesn't concern them.

Some stakeholders want to be informed and involved in the project (**high interest**), but just don't have the power to have impact on the project (**low power**). The project manager certainly shouldn't ignore this group, because their high level of interest could make them of use to the project at some point along the way. Providing as much information as possible about the project to these people is important in order to satisfy their interest.

The **high-power/high-interest** group is the group that occupies the bulk of the project manager's time and attention. In order to succeed within almost any organization, the project need to impress and satisfy these people, especially those that are directly responsible for the project work and the results of your projects. The project manager has to make sure that every stakeholder in this part of the grid is getting exactly what she or he needs to remain happy with the progress of the project and the project team. Stakeholders that lie in the Manage Closely quadrant can easily ensure project failure if not managed properly.

1.3 Documentation

The results of Identify Stakeholders are documented in the **stakeholder register**.

2 Plan Stakeholder Management

Development of appropriate management strategies to effectively engage stakeholders throughout the project life cycle, based on the analysis of their needs, interests, and potential impact on project success.

It provides a clear, actionable plan to interact with project stakeholders to support the project's interests.

The stakeholder engagement assessment matrix supports comparison between the current and desired levels of stakeholder engagement.

The engagement of stakeholders can be classified as:

- ***Unaware*** of the project and potential impacts.
- Aware of the project and potential impacts but ***resistant*** to any changes that may occur as a result of the project.
- ***Neutral***. Aware of the project, but neither supportive nor unsupportive.
- Aware of the project and potential impacts and ***supportive*** of the work and its outcomes.
- ***Leading***. Aware of the project and potential impacts and actively engaged in ensuring that the project is a success.

Stakeholder	unaware	resistant	neutral	supportive	leading
Stakeholder 1	C current			D desired	
Stakeholder 2			C	D	
Stakeholder 3				C D	

Table 9: Example of a stakeholder engagement assessment matrix

The gap between "current" and "desired" for each stakeholder directs the level of communication necessary to raise the engagement level for each stakeholder.

[PMBOK Guide, p. 521/522]

3 Manage Stakeholder Engagement

Manage Stakeholder Engagement addresses communicating and working with stakeholders to meet their needs and expectations, address issues as they occur, and foster appropriate stakeholder participation.

It allows the project manager to increase support and minimize resistance from stakeholders, significantly increasing the chances to achieve project success. In the end, the project manager has to ensure that stakeholders understand at all times the project goals, objectives, benefits, risks, and twists, as well as how their contribution will enhance project success.

The results of this process are documented in the stakeholder register and stakeholder engagement plan among other documents.

[PMBOK Guide, p. 523/524]

4 Monitor Stakeholder Engagement

Monitor Stakeholder Engagement addresses monitoring overall project stakeholder relationships and adjusting strategies and plans for engaging stakeholders.

It maintains or increases the efficiency and effectiveness of stakeholder engagement activities as the project evolves and its environment changes.

Monitoring stakeholder engagement may result in change requests that leads to corrective or preventive actions to improve the current level of stakeholder engagement. Change requests are processed for review and disposition through Perform Integrated Change Control.

[PMBOK Guide, p. 530/535]

L References

Project Management Institute, A guide to the project management body of knowledge (PMBOK Guide), Sixth Edition, 2017.

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M Acronyms

AC	Actual cost
BAC	Budget at completion
COQ	Cost of quality
CPAF	Cost plus award fee
CPFF	Cost plus fixed fee
CPI	Cost performance index
CPIF	Cost plus incentive fee
CPM	Critical path method
CV	Cost variance
EAC	Estimate at completion
EF	Early finish date
ES	Early start date
ETC	Estimate to complete
EV	Earned value
EVM	Earned value management
FF	Finish-to-finish
FFP	Fixed firm price
FPEPA	Fixed price with economic price adjustment
FPIF	Fixed price incentive fee
FS	Finish-to-start
IFB	Invitation for bid
LF	Late finish date
LS	Late start date
OBS	Organizational breakdown structure
PDM	Precedence diagramming method
PMBOK	Project management body of knowledge
PV	Planned value
RACI	Responsible, accountable, consult, and inform
RAM	Responsibility assignment matrix
RBS	Risk breakdown structure
RFI	Request for information
RFP	Request for proposal
RFQ	Request for quotation
SF	Start-to-finish
SOW	Statement of work
SPI	Schedule performance index
SS	Start-to-start

SV	Schedule variance
SWOT	Strengths, weaknesses, opportunities, and threats
T&M	Time and material contract
VAC	Variance at completion
WBS	Work breakdown structure

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Q Glossary

Acceptance criteria. A set of conditions that is required to be met before deliverables are accepted.

Accepted deliverables. Products, results, or capabilities produced by a project and validated by the project customer or sponsors as meeting their specified acceptance criteria.

Accuracy. Within the quality management system, accuracy is an assessment of correctness.

Activity. A distinct, scheduled portion of work performed during the course of a project.

Activity duration. The time in calendar units between the start and finish of a schedule activity.

Activity duration estimates. Quantitative assessments of the likely number of time periods that are required to complete an activity.

Activity list. Table of schedule activities that shows the activity description, activity identifier, and a sufficiently detailed scope of work description.

Actual cost. The realized cost incurred for the wort performed on an activity during a specific time period.

Adaptive life cycle. A project life cycle that is iterative or incremental.

Affinity diagrams. A technique that allows large numbers of ideas to be classified into groups for review and analysis.

Agreements. Any document or communication that defines the initial intentions of a project. This can take the form of a contract, memorandum of understanding (MOU), letter of agreement, etc.

Alternative analysis. Technique used to evaluate identified options in order to select the options or approaches to use for executing and performing the work of the project.

Analogous estimating. Technique for estimating the duration or cost of an activity or a project using historical data from a similar activity or project.

Assumption log. Project document used to recall all assumptions and constraints throughout the project life cycle.

Attribute sampling. Method of measuring quality that consists of noting the presence (or absence) of some characteristic (attribute) in each of the units under consideration.

Authority. The right to apply project resources, expend funds, make decisions, or give approvals.

Backward pass. Critical path method technique for calculating the late start and late finish dates by working backward through the schedule model from the project end date.

Baseline. Approved version of a work product that can be changed only through formal change control procedures and is used as a basis for comparison to actual results.

Bottom-up estimating. Method of estimating project duration or cost by aggregating the estimates of the lower-level components of the work breakdown structure (WBS).

Budget at Completion. The sum of all budgets established for the work to be performed.

Business Case. Documented economic feasibility study used to establish validity of the benefits of a selected component lacking sufficient definition and that is used as a basis for the authorization of further project management activities.

Cause-and-effect diagram. Composition technique that helps trace an undesirable effect back to its root cause.

Change control. Process whereby modifications to documents, deliverables, or baselines associated with the project are identified, documented, approved, or rejected.

Change Control System. Set of procedures that describes how modifications to the project deliverables and documentation are managed and controlled.

Change log. Comprehensive list of changes submitted during the project and their current status.

Change management plan. Component of the project management plan that documents the extent of its authority, and describes how the change control system will be implemented.

Change request. Formal proposal to modify a document, deliverable, or baseline.

Claim. Request, demand, or assertion of rights by a seller against a buyer, or vice versa, for consideration, compensation, or payment under the terms of a legally binding contract, such as for a disputed change.

Code of accounts. Numbering system used to uniquely identify each component of the work breakdown structure (WBS).

Colocation. Organizational placement strategy where the project team members are physically located close to one another in order to improve communication, working relationships, and productivity.

Communication method. Systematic procedure, technique, or process used to transfer information among project stakeholders.

Communication model. Description, analogy, or schematic used to represent how the communication process will be performed for the project.

Configuration management plan. Component of the project management plan that describes how to identify and account for project artifacts under configuration control, and how to record and report changes to them.

Conformance. Within the quality management system, conformance is a general concept of delivering results that fall within the limits that define acceptable variation for a quality requirement.

Contingency. Event or occurrence that could affect the execution of the project that may be accounted for with a reserve.

Contingency reserve. Time or money allocated in the schedule or cost baseline for known risks with active response strategies.

Contingent response strategies. Responses provided which may be used in the event that a specific trigger occurs.

Control account. Management control point where scope, budget, actual cost, and schedule are integrated and compared to earned value for performance measurement.

Control costs. Process of monitoring the status of the project to update the project costs and manage changes to the cost baseline.

Control limits. The area composed of three standard deviations on either side of the centerline or mean of a normal distribution of data plotted on a control chart, which reflects the expected variation in the data.

Corrective action. Intentional activity that realigns the performance of the project work with the project management plan.

Cost aggregation. Summing the lower-level cost estimates associated with the various work packages for a given level within the project's WBS or for a given cost control account.

Cost baseline. Approved version of the time-phased project budget, excluding any management reserves, which can be changed only through formal change control procedures and is used as a basis for comparison to actual results.

Cost-benefit analysis. Financial analysis tool used to determine the benefits provided by a project against its costs.

Cost of quality. All costs incurred over the life of the product by investment in preventing nonconformance to requirements, appraisal of the product or service for conformance to requirements, and failure to meet requirements.

Cost performance index. Measure of the cost efficiency of budgeted resources expressed as the ration of earned value to actual cost.

Cost variance. Amount of budget deficit or surplus at a given point in time, expressed as the difference between the earned value and the actual cost.

Crashing. Technique used to shorten the schedule duration for the least incremental cost by adding resources.

Critical path. Sequence of activities that represents the longest path through a project, which determines the shortest possible duration.

Critical path method. Method used to estimate the minimum project duration and determine the amount of schedule flexibility on the logical network paths within the schedule model.

Decision tree analysis. Diagramming and calculation technique for evaluating the implications of a chain of multiple options in the presence of uncertainty.

Decomposition. Technique used for dividing and subdividing the project scope and project deliverables into smaller, more manageable parts.

Defect. Imperfection or deficiency in a project component where that component does not meet its requirements or specifications and needs to be either repaired or replace.

Defect repair. Intentional activity to modify a nonconforming product or product component.

Deliverable. Any unique and verifiable product, result, or capability to perform a service that is required to be produced to complete a process, phases, or project.

Diagramming techniques. Approaches to presenting information with logical linkages that aid in understanding.

Discretionary dependency. Relationship that is established based on knowledge of best practices within a particular application area or an aspect of the project where a specific sequence is desired.

Early finish date. In the critical path method, the earliest possible point in time when the uncompleted portions of a schedule activity can finish based on its date, the schedule network logic and any schedule constraints.

Early start date. In the critical path method, the earliest possible point in time when the uncompleted portions of a schedule activity can start based on its date, the schedule network logic and any schedule constraints.

Earned value. The measure of work performed expressed in terms of the budget authorized for that work.

Emotional intelligence. Ability to identify, assess, and manage the personal emotions of oneself and other people as well as the collective emotions of groups of people.

Enterprise environmental factors. Conditions, not under the immediate control of the team, that influence, constrain, or direct the project, program, or portfolio.

Estimate at completion. The expected total cost of completing all work expressed as the sum of the actual cost to date and the estimate to complete.

Estimate to Complete. Expected cost to finish all the remaining project work.

Expert judgement. Judgment provided based upon expertise in an application area, knowledge area, discipline, industry, etc. as appropriate for the activity being performed. Such expertise may be provided by any group or person with specialized education, knowledge, skill, experience, or training.

External dependency. Relationship between project activities and non-project activities.

Fallback plan. Alternative set of actions and tasks available in the event that the primary plan needs to be abandoned because of issues, risks, or other causes.

Fast tracking. Schedule compression technique in which activities or phases normally done in sequence are performed in parallel for at least a portion of their duration.

Float. Also called slack. *See total float and free float*

Flowchart. Depiction in a diagram format of the inputs, process actions, and outputs of one or more processes within a system.

Focus group. Elicitation technique that brings together prequalified stakeholders and subject matter experts to learn about their expectations and attitudes about a proposed product, service, or result.

Forward pass. Critical path method technique for calculating the early start and early finish dates by working forward through the schedule model from the project start date or a given point in time.

Free float. Amount of time that a schedule activity can be delayed without delaying the early start date of any successor or violating a schedule constraint.

Funding limit reconciliation. The process of comparing the planned expenditure of project funds against any limits on the commitment of funds for the project to identify any variances between the funding limits and the planned expenditures.

Grade. Category or rank used to distinguish items that have the same functional use but do not share the same requirements for quality.

Ground rules. Expectations regarding acceptable behavior by project team members.

Imposed date. Fixed date imposed on a schedule activity or schedule milestone, usually in the form of a “start no earlier than” and “finish no later than”.

Independent estimates. Process of using third party to obtain and analyze information to support prediction of cost, schedule, or other items.

Influence diagram. Graphical representation of situations showing causal influences, time ordering of events, and other relationships among variables and outcomes.

Inspection. Examination of a work product to determine whether it conforms to documented standards.

Interpersonal skills. Skills used to establish and maintain relationships with other people.

Interviews. Formal or informal approach to elicit information from stakeholders by talking to them directly.

Issue log. Project document where information about issues is recorded and monitored.

Lag. Amount of time whereby a successor activity will be delayed with respect to a predecessor activity.

Late finish date. In the critical path method, the latest possible point in time when the uncompleted portions of a schedule activity can finish based on its date, the schedule network logic and any schedule constraints.

Late start date. In the critical path method, the latest possible point in time when the uncompleted portions of a schedule activity can start based on its date, the schedule network logic and any schedule constraints.

Lead. Amount of time whereby a successor activity can be advanced with respect to a predecessor activity.

Logical relationship. Dependency between two activities, or between an activity and a milestone.

Make-or-buy analysis. Process of gathering and organizing data about product requirements and analyzing them against available alternatives including the purchase or internal manufacture of the product.

Make-or-buy decision. Decisions made regarding the external purchase or internal manufacture of a product.

Management reserve. Amount of the project budget or project schedule held outside of the performance measurement baseline for management control purposes, that is reserved for unforeseen work that is within scope of the project.

Mandatory schedule. Relationship that is contractually required or inherent in the nature of the work.

Matrix diagram. Quality management and control tool used to perform data analysis within the organizational structure created in the matrix. The matrix diagram seeks to show the strength of relationships between factors, causes, and objectives that exist between the rows and columns that form the matrix.

Milestone. Significant point or event in a project, program or portfolio.

Mind-mapping. Technique used to consolidate ideas created through individual brainstorming sessions into a single map to reflect commonality and differences in understanding and to generate new ideas.

Monte Carlo simulation. Analysis technique where a computer model is iterated many times, with the input values chosen at random for each iteration driven by the input data, including probability distributions and probabilistic branches. Outputs are generated to represent the range of possible outcomes for the project.

Multicriteria decision analysis. This technique utilizes a decision matrix to provide a systematic analytical approach for establishing criteria, such as risk levels, uncertainty, and valuation, to evaluate and rank many ideas.

Network logic. All activity dependencies in a project schedule network diagram.

Nominal group technique. Technique that enhances brainstorming with a voting process used to rank the most useful ideas for further brainstorming or for prioritization.

Opportunity. Risk that would have a positive effect on one or more project objectives.

Organizational breakdown structure. Hierarchical representation of the project organization, which illustrates the relationship between project activities and the organizational units that will perform those activities.

Organizational learning. Discipline concerned with the way individuals, groups, and organizations develop knowledge.

Organizational process assets. Plans, processes, policies, procedures, and knowledge bases that are specific to and used by the performing organization.

Overall project risk. Effect of uncertainty on the project as a whole, arising from all sources of uncertainty including individual risks, representing the exposure of stakeholders to the implications of variations in project outcome, both positive and negative.

Parametric estimating. Estimating technique in which an algorithm is used to calculate cost or duration based on historical data and project parameters.

Performance measurement baseline. Integrated scope, schedule, and cost baselines used for comparison to manage, measure, and control project execution.

Performance reviews. Technique that is used to measure, compare, and analyze actual performance of work in progress on the project against the baseline.

Perform Integrated Change Control. The process of reviewing all change requests; approving changes and managing changes to deliverables, organizational process assets, project documents, and the project management plan; and communicating the decisions.

Phase gate. Review at the end of a phase in which a decision is made to continue to the next phase, to continue with modification, or to end a project or program.

Planned value. The authorized budget assigned to scheduled work.

Planning package. Work breakdown structure component below the control account with known work content but without detailed schedule activities.

Plurality. Decisions made by the largest block in a group, even if a majority is not achieved.

Precedence diagramming method. Technique used for constructing a schedule model in which activities are represented by nodes and are graphically linked by one or more logical relationships to show the sequence in which the activities are to be performed.

Precedence relationship. Logical dependency used in the precedence diagramming method.

Preventive action. Intentional activity that ensures the future performance of the project work is aligned with the project management plan.

Probability and impact matrix. Grid for mapping the probability of occurrence of each risk and its impact on project objectives if that risk occurs.

Procurement audits. Review of contracts and contracting processes for completeness, accuracy, and effectiveness.

Product analysis. For projects that have a product as a deliverable, it is a tool to define scope that generally means asking questions about a product and forming answers to describe the use, characteristics, and other relevant aspects of what is going to be manufactured.

Product scope. Features and functions that characterize a product, service, or result.

Progressive elaboration. Iterative process of increasing the level of detail in a project management plan as greater amounts of information and more accurate estimates become available.

Project charter. Document issued by the project initiator or sponsor that formally authorizes the existence of a project and provides the project manager with the authority to apply organizational resources to project activities.

Project funding requirements. Forecast project costs to be paid that are derived from the cost baseline for total or periodic requirements, including projected expenditures plus anticipated liabilities.

Project governance. Framework, functions, and processes that guide project management activities in order to create a unique product, service, or result to meet organizational, strategic, and operational goals.

Project management knowledge area. Identified area of project management defined by its knowledge requirements and described in terms of its component processes, practices, inputs, outputs, tools, and techniques.

Project management office. Management structure that standardizes the project-related governance processes and facilities the sharing of resources, methodologies, tools, and techniques.

Project management process group. Logical grouping of project management inputs, tools and techniques, and outputs. The project management process groups include initiating processes, planning processes, executing processes, monitoring and controlling processes, and closing processes. Project management process groups are not phases.

Project organization chart. Document that graphically depicts the project team members and their interrelationships for a specific project.

Project phase. Collection of logically related project activities that culminates in the completion of one or more deliverables.

Project scope. Work performed to deliver a product, service, or result with the specified features and functions.

Project scope statement. Description of the project scope, major deliverables, assumptions, and constraints.

Proposal evaluation techniques. Process of reviewing proposals provided by suppliers to support contract award decisions.

Quality. Degree to which a set of inherent characteristics fulfills requirements.

Quality audits. A quality audit is a structured, independent process to determine if project activities comply with organizational and project policies, processes, and procedures.

Quality metrics. Description of a project or product attribute and how to measure it.

Quality policy. A policy specific to the project quality management knowledge area, it establishes the basic principles that should govern the organization's actions as it implements its system for quality management.

Quality requirement. Condition or capability that will be used to assess conformance by validating the acceptability of an attribute for the quality of a result.

Questionnaires. Written sets of questions designed to quickly accumulate information from a large number of respondents.

Regression analysis. Analytical technique where a series of input variables are examined in relation to their corresponding output results in order to develop a mathematical or statistical relationship.

Regulations. Requirements imposed by a governmental body. These requirements can establish product, process, or service characteristics, including applicable administrative provisions that have government-mandated compliance.

Requirement. Condition or capability that is necessary to be present in a product, service, or result to satisfy a business need.

Requirements traceability matrix. Grid that links product requirements form their origin to the deliverables that satisfy them.

Reserve. Provision in the project management plan to mitigate cost and/or schedule risk. Often used with a modifier (e.g. management reserve, contingency reserve to provide further detail on what types of risk are meant to be mitigated.

Reserve analysis. Analytical technique to determine the essential features and relationships of components in the project management plan to establish a reserve for the schedule duration, budget, estimated cost, or funds for a project.

Residual risk. The risk that remains after risk responses have been implemented.

Resource breakdown structure. Hierarchical representation of resources by category and type.

Resource leveling. Resource optimization technique in which adjustments are made to the project schedule to optimize the allocation of resources and which may affect critical path.

Resource optimization technique. Technique in which activity start and finish dates are adjusted to balance demand for resources with the available supply.

Resource smoothing. Resource optimization technique in which free and total float are used without affecting the critical path.

Responsibility assignement matrix. Grid that shows the project resources assigned to each work package.

Rework. Action taken to bring a defective or nonconforming component into compliance with requirements or specifications.

Risk. Uncertain event or condition that, if it occurs, has a positive or negative effect on one or more project objectives.

Risk acceptance. Risk response strategy whereby the project team decides to acknowledge the risk and not take any action unless the risk occurs.

Risk appetite. The degree of uncertainty an organization or individual is willing to accept in anticipation of a reward.

Risk audit. Type of audit used to consider the effectiveness of the risk management process.

Risk avoidance. Risk response strategy whereby the project team acts to eliminate the threat or protect the project from its impact.

Risk breakdown structure. Hierarchical representation of potential sources of risks.

Risk enhancement. Risk response strategy whereby the project team acts to increase the probability of occurrence or impact of an opportunity.

Risk escalation. Risk response strategy whereby the team acknowledges that a risk is outside of its sphere of influence and shifts ownership of the risk to a higher level of the organization where it is more effectively managed.

Risk exploiting. Risk response strategy whereby the project team acts to ensure that an opportunity occurs.

Risk exposure. An aggregate measure of the potential impact of all risks at any given point in time in a project, program, or portfolio.

Risk mitigation. Risk response strategy whereby the project team acts to decrease the probability of occurrence or impact of a threat.

Risk owner. The person responsible for monitoring the risks and for selecting and implementing an appropriate risk response strategy.

Risk review. Meeting to examine and document the effectiveness of risk responses in dealing with overall project risk and with identified individual project risks.

Risk sharing. Risk response strategy whereby the project team allocates ownership of an opportunity to a third party who is best able to capture the benefit of that opportunity.

Risk threshold. The level of risk exposure above which risks are addressed and below which risks may be accepted.

Risk transference. Risk response strategy whereby the project team shifts the impact of a threat to a third party, together with ownership of the response.

Roll wave planning. An iterative planning technique in which the work to be accomplished in the near term is planned in detail, while the work in the future is planned at a higher level.

Root cause analysis. Analytical technique used to determine the basic underlying reason that causes a variance or a defect or a risk. A root cause may underlie more than one variance or defect or risk.

Schedule baseline. The approved version of a schedule model that can be changed using formal change control procedures and is used as the basis for comparison to actual results.

Schedule compression. Technique used to shorten the schedule duration without reducing the project scope.

Schedule network analysis. Technique to identify early and late start dates, as well as early and late finish dates, for the uncompleted portions of project activities.

Schedule performance index. Measure of schedule efficiency expressed as the ratio of earned value to planned value.

Schedule variance. Measure of schedule performance expressed as the difference between the earned value and the planned value.

Scope baseline. The approved version of a scope statement, work breakdown structure (WBS), and its associated WBS dictionary, that can be changed using the formal change control procedures and is used as a basis for comparison to actual results.

Scope creep. The uncontrolled expansion to product or project scope without adjustments to time, cost, and resources.

Secondary risk. A risk that arises as a direct result of implementing a risk response.

Self-organizing team. Team formation where the team functions with an absence of centralized control.

Sensitivity analysis. An analysis technique to determine which individual project risk or other sources of uncertainty have the most potential impact on project outcomes, by correlating variations in project outcomes with variations in elements of a quantitative risk analysis model.

Service level agreement. Contract between a service provider (either internal or external) and the end user that defines the level of service expected from the service provider.

Simulation. Analytical technique that models the combined effect of uncertainties to evaluate their potential impact on objectives.

Stakeholder. Individual, group, or organization that may affect, be affected by, or perceive itself to be affected by a decision, activity, or outcome of a project, program, or portfolio.

Stakeholder engagement assessment matrix. Matrix that compares current and desired stakeholder engagement levels.

Start-to-finish. Logical relationship in which a successor activity cannot finish until a predecessor activity has started.

Start-to-start. Logical relationship in which a successor activity cannot start until a predecessor activity has started.

Statement of Work. A narrative description of products, services, or results to be delivered by the project.

SWOT analysis. Analysis of strengths, weaknesses, opportunities, and threats of an organization, project, or option.

Tacit knowledge. Personal knowledge that can be difficult to articulate and share such as beliefs, experience, and insights.

Team charter. A document that records the team values, agreements, and operating guidelines, as well as establishing clear expectations regarding acceptable behavior by project team members.

Threat. A risk that would have a negative effect on one or more project objectives.

Three-point estimating. Technique used to estimate cost or duration by applying an average or weighted average of optimistic, pessimistic, and most likely estimates when there is uncertainty with the individual activity estimates.

Threshold. Predetermined value of a measurable project variable that represents a limit that requires action to be taken if it is reached.

To-complete performance index. Measure of the cost performance that is required to be achieved with the remaining resources in order to meet a specified management goal, expressed as the ratio of the cost to finish the outstanding work to the remaining budget.

Tolerance. The quantified description of acceptable variation for a quality requirement.

Tornado diagram. Special type of bar chart used to in sensitivity analysis for comparing the relative importance of the variables.

Total float. Amount of time that a schedule activity can be delayed or extended from its early start date without delaying the project finish date or violating s schedule constraint.

Trend analysis. Analytical technique that uses mathematical models to forecast future outcomes based on historical results.

Trigger condition. Event or situation that indicates that a risk is about to occur.

Unanimity. Agreement by everyone in the group on a single course of action.

Validation. The assurance that a product, service, or result meets the needs of the customer and other identified stakeholders.

Variance analysis. Technique for determining the cause and degree of difference between the baseline and actual performance.

Variance at completion. Projection of the amount of budget deficit or surplus, expressed as the difference between the budget at completion and the estimate at completion.

Verification. The evaluation of whether or not a product, service, or result complies with a regulation, requirement, specification, or imposed condition.

Verified deliverables. Completed project deliverables that have been checked and conformed to correctness through the control quality process.

WBS dictionary. Document that provides detailed deliverable, activity, and scheduling information about each component in the work breakdown structure.

What-if scenario analysis. Process of evaluating scenarios in order to predict their effect on project objectives.

Work performance data. The raw observations and measurements identified during activities being performed to carry out the project work.

Work performance information. The performance data collected from controlling processes, analyzed in comparison with project management plan components, project documents, and other work performance information.

Work performance reports. The physical or electronic representation of work performance information compiled in project documents, intended to generate decisions, actions, or awareness.