Guides for managing innovation

Part II: Project management

Catalunya Innovació

Generalitat de Catalunya
CIDEM

Catalunya Innovació

INNOVATION MANAGEMENT GUIDE

PART II: PROJECT MANAGEMENT

Generalitat de Catalunya
CIDEM

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“If the rate of change in the marketplace is greater than your rate of change, the end for your company is near. It’s just a question of when.”

Jack Welch
Former President of General Electric

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THE INNOVATION PROCESS INVOLVES CONSTANT INTERPLAY BETWEEN DIAGNOSIS AND STRATEGY, AND BETWEEN CREATIVITY AND FOCUS, AIMED AT CONTINUOUSLY GENERATING FUTURE PROJECTS

1 INNOVATION WITHIN THE COMPANY

In most companies, innovation is without a doubt one of the least-structured processes and this is especially true in the case of SMEs. Companies which usually have no problem identifying steps in processes that fall within their immediate work cycle (such as invoicing, receiving raw materials and repairing machinery) rarely find the time or resources to define an aspect as important as how the company can be fine-tuned to compete in the markets of tomorrow. We cannot simply suppose things will stay as they are, and the rate of change in technology and markets makes innovation a powerful business process that ought to be at the heart of all public policy-making and business-management systems in the 21st century.

Managers and members of the technical staff often struggle to define “innovation” precisely and find it difficult to specify which activities fall within its scope and which do not. From a **legal** point of view, and for tax purposes, innovation is considered to be **“that activity which aims to obtain new products1 or production processes, or significant technological improvements. New products or processes should be considered as those whose characteristics or uses are significantly different from existing ones2 from a technologic point of view”.**

Nonetheless, from a **business-management** point of view, innovation is a **process (a set of systematic activities) which aims to obtain competitive advantages by incorporating scientific, technological or organizational improvements, or advances in knowledge or design into a company’s products, services or ways of operating.**

Innovation arises out of a company’s desire to stand out from the competition by seeking new ways of doing things, different lines of action that involve introducing new technologies (technological innovation), new organizational structures, new aesthetic values and ease-of-use criteria (design) or new ways of gaining and using internal know-how (knowledge management).

Innovation arises out of a company’s desire to stand out from the competition by seeking new ways of doing things, different lines of action that involve introducing new technologies (technological innovation), new organizational structures, new aesthetic values and ease-of-use criteria (design) or new ways of gaining and using internal know-how (knowledge management).

1. UNE-EN 9000:2000 recognizes four general product categories: processed materials, machinery, programming and services, or any combination of these.
2. See the guide *Nous incentius per innovar*, CIDEM, 2001.

1.1. Implementing an innovation process in a company

As the market and the technological environment in which a company operates become more difficult to predict, a company must regularly make time to define future lines of action. This exercise is key to the innovation process and consists of four basic steps:

1- Organizing and assigning responsibilities: The innovation process has to involve all the organization's departments and personnel. Someone, however, **has to lead the process.** Someone has to be responsible for putting forward and developing innovation projects in the company and given a deadline to achieve results.

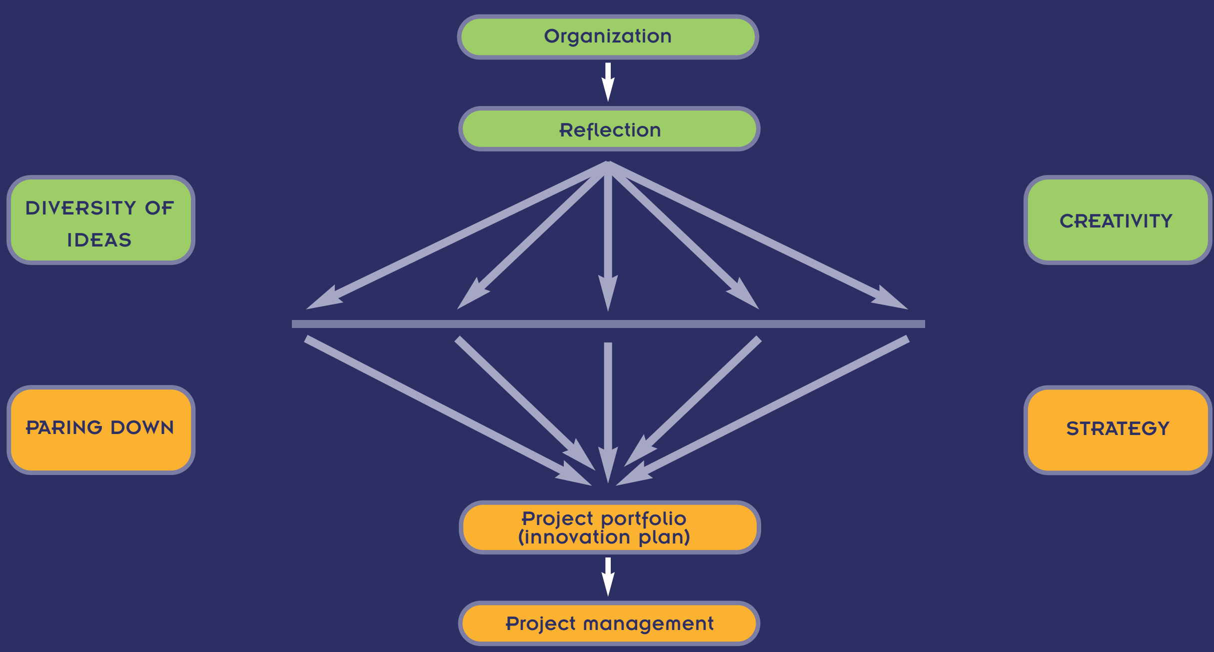
2- Self-diagnosis: An analysis of the organization's capacity for innovation. This involves reviewing the company's ways of operating and detecting opportunities for improvements based on the best practices of innovative companies.

3- Strategy: An analysis of future scenarios foreseen for the company and a commitment to one or more of them to channel resources aimed at innovation projects.

4- Execution of innovation projects: Once the starting point and predicted future scenario have been selected, the projects that come out of this process have to be efficiently selected and executed. This phase of the process is an exercise in efficient project management.

After the diagnosis of the current situation, there follows a creative stage, where the aim is to brainstorm for ideas for the future not restricted to the scope of the company's usual business, and then a strategic component (focus) to select those ideas (innovation projects) in line with the vision the company has of the future. It is, consequently, a process with a stage in which ideas are diversified followed by a stage in which they are pared down. Represented graphically, it takes the form of a "diamond".

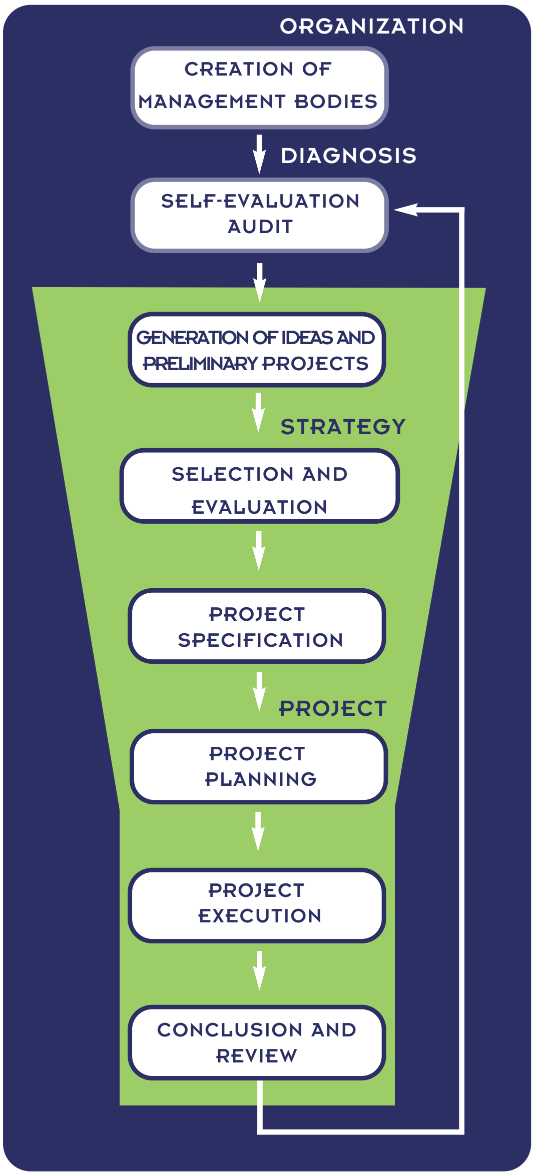
THE INNOVATION DIAMOND



1.2. Innovation projects

The process of internal reflection3 (self-diagnosis) provides a snapshot of the current state of the company's innovation process and enables its situation to be compared with ideal practices. The process of carrying out this audit requires a special effort by the organization, regardless of whether it is done by a small group of managers or by a specially created multidisciplinary team. In either case, the very act of carrying out this process allows those involved to tackle a series of ideas and preconceptions on how to manage innovation within the company. Some suggestions for change may also be put forward.

The aim of carrying out a self-diagnosis is for the company's managers and technical staff to share and discuss different points of view in order to detect the organization's capacity for innovation.



This will be the starting point for expanding on the four steps of the innovation process (organization, diagnosis, strategy and projects). These four steps, in turn, can be broken down into the stages shown in the figure, which shows the project's life cycle and will be used for the development of this guide. It should be noted that some of the stages are repeated and it is often necessary to redefine them depending what comes after them.

The first stage in the process is the designation of a working team (an R&D&I management unit4 or innovation committee) responsible for encouraging the generation of ideas and the selection, execution and subsequent review and improvement of management procedures for the company's innovation projects.

This team first carries out the innovation self-diagnosis (audit) with the aim of detecting deviations between the current situation and the one desired and creating opportunities for improvement.

Innovative ideas are then generated to come up with answers to the problems and opportunities considered before. CREATIVE CAPACITY is paramount in this phase.

These ideas generate projects that will be evaluated and selected according to different criteria. Some of them will go through to the specification stage and then

3. *Guia per gestionar la innovació,* CIDEM, 1999.
4. UNE 166000.

to the planning stage, leading to their implementation /execution. STRATEGIC CAPACITY is vital in the selection phase, as is EFFICIENCY in the execution phase.

Finally, the project is concluded and revised to document the positive and negative aspects of each stage, with the aim of creating an organization capable of learning from its own experience.

The projects pass through each stage in process and become progressively filtered, represented by the green funnel in the diagram. A high level of activity along this funnel means the strategic innovation system is working well.

Sometimes initial projects aim at organizational development to simply manage the innovation process better. They seek to create a structure to allow for the creation of subsequent projects, such as creating an R&D Department, a Marketing Department, a multidisciplinary industrialization team or a procedure to stimulate new ideas.

Therefore, applying the audit model provides:

a) An idea of the processes in which the company has more or less potential for innovation.An idea of the processes in which the company has more or less potential for innovation.

b) A portfolio of modifications to the structure, with the aim of acquiring the organizational capacity required to consistently manage, analyse and develop innovation projects

A portfolio of modifications to the structure, with the aim of acquiring the organizational capacity required to **consistently** manage, analyse and develop innovation projects

c) A new perspective on the company and an initial notion of possible projects to develop.

The most important aim of the diagnosis process is to get the heads of different departments to arrange regular meetings to reach agreements on the current and future model of the company.

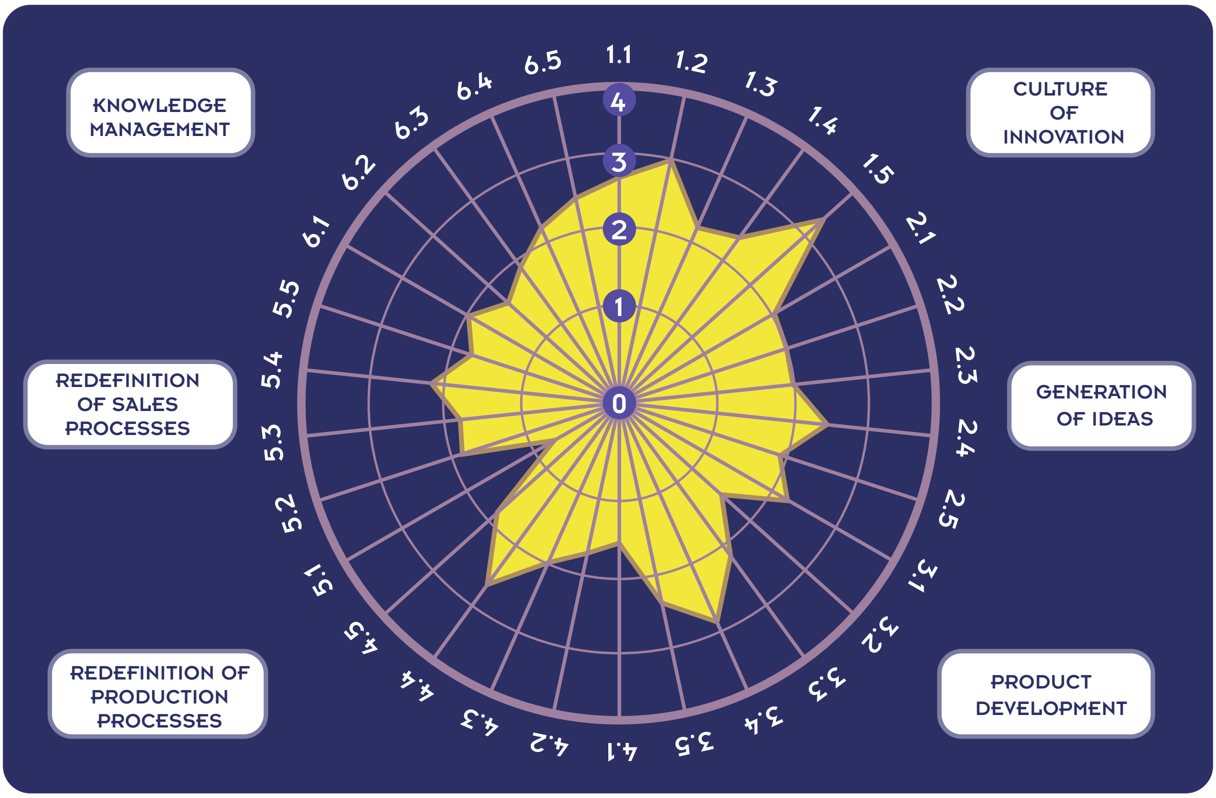
Example

This is the initial diagnosis5 from a machinery manufacturer, obtained following a series of meetings of its managers.

The self-diagnosis was first carried out individually and then the different points of view were shared with the group.

One of the most alarming aspects to emerge was the lack of processes that encouraged the generation of new ideas and the fact that, although technology in the industry had evolved significantly, the company had been producing the same machinery for the past five years.

In conclusion, new projects were launched aimed at overcoming these weaknesses, including the creation of a procedure for gathering, selecting and evaluating employees' ideas (which was then included in the ISO quality manual), creating a team to analyse the value of these ideas and a working group to organize the information on technology and customer trends. Everyone attending trade fairs would have to give a public presentation of their experience.



5.*Guia per gestionar la innovació*, CIDEM, 1999.

1.3. THE FOUR INNOVATION VECTORS

Diagnosis is only the first step. The process of innovation involves constant interplay between diagnosis and strategy, and between creativity and focus, aimed at continuously generating future projects.

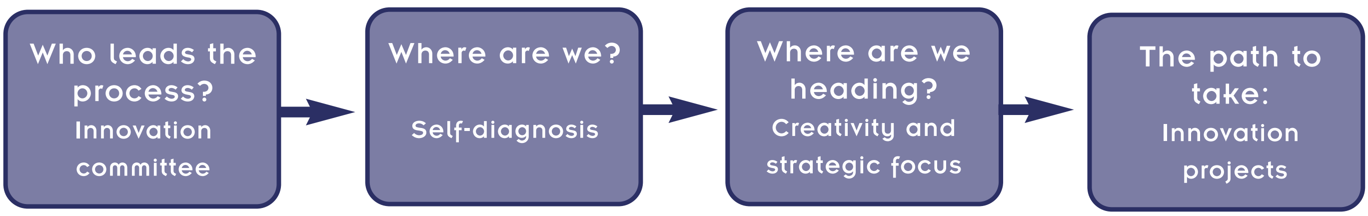
The fundamental elements of this process6, which coincide with the steps described above, are as follows:

a) Leadership: Innovation is a strategic process for the company and requires commitment from management. This calls for the definition of a clear strategy with quantified objectives that involves the whole organization.

b) Creativity: Those managers who have decided to promote creativity by reducing their control or changing traditional communication mechanisms have achieved significant changes in their organizations' capacity for innovation.

c) Focus: "A bad plan is better than no plan at all" (M. Botvinnik). In any creative organization, there is always a lack of resources to develop all the interesting ideas that are put forward. A plan for the future has to be decided upon in accordance with the corporate strategy so that the resources available can be allocated efficiently.

d) Efficiency: "Strength comes through following instructions" (Sun-Tzu). The project manager is a crucial figure in the organization to maintain a balance between time to market and development and production costs. Efficiency is achieved by optimizing these variables through proper management of innovation projects.



6. Kenneth Sandven, Cap Gemini Ernst & Young, *Expansión*, May 2002.

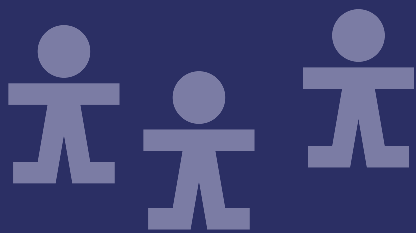
GETTING THE ORGANIZATION READY TO INNOVATE

CULTURE OF INNOVATION

People

Values

Vision of the future



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APPROPRIATE ORGANIZATIONAL STRUCTURE

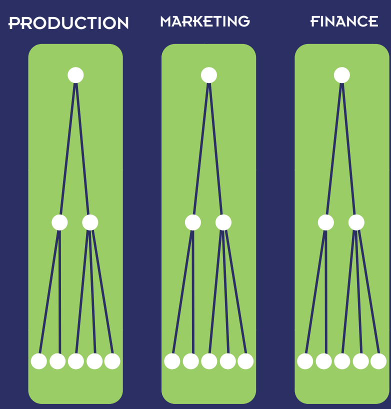
Organization managed by people

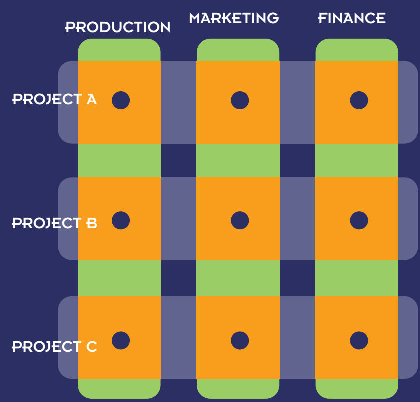
Multidisciplinary nature

The project as the basic flow unit

VERTICAL STRUCTURE + HORIZONTAL STRUCTURE

MATRIX STRUCTURE





2 GETTING THE ORGANIZATION READY

2.1 The culture of innovation

The first thought that comes to mind when considering innovation in SMEs is how difficult it is amid all the hectic daily activity to find the time to consider the future and think about innovation. Initially, then, innovation would appear to be an activity that conflicts with the everyday demands of the business, i.e., it creates tension in the organization. In fact, it is far easier for an organization to always do the same thing than to think up and manage changes.

For a company to begin to manage innovation in a systematic fashion there must be a COMMITMENT to dedicate economic, financial, material, human and managerial resources to it, and the direct involvement of management and shareholders. It is vital to convey a sense of urgency when it comes to fine-tuning the company and structuring the innovation process.

There must first be a culture of innovation within the company that incorporates several differentiating VALUES, one of which is innovation. These values7 are: the company's individual capacity to direct the behaviour of its managers and staff; beliefs about what is justifiable, desirable or valuable; and a VISION OF THE FUTURE picturing where the company should be in the medium term.

There must first be a culture of innovation within the company that incorporates several differentiating VALUES, one of which is innovation.

In strategic terms, the company's vision refers to the future scenario in terms of its market position, how its wants to be seen by its customers, the products or services it intends to sell and the competitive advantages and organizational form it aims to have

Innovation has to be seen as a process that permeates the whole company, crosses the boundaries of functional departments and involves different players simultaneously.

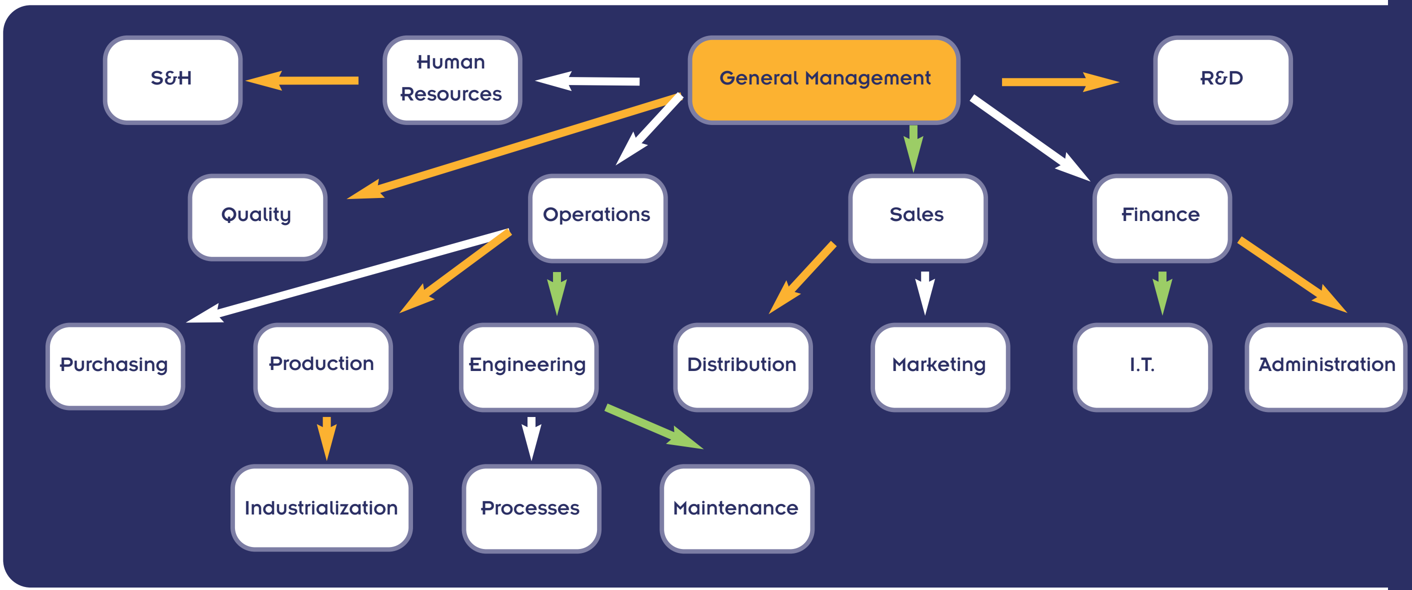
For the company to come up with this proposed vision of the future, its values have to include innovation as the driving force for transformation. The effectiveness of innovation will depend on the extent to which these values are accepted throughout the organization.

Innovation has to be seen as a process that permeates the whole company, crosses the boundaries of functional departments and involves different players simultaneously. The typical hierarchical structure is designed to provide stability for the company's most common processes, viz., those most directly related to manufacturing products and obtaining and handling orders. It is normally a rigid structure and not designed to promote change, which is the very lifeblood of innovation. Therefore, innovation processes have to flow through these existing hierarchical structures and overcome the typical functional obstacles that often form in inactive departments with their own subcultures and partial objectives.

7. *L'enfocament estratègic de l'empresa,* Xavier Gimbert, ESADE, ed. Deusto, 1998.

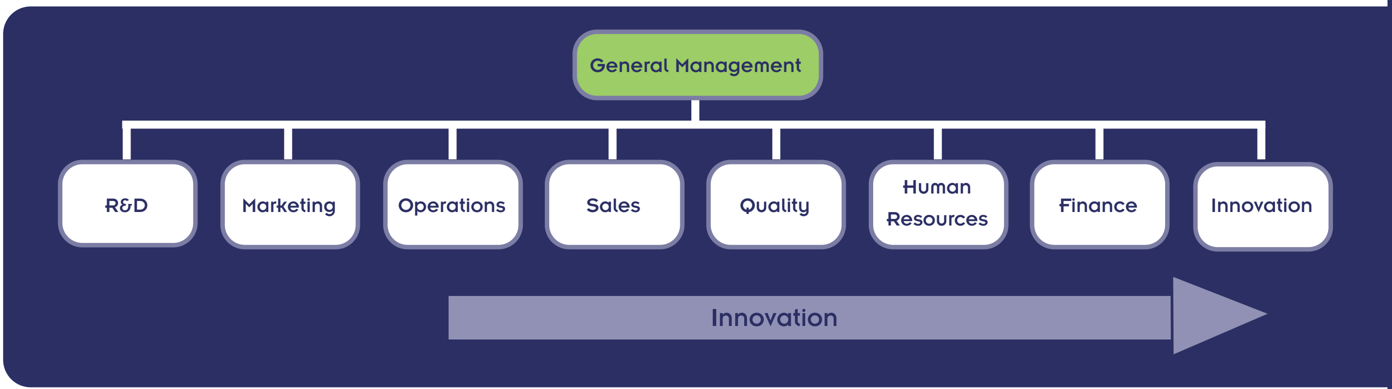
Innovation as a process has to be seen in the context of an organization managed by processes, in the context of a move away from a hierarchical structure.

From a hierarchical and functional structure...



How many times has the Marketing Department demanded products from the Production Department at prices that barely cover costs, and new products within unrealistic deadlines? How often is industrial production left out when developing new products? A process-based organization provides better horizontal communication and planning, rather then simply putting pressure on an internal supplier.

...to a process-based organization.



The processed-based organization has a flat, parallel structure. Ideally, the players involved should be multifunctional (have an overall vision of the process) and trained in different departments to appreciate all points of view and harmonize each department's individual objectives with the company's overall vision. Innovation projects will have a leader, the project manager, whose responsibilities will include ensuring that all the skills and restricted needs called for by project are included in or considered by the project right from the start. The project manager will therefore recruit the appropriate people from different departments.

Example

TELSTAR, winner of the Catalan Government's Technological Innovation Award in 2001, selects its project managers from among highly qualified staff who have been involved and trained in all stages of product development, including R&D, finance, quality, and sales. This provides an overall perspective of the process and makes it possible to foresee possible problems in later stages. This multidisciplinary approach encourages the generation of more new concepts, which provide the basis for continuously launching new products.

Processes are sets of sequential activities that are executed in a horizontal and recurring fashion in the organization, with the aim of obtaining a result (a product or service) to satisfy a specific customer (internal or external).

Each process contains flow units that pass from one stage to another, gaining added **value** as they do so.

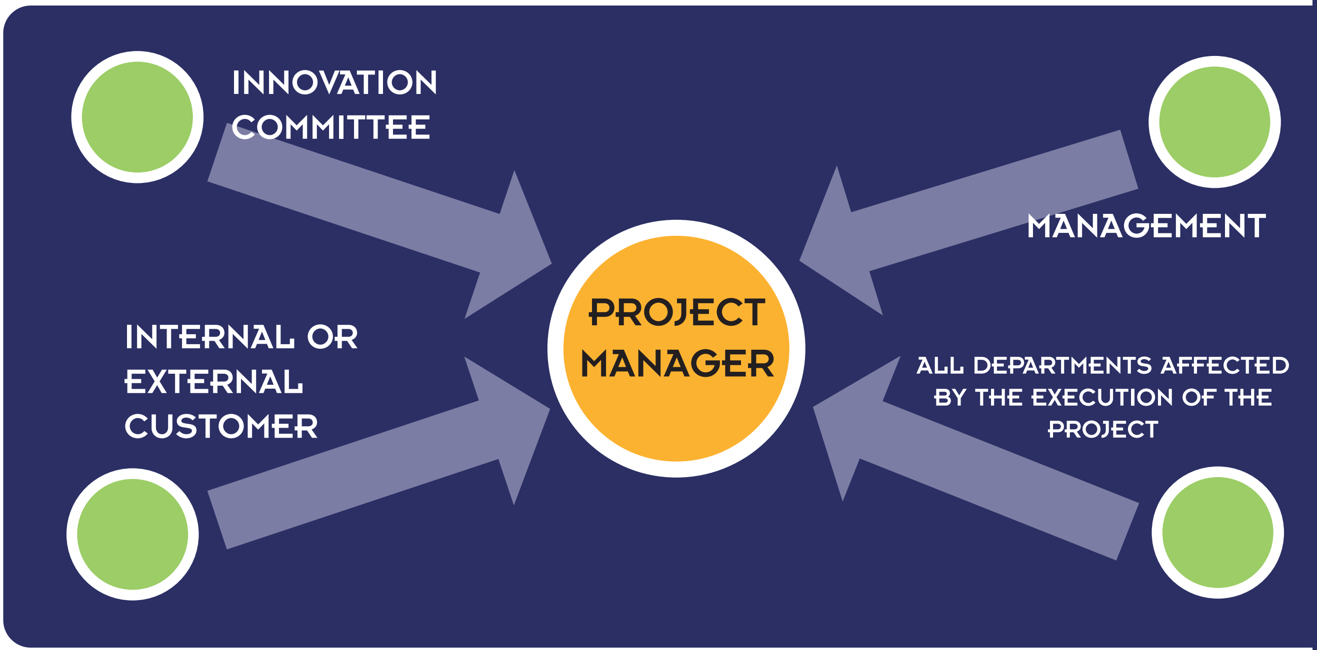
In the manufacturing process, the flow unit is the product, which takes shape from the raw materials and components until finally becoming the finished product. In the process of attending to patients in a hospital, the flow unit is the patient, who progresses from admission to discharge. In the innovation process, the flow unit is the project, which evolves from the initial idea to execution and calculation of its impact on the company's competitiveness. Only when companies begin to observe and measure flows in processes can they start managing them effectively.

In the innovation process, the flow unit is the project

Every process needs a leader (a body, committee or individual) to take responsibility for it, monitor its evolution and lead it from start to finish across the barriers of functional departments. The various project managers who carry out the specific activities in the process will be answerable to this body or committee.

It is vital for each project manager to have a SPONSOR from top management to oversee the project's proper execution, ensure the availability of the resources allocated by the functional managers and support the different managers when it comes to resolving any problems that the project generates as it is carried out.

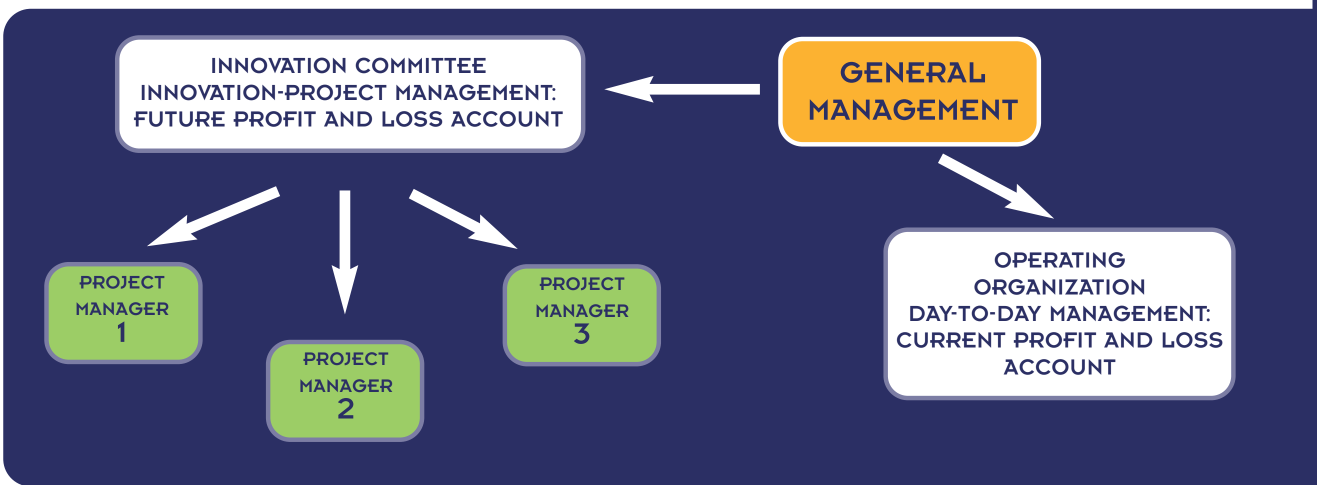
Every process needs a leader (a body, committee or individual) to take responsibility for it, monitor its evolution and lead it from start to finish across the barriers of functional departments.



The need to dedicate organizational resources to both innovation and day-to-day management (buying raw materials, planning production, producing, distributing, selling and invoicing the product effectively) justifies the existence of **two parallel organizations**. The first, which will serve as the basis for the future profit and loss account, defines strategy and oversees processes, including innovation; the second, which is more operative, produces the current profit and loss account.

The size of the innovation organization will depend on the company's size and resources. An SME does not need hundreds of engineers in its R&D department when it can manage with a small group of people who are responsible for leading the innovation process and have knowledge of or actual experience in all the company's departments (Marketing, Production, Development, Engineering and Finance) and the authority to lead work teams without answering to their department heads.

Example 1: The company's scarcest resource – managers' time: A textile company taking part in one of CIDEM's innovation-management pilot projects found it impossible to set aside time for meetings of the innovation committee. It therefore decided to establish fixed meetings for its managers between 3 and 5 pm on Fridays, once a fortnight, to plan the company's innovation process. Now, fifteen managers meet every two



weeks to discuss future proposals and oversee the development of innovation projects. Some of these managers, such as the Marketing and Production Managers, work in different buildings and rarely have the chance to exchange opinions.

Example 2: An innovation department. An SME making specialized machinery that has managed to continuously and successfully launch new products decided to set up a special department staffed by three people who had received training in all the company's departments. This department's sole purpose is to present top management with innovation projects (new projects or lines of business) with fixed quantitative aims. This department devises, documents and puts forward around 100 new future projects a year, only three or four of which are finally accepted by management, allocated resources and assigned a project team to become market realities.

2.2 The organization of the project within the structure of the company

Any project can be assigned one or more managers to play key roles throughout the development of the project. These roles are the following:

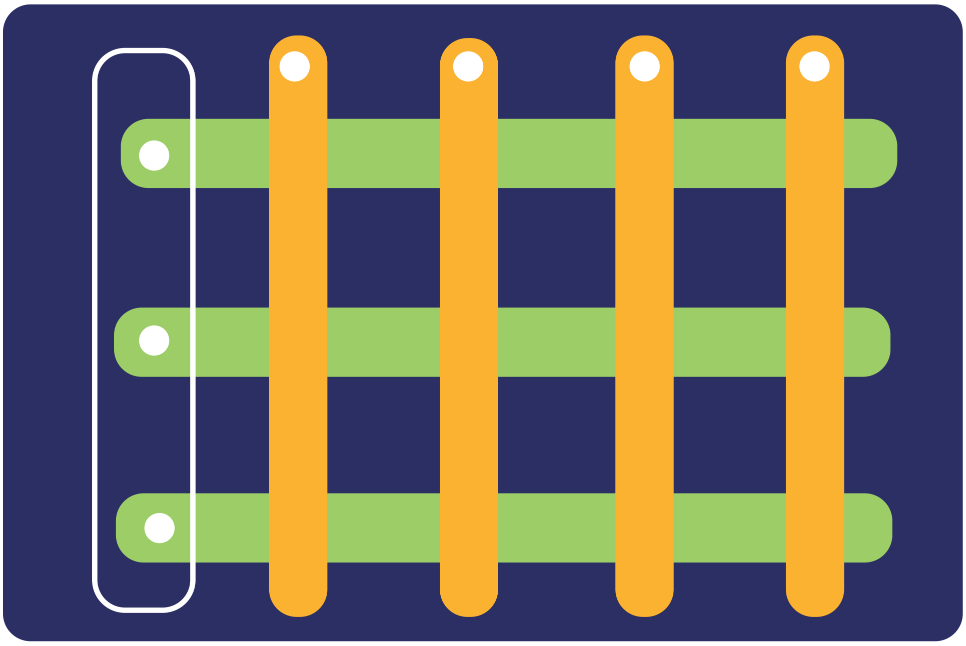
Sponsor	Manager with ultimate responsibility for the project. May be advised by a monitoring committee, which ensures resources are available and best understands the link the project has with the company's overall strategy.
Customers	People or departments that will use the results of the project: the Marketing or Production Departments, for instance.
Project Manager	Manager with direct responsibility for the detailed execution of the project.
Functional Managers	Managers of the company's different functional areas that will provide resources for the project. They should have a thorough knowledge of the project and be aware of their role. The success of the project should be among their specific aims.
Administrator	Person or department with the task of keeping all the project's documentation and records.
Team	People from the different areas that will collaborate on the project for a significant period of time.
Suppliers	They should be brought on board as early as possible, as they can provide useful know-how for the project.
Others involved	All other people affected by the project.

A key point to consider when organizing the project is how to structure it within the company's usual operations. As stated above, innovation projects ought to coexist side by side with each department's functional tasks and the project team should meet regularly. In this way, the project manager will be able to coordinate with the functional directors and share resources with them, with the team's commitment to develop projects with medium-term results.

Another possibility is to create an independent project group unattached to any other activity for the duration of the project. The group members would then report exclusively to the project manager and temporarily cease to answer functionally to their own departments. There is also a matrix structure that connects these two organizational forms, in which people report to both their own functional manager and the project manager.

Functions (R+D, Production, Engineering, Marketing)

Projects



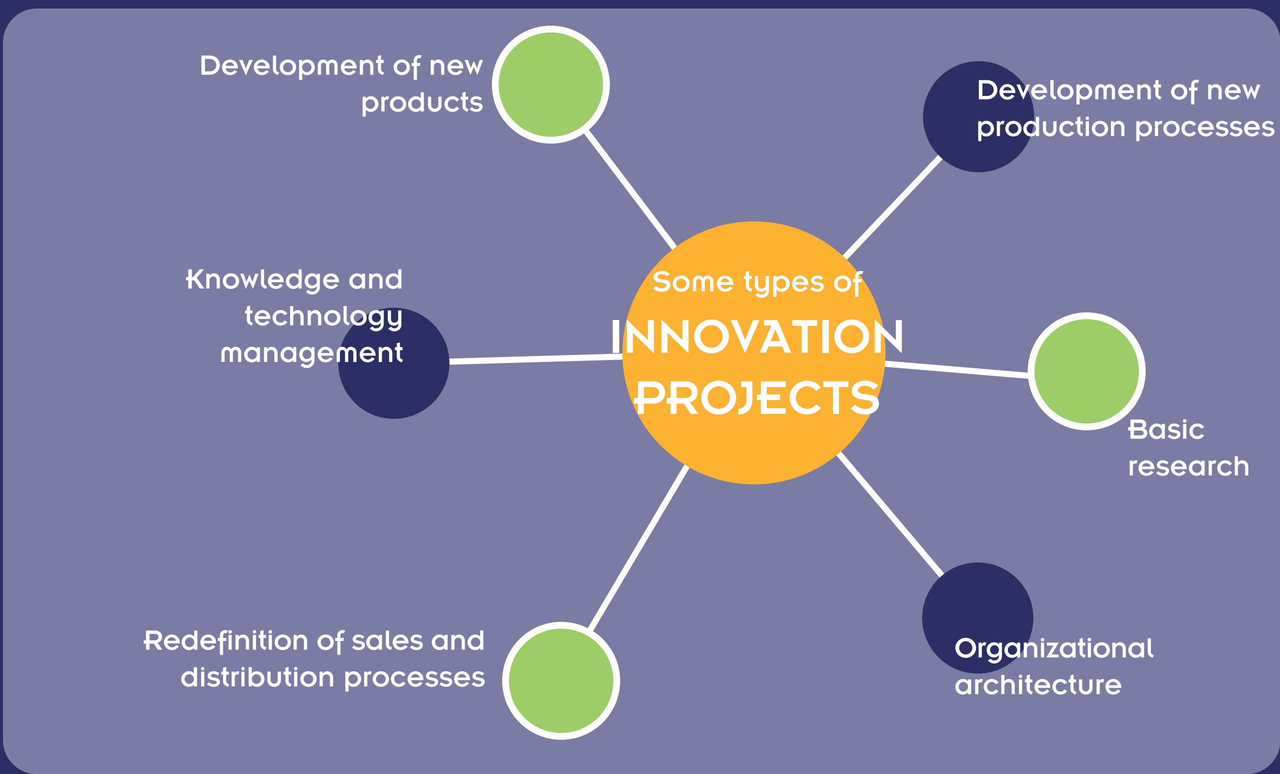
Finally, the organization must have a positive attitude towards these projects and facilitate their execution. This calls for:

- Well-defined, documented project-management procedures.
- Clearly specified deadlines for each stage.
- Well-prepared standard documents, templates and spreadsheets that avoid the need for each project manager to reinvent them for each new case.
- An IT system for managing projects that allows for easy monitoring of execution, costs and the resources dedicated to each task.
- A project office to give support to the various Project Managers and file the knowledge generated by the different projects carried out by the company (knowledge management).

The system for managing and documenting projects will be laid out in the following chapters (see Chapters 7 and 8 on specifying and planning projects).

DEFINITION AND DIFFERENT KINDS OF INNOVATION PROJECTS

INNOVATION CALLS FOR A **CONTINUOUS FLOW** OF PROJECTS



3 DEFINITION & DIFFERENT KINDS OF INNOVATION PROJECTS

3.1 A project is:

A single process consisting of a set of coordinated and controlled activities with starting and finishing dates carried out to achieve an objective in accordance with specific requirements, including time, cost and resource commitments[8].

A successful project:

- Achieves the objective set (products, service, plan or knowledge specifications) and satisfies the customer.
- Is carried out in the stipulated time.
- Is carried out within budget (use of resources).

These parameters define the restraints on the project: the cost of carrying it out (economic resources), deadlines and specifications, all detailed in the initial requirements. In actual fact, a completed project is unlikely to meet all three requirements, as, in addition to the alterations all projects naturally undergo, modifications are usually introduced as more and improved information becomes available, or the customer or sponsor learns more about technology and the market. In many development projects, defining specifications more precisely represents a highly significant way to move the project forward.

All companies have been innovators at some time or other, and some may still be sporadically. The aim is to be innovative systematically and thus ensure that the flow of innovation projects is not simply left to chance, but is **managed as far as possible as a business process in the form of a continuous sequence of projects.**

The first step to take in order to properly manage the portfolio of innovation projects that have been generated by the audit (prior diagnosis) is to CORRECTLY IDENTIFY THEM. Each project must have an initial datasheet containing basic information and features.

Innovation is managed as a business process in the form of a continuous sequence of projects.

8. UNE 66904-6:2000.

The project can be dated from the time this fundamental step is taken. This document sketches out the general outline of the project and includes general estimated or calculated data so the project can be included in the selection and approval process, which corresponds to the first stage in the "innovation funnel" described below.

This datasheet basically should include the following points in sufficient detail for management to be able to take decisions on its suitability and allow it to pass to the following stage:

- Project title, the date it was proposed and the company, department or area that proposed it (identification of project).
- Brief description of the proposal's objectives (evaluation of aims) and justification.
- Evaluation of resources and feasibility analysis: summary of technical, economic and financial evaluations.
- General action timetable.
- List of signatures and approvals.

When a company first begins to manage its innovation process, it does not usually possess all the datasheets for the projects being carried out at the time, whether formally or not. It is useful to make a certain effort to record the most important projects under way, although this should not be used as an excuse not to proceed with projects until they are all identified and recorded. It is worth remembering that it is more important to concentrate on defining what has yet to be done than to go into detail about what is currently being done.

3.2 Kinds of projects

After the initial description, it can be useful to classify innovation projects following the model already used for the prior self-diagnosis9. In more detail, innovation projects could involve:

Organizational architecture Aimed at modifying the organization to make it more efficient, or creating teams to systematically generate new concepts or innovation projects.

Basic research Aimed at generating new knowledge or technologies applicable to products and processes.

Development of new products Aimed at launching new products.

Development of new production processes Aimed at producing the same products using new or improved processes.

Redefinition of sales and distribution processes Aimed at taking advantage of untried opportunities to break into new markets or at commercial repositioning.

Knowledge and technology management Aimed at transforming the company's information flows into referenced, useful knowledge, or taking on board new external knowledge or technologies.

9. *Guia per gestionar la innovació*, CIDEM, 1999.

Innovation projects never aim at providing solutions for the standard business cycle, or meeting day-to-day demands, but at maintaining or significantly improving upon the business's medium-term results.
The results may vary from the initial aims, but this does not make them any less valuable (UNE 166001).

Furthermore, if it is based on technology, each of the above projects could be classified as:

Support Projects that do not involve any technological variation compared with previous projects carried out and are not expected to make much impact on the market.

Derivatives Projects that involve a slight technological variation or an improvement in the competitive market position.

Platform Projects that involve new-generation technology compared with previous projects carried out or a new category of products on the market.

Disruptive Products that involve introducing a completely new technology compared with previous projects carried out or that are expected to have strong repercussions in the market.

Innovation projects that either a) aim at obtaining new products, processes, or significant technological improvements on the present situation, or b) involve basic research aimed at obtaining new knowledge or increased understanding in scientific or technological fields, are eligible for tax deductions[10].

Therefore, it is vital to manage and document these projects efficiently[11] (see Chapters 6 to 10).

Examples of innovation projects:

Organizational architecture

• Creating a procedure for gathering and evaluating ideas from any part of the organization with a manager and timeframe.

• Drawing up plans for ongoing training and evaluation, depending on the company's technological needs, and creating a team to monitor technology.

• Training a parallel multidisciplinary engineering team, including guest engineers, with the aim of reducing the time required to develop new products and add value through new designs.

10. *Nous incentius fiscals per innovar*, CIDEM, 2000.
11. See standards UNE 166000, 166001 and 166002.

Basic research

• Creating a research line to synthesize a new molecule aimed at opening a new market in the field of pharmacology.

• Agreement with a university to characterize the physical and chemical parameters of the vulcanization of rubber.

Product development

• Acquiring a simulation program with the aim of predicting fissure defects in a metallurgy process.

• Installing CAD-CAM-CAE software to optimize the product-development process.

• Installing a scale auxiliary line for prototypes, displays and presentations.

Development of production processes

• Programming a traceability system for intermediary stock in the production plant to be connected to the Internet and accessed by managers at home.

• Purchasing and installing a program for project management. Creating a reengineering team to evaluate the allocation of resources and optimize planning of resources.

• Programming an expert system to determine the optimal circuit for material in the process using the experience of a technical expert and taking decisions based on this knowledge.

• Installing artificial-intelligence algorithms to minimize robot movement on a production line.

Redefining sales processes

• Creating a new brand image with quality positioning for a specific product line.

• Using the Internet as a new sales channel.

• Opening a website to provide assistance and customer-service that could also be used to gauge market opinion.

Knowledge and technology management

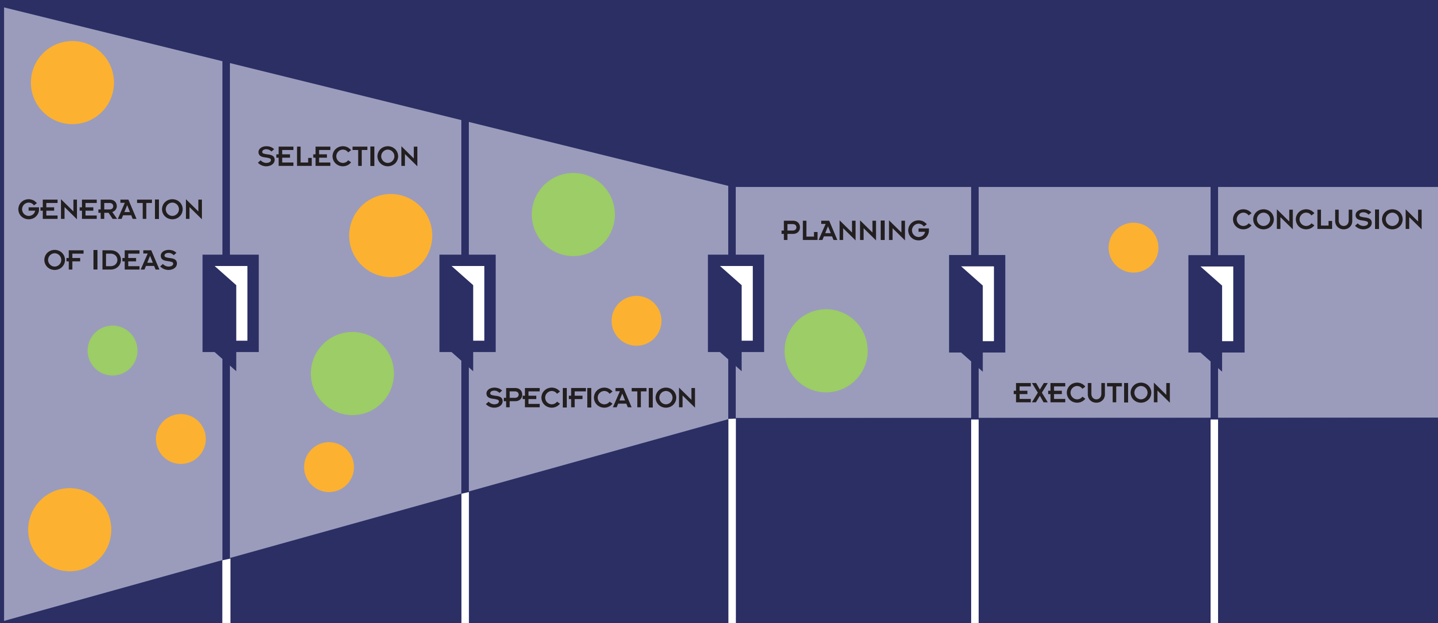
• Programming an Internet robot to automatically track down and monitor the competition's latest products.

• Installing a program to redefine preventive maintenance at the plant, based on records of past breakdowns.

• Installing an intranet to provide a record of the company's projects, with an internal smart search engine with specific modules.

INNOVACION AS A FLOW OF PROJECTS

The innovation process is a flow of projects that can be represented by a funnel containing the different stages.



Creative techniques are used to come up with projects.

The projects most in keeping with the company's strategy are selected.

The selected projects' requirements are defined in detail.

The project-execution stages are planned.

Execution of the initial plan is monitored and controlled.

Deviations from the initial plan during execution are analysed.

STAGE GATES MUST BE SET UP BETWEEN ALL STAGES:

These fixed mechanisms decide which projects will go through to the next phase.

4 INNOVATION AS A FLOW OF PROJECTS

4.1. The project phases

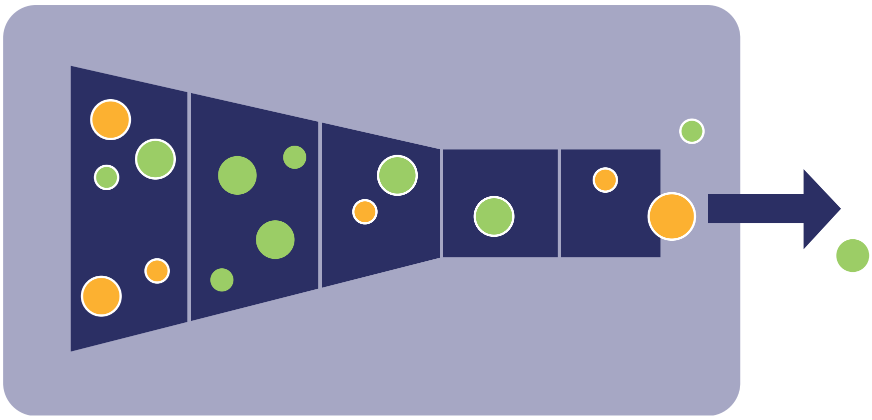
The innovation process has already been described as a series of simultaneously managed projects. These projects may be of different types, have their own resources, be in different phases of development and be planned and executed by multidisciplinary teams.

The challenge faced by innovative companies is to know how to continuously plan and execute different innovation projects simultaneously. Proper management of innovation involves a continuous flow of projects, which are successfully devised, executed and concluded.

Along the course of this process, some projects naturally fall by the wayside: for various reasons, not all the selected projects are ultimately executed and implemented in full. Sometimes, erroneous selection leads to a project being interrupted at an advanced phase, as new factors mean it is no longer deemed a priority. Other times, hasty planning makes execution impossible, due to a lack of resources or the inability to scale up the project. Some projects are killed off right at the start if they do not prove as profitable as the company hoped. Repositioning by competitors or changes in legislation may also mean that initially promising projects lose their shine and it becomes more effective to rule them out (or put them on hold) than execute them in full. Consequently, each of the product-development phases has to be carried out meticulously and each stage must support subsequent ones.

The innovation process was presented above as a flow of projects that can be represented by a funnel. Projects enter and are progressively filtered as they pass along this funnel, with only a few successfully making it to the end.

The challenge faced by innovative companies is to know how to continuously plan and execute different innovation projects simultaneously. Proper management of innovation involves a continuous flow of projects, which are successfully devised, executed and concluded.



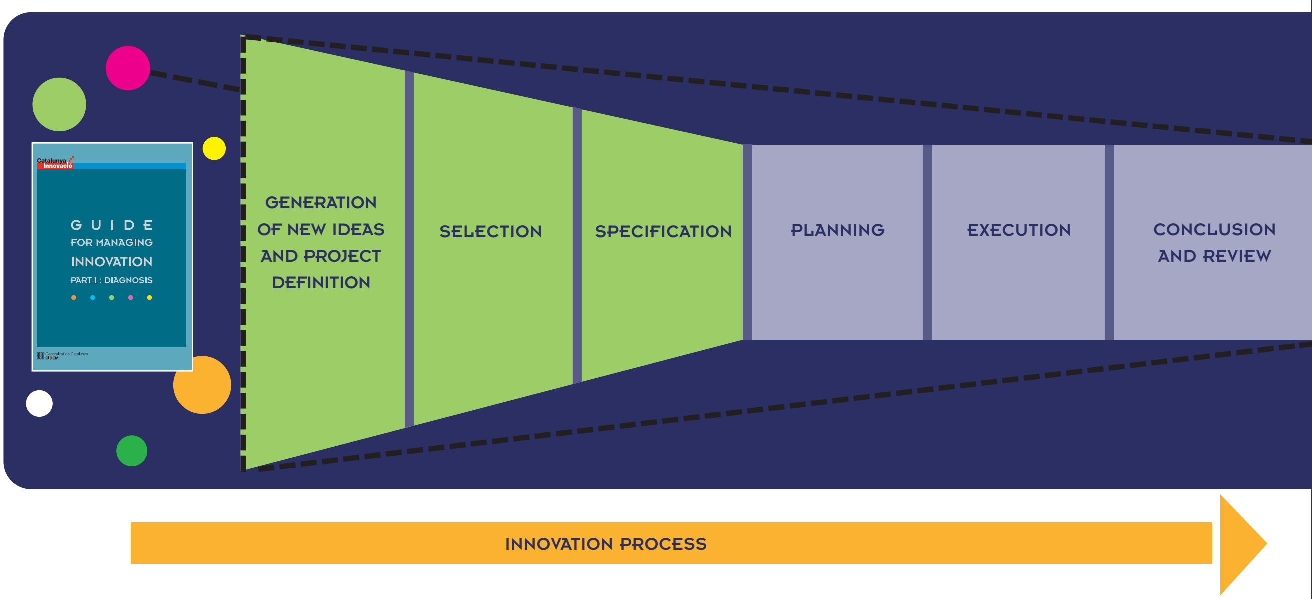
The shape of the funnel determines the projects' survival rate. In SMEs, the critical phase is selection, as the scarcity of resources means that the process can only sustain a few active projects (even though many new concepts and ideas may be generated). A large company can afford to set many projects in motion and weed out weaker ones at later stages.

Every company has to get the balance right for itself: ruling out too many projects at the start could mean losing ones which might have proved themselves market winners later on; however, backing and managing lots of projects with the aim of filtering them out in later stages involves dedicating resources to projects that may never reach the market.

The system clearly works best when effort is concentrated in the early phases where ideas are generated, selected and specified, so that the projects that make it past this stage can be successfully implemented. The idea is to avoid wasting resources on projects that will never see the light of day, whilst allowing potentially successful projects to proceed.

The green section on the following diagram shows how the number of projects in the funnel decreases between the generation and planning stages, at which point practically all those left will make it to the end of the process. If not enough emphasis is put on the work in these early stages, the selection funnel becomes much more drawn out, as shown by the dotted line in the diagram, thus allowing many more projects to continue on their way before being eliminated in much later stages, such as when they are being implemented.

The system clearly works best when effort is concentrated in the early phases where ideas are generated, selected and specified, so that the projects that make it past this stage can be successfully implemented.



The diagram also shows a portfolio of projects represented by a series of circles of different colours and diameters. The colour stands for the kind of project (research, product development, new-process development, sales redefinition, knowledge management or organizational architecture) and the diameter is proportional to the resources allocated to execute it.

The colour stands for the kind of project.

The shape of the funnel in the diagram represents the amount of wasted resources (the area between the dotted line and the green section). There is even the risk of incorrectly defined projects being selected, making it through to the end and still not being useful.

The funnel diagram is a useful tool for visualizing the state of the innovation process: the number of projects on the go, the relative amount of resources they consume (represented by the diameter of the circles) and which phase they are in.

The funnel management model is a tool for management to visualize the innovation process stage-by-stage.

The projects that emerge from the idea-generating process then have to be set out in an initial document that broadly identifies and defines their aims, development costs and an action timetable (see Chapter 3). Based on this information, in the first **selection** phase, projects are chosen in accordance with the company's technological and business strategy. The set of projects selected and under way make up the company's **innovation plan.**

THE CHANCE FOR DIVERSIFICATION.
When the question arises of the different options for investing money, any financial advisor will advise diversifying the type of investments. Similarly, when it comes to selecting a portfolio of innovation projects, company management should consider allocating resources to more than one kind of project and value the cost of lost opportunities in alternative projects.

Once the projects have been selected, we have to specify what exactly is to be done and how, avoiding any possible ambiguities or misunderstandings by those forming part of the project. These people should produce a "contract booklet" laying out the project's specific requirements (combining any requirements of the end product or of the process determining the end product, in the case of development projects). Progress cannot be made past this phase until these requirements are clear, agreed upon and recorded.

The diameter is proportional to the resources allocated to execute it.

The next phase is **planning:** identifying which resources are available (temporal, financial, human and material) and deciding what action sequence to follow, taking into account the limited resources. There is often a return mechanism between the planning phase and the specification phase that modifies the specifications.

Finally, the project has to be **executed** in a controlled fashion, dealing with unforeseen turns of events or variations in the consumption of resources from what was anticipated. This is why it is so important to monitor the project: a project cannot be controlled without a plan.

Once the project is executed, all the players involved have to accept it, scale it up (if necessary), validate it and carry out a post-mortem analysis (**conclusion** and review of the project: considering both the mistakes and wise moves made in order to increase the organization's knowledge for future projects).

The funnel management model is a tool for management to visualize the various stages that make up the project as a whole. It is often useful to draw each kind of project in a different colour and represent the estimated resources by circle diameters.

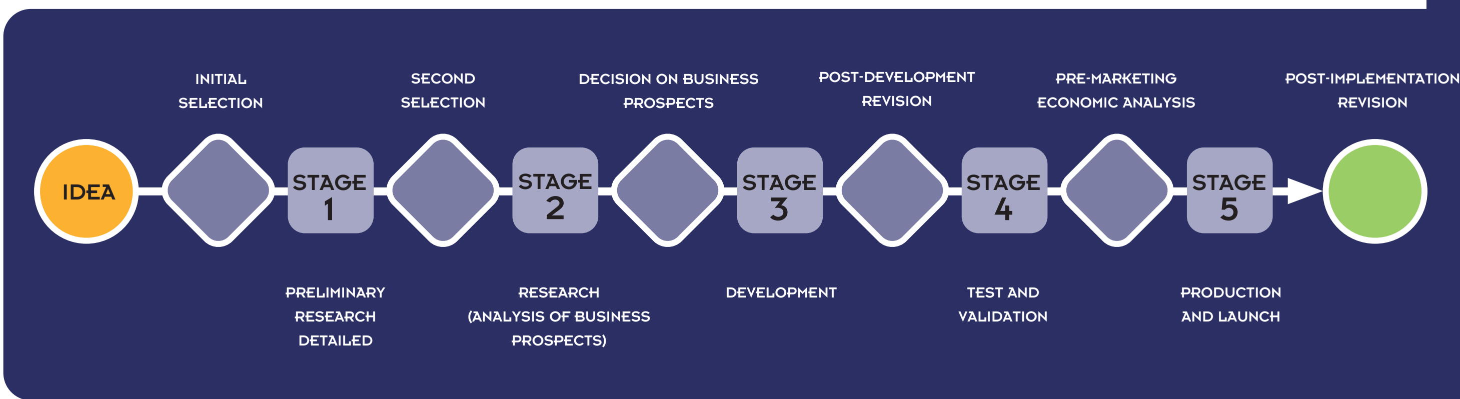
The set of projects selected and under way make up the company's innovation plan.

4.2 How the projects pass successfully through the different phases: Stage gates

Each project is introduced into a process in which it has to pass successfully through various phases, which are subdivided into stages that vary depending on the nature of the project. As it successfully passes through each of these stages, the project is subjected to successive reviews, which ensure it meets a series of previously defined criteria.

Stage gates provide a simple project-management model.

Stage gates[12] provide a simple project-management model, an example of which is shown in the following diagram:



12 Robert G. Cooper, Product Leadership, *Creating and Launching Superior New Products*, Perseus Books, 1998.

The project begins on the left with an idea, which then undergoes revisions at the different gates as it moves into the corresponding stages. Gates 1 and 2 correspond to initial selection. The first involves a quick, broad definition that outlines the project and allows for some projects to be ruled out early on. Projects that successfully pass this stage go on to stage 2, where they are researched in more detail.

The development stage (3) is followed by the test and validation stage (4). The final stage is production and launch (5). The process concludes with "post-implementation revision". Let's look at these stages in more detail:

Stage 1: Preliminary research. Basic research and initial selection of projects. This stage provides information without committing a lot of resources and means the projects can start to be selected.

Stage 2: Detailed research. (Determining business prospects). This stage is when the most important work into past cases and preliminary studies is done, with the aim of providing a clear picture of the whole project, including different possible scenarios, consequences, risks and market surveys. This stage determines the project's business projects, including the (possible) definition, justification and plan.

Stage 3: Development. This stage is when the new product is actually developed, including a test stage in the case of product development. If a product is developed, the result of this stage is a prototype.

Stage 4: Test and validation. In this stage all the product and process's commercial stages are validated and this includes vital laboratory, production-plant and market tests.

Stage 5: Production and launch. This stage is when the product is marketed and signals the start of the production, marketing and sales stage. Plans for marketing, production, operations, distribution, quality control and after-sales monitoring are drawn up.

In this stage-gate model, it is important to reach agreement on which aspects will be evaluated at each gate and the anticipated results. Each of the specific stages, as well as the conditions for passing to the next stage, should be specified and planned in detail. (Chapters 6 and 7).

The model should also be adapted to the individual needs of each company and project. At each revision at a stage gate, the opportunity should also be taken to keep all the departments involved (Sales, Engineering and Production, for instance) up to speed with the project's progress.

It is important to reach agreement on which aspects will be evaluated at each gate and the anticipated results.

example

An example of a continuous flow of projects: Medtronic Inc.

Medtronic Inc. was founded in Minneapolis in 1949. At the end of the 1980s, management succeeded in reversing a steep decline in the company's cardiac-pacemaker business: its market share had fallen from 70% in the early 1970s to less than 30% in 1986, but by 1997, the company was once again the market leader with a share of more than 50%.

Management attributed much of the success of this turnabout to a series of "strategic blocks" they had set up, including the continuous combination of platform projects and derivative ones in its portfolio, monitoring and making the most of outside technological developments (from universities and other industries), creating "heavy-duty" teams for platform projects and "light-weight" teams for derivative ones, stressing involvement in projects as an important element in employees' promotion and professional careers, planning and monitoring projects in its innovation funnel, defining and measuring projects' progress and success, and, above all, establishing a demanding innovation programme with set deadlines, like a train timetable. The company always knew in which stage future projects had to be in so they could develop as expected. Even though they did not know precisely which projects they would be dealing with, the managers and technical staff set aside blocks of time in their schedules to ensure the desired flow of projects was viable at every point in the future.

Source: Clayton M. Christensen, Case HBS 9-698-004,
We've Got Rhythm! Medtronic Corporation's Cardiac Pacemaker Business,
Harvard Business School.

PHASE 1: GENERATING NEW IDEAS

NEW IDEAS MUST BE CONSTANTLY GENERATED IN ORDER TO ESTABLISH A CONTINUOUS FLOW OF PROJECTS

COMPETITORS

CLIENTS

EMPLOYEES

PUBLICATIONS

Sources of ideas to be identified

NEW NEEDS AND NEW REQUIREMENTS

With the help of creativity techniques

LISTING ATTRIBUTES

List of characteristics

(Can we improve any of them?)

BRAINSTORMING

(Regular and reverse)

MORPHOLOGICAL ANALYSIS

Breakdown into constituent parts

6-3-5 METHOD

6 people - 3 ideas - 5 minutes

5 PHASE I: GENERATING NEW IDEAS

5.1 Background

A company's ability to generate new concepts and ideas is not something that can be improvised. Not all ideas or concepts can be carried all the way through to market launch. A selection mechanism must be established, and it must be closely linked to anticipating customer needs or creating new ones.

Businesses begin with an idea, and their development, stability and success depend, more than ever, on innovation and the continuous flow of creative thought. However, the majority of managers do not have a clear idea of what creativity is, how it can be stimulated, or how to work creatively in order to achieve corporate objectives[13].

Several studies have shown the variables connected with marketing to be the main business weaknesses that can lead to commercial failure when launching new products, e.g., insufficient market research, inappropriate market timing, weak marketing, product defects or high costs. The recommendations resulting from such studies point to more market research, greater effort in positioning products, more effective product testing, etc. In short, they point to the generation of innovations that are strongly market-oriented.

Businesses begin with an idea, and their development, stability and success depend, more than ever, on innovation and the continuous flow of creative thought.

In order to generate a creative ideas portfolio, one should ask questions about the market and the company's own organizational capacity:

- How can current and future customer requirements and the activities of competitors be identified in order to create new products?
- How does a company stimulate the creativity of its workforce, the input of new ideas and a spirit of innovation?
- Is the generation of new concepts planned with a time frame? Who participates in this process?
- How are ideas filtered and how are the concepts that are to receive development financing selected?
- Is there a clear and continuous use of advanced tools for generating new concepts?

13. Franc Ponti, EADA, *La Empresa Creativa,* Ediciones Granica, 2001.

5.2 Why generate new concepts?

New concepts are usually generated as the result of spontaneous and evolving actions, but this does not mean that one cannot introduce a certain degree of systematization that will lead to the creation of more ideas. It is in this way that we can define techniques for the stimulation of creativity.

Concept generation is aimed at proposing a sufficient number of quality ideas. Then, with the application of strict and systematic procedures, one's attentions and efforts become concentrated on an ever-decreasing number of ideas so that company resources can eventually be allocated to the right project or projects.

An analogy that may assist us in understanding what is meant here is the example of the funnel, mentioned earlier. The mouth of the funnel should be filled with as many ideas as possible; these ideas are then filtered through subsequent stages at different levels of development in order to concentrate the relevant analysis, evaluation and development work on an ever-decreasing number. This working method ensures a dynamic balance between cost and uncertainty; when we reduce uncertainty, costs increase as a consequence of the greater level of resources gradually invested.

It is fundamentally important to generate many ideas, though we must know how to apply an effective filter at the outset that will, at the same time, allow us rapidly to reject some of these ideas. If we do not, the process is of little use. No company can allocate the time and resources required to make an in-depth analysis of all the ideas generated.

In general, creative thinking acts at an unconscious and intuitive level. Nevertheless, a systematic and structured approach can be learned, like any other skill, and applied to various working areas, not only those of marketing and research.

5.3 The concept-generation process

The aim is to come up with the greatest possible number of ideas from any area or environment. At this stage, priority is given to quantity rather than quality. During subsequent stages in the process, any ideas that are not practicably applicable or do not conform to the company's objectives will be eliminated.

The main elements used to generate a large number of concepts:

- Challenge common sense.
- Generate spontaneous ideas and develop them collectively.
- Impractical ideas are welcome.
- Use graphic and physical media (blackboard, slides, post-its).
- Create analogies.
- Systematically question hypotheses.
- Ask “why” frequently in order to reach the fundamental reason.
- Use related and non-related stimuli.
- Work in groups.

5.4 How can we generate new concepts?

It is vitally important to stimulate fertile creativity in order to generate the greatest possible number of ideas. This can be achieved in ways that are very different but nevertheless closely related.

On the one hand, there is the identification of other sources of ideas for potentially complementary products, which could come from customers, scientific and technical research, replacement products, the company's own personnel or many other sources.

Some ideas may result from a close and fruitful relationship with one's customers, with a view to being able to identify what they actually require at all times. Suggestions from personnel at all levels of the company, if properly channelled, could also be a source of ideas for new concepts.

In this regard, if it is to maintain or improve its competitive position, a company must constantly observe and monitor the movements of its current and potential competitors. This could give rise to ideas for new products. Consideration should also be given to the possibility of replacement products, or unrelated products that cover the same requirements as our own.

It is always a good idea to consult various sources, such as researching new patents and licences or studying periodical publications. The use of specialist consultants could also assist us in identifying new ideas for development.

Moreover, it is important to be aware of the most important techniques for stimulating creativity, including the following:

a) List of attributes

Make a list of the attributes or properties of a particular item with a view to modifying some of them or finding a new combination that will improve the product.

b) Brainstorming (see the following box)

c) Morphological analysis

Isolate the most important aspects of a problem so that each and every one of the links between them can be examined. A number of combinations will result from the number of alternatives considered for each aspect. The following step consists of reviewing each of these combinations in order to detect new ideas. Some combinations will be familiar, while others will give rise to ideas that are absurd or impractical. Some will eventually result in ideas that are new or unconventional.

d) The 6-3-5 method

The aim is to generate ideas in a group. A structured process is used in which participants write down ideas and exchange them with each other. Under this system there are 6 participants in each group, 3 ideas are generated and each contribution is worked on for 5 minutes.

e) Reverse brainstorming

The aim is to evaluate and select ideas, and is almost identical to normal brainstorming, except that reverse brainstorming gives rise to critiques rather than ideas. It is not restricted to ideas generated by brainstorming but can also be applied to ideas originating from other sources.

example

Brainstorming [14]

Brainstorming is a process that results from a meeting called specifically for the generation of new ideas. Ideally, the group should comprise between five and seven people and should be heterogeneous, though it is not essential that everyone be connected with the problem (it is normally beneficial to have some external input). The first phase, which lasts approximately 15 minutes, is used to give a brief outline of the background to the problem and the purpose of the meeting. This first phase is also aimed at making the participants feel relaxed and building trust among them, in order to avoid any pressure or prejudice.

The process starts with a redefinition of the problem. Example: what expansion of our services might our customers want to see?

Then the brainstorming proper begins, lasting approximately 40 minutes. The rules to be followed by the group are set out on a blackboard. These rules are as follows:

- *All ideas are valid*
- *Defer judgement on any idea that arises*
- *Improve and elaborate on these ideas*
- *Let these ideas give rise to new ones*
- *Do not allow hierarchies to develop*

All the members of the group begin to put ideas forward, and these are listed on a blackboard by the group moderator so that everyone can see them. When the time is up, the moderator decides whether there are enough ideas. It may be that the group has run out of ideas and the flow is insufficient. New stimuli are introduced during a second phase, and ideas are tested with questions such as:

Can it be applied in another way?	*Can it be replaced?*
Can it be adapted?	*Can it be reorganized?*
Can it be modified?	*Can it be reversed?*
Can it be extended?	*Can it be combined?*
Can it be reduced?	

The basic principle requires ***deferring judgement*** *while ideas are being generated, in order to prevent the critical faculty from interfering with the creative faculty.*

14. For more information, see *Eines bàsiques de qualitat,* Catalan Quality Centre, CIDEM.

e x a m p l e

Challenging conventional thinking.

This involves trying to break the implicit rules of the game.

"A gardener receives special instructions to plant four trees in such a way that each of them is equidistant from the other three. How can the trees be positioned?"

This process consists of trying to place four points on a piece of paper in such a way that they are all equidistant from one another. However, it is found that it is impossible to arrange them in such a way that each one is the same distance from the other three. The problem would seem to have no solution.

One begins with the supposition that these four trees are being planted on a flat piece of land. However, if you dispense with this supposition, you can see that it is possible to plant them as required: one tree is planted on top of a small mound and the other three are arranged around it at the foot of the mound. This means that they are equidistant from one another (in fact they form the vertices of a tetrahedron). This problem can also be solved by planting one tree in the centre of a hollow and arranging the other three around its perimeter.

f) Deconstruction

An existing model is reduced to its most elementary elements. For example, a problem such as "improving the quality and profitability of bus transport" can be broken down into:

- Route selection
- Frequency of service
- Convenience of service
- Probable number of passengers
- Bus capacity
- Other forms of transport•
- Costs and income

The individual elements are not mutually exclusive, as they are overlap in several areas. Example: costs and income depend on bus capacity and the number of passengers.

These elements are selected in order to restructure the problem. The aim of this technique is to break up and reorganize.

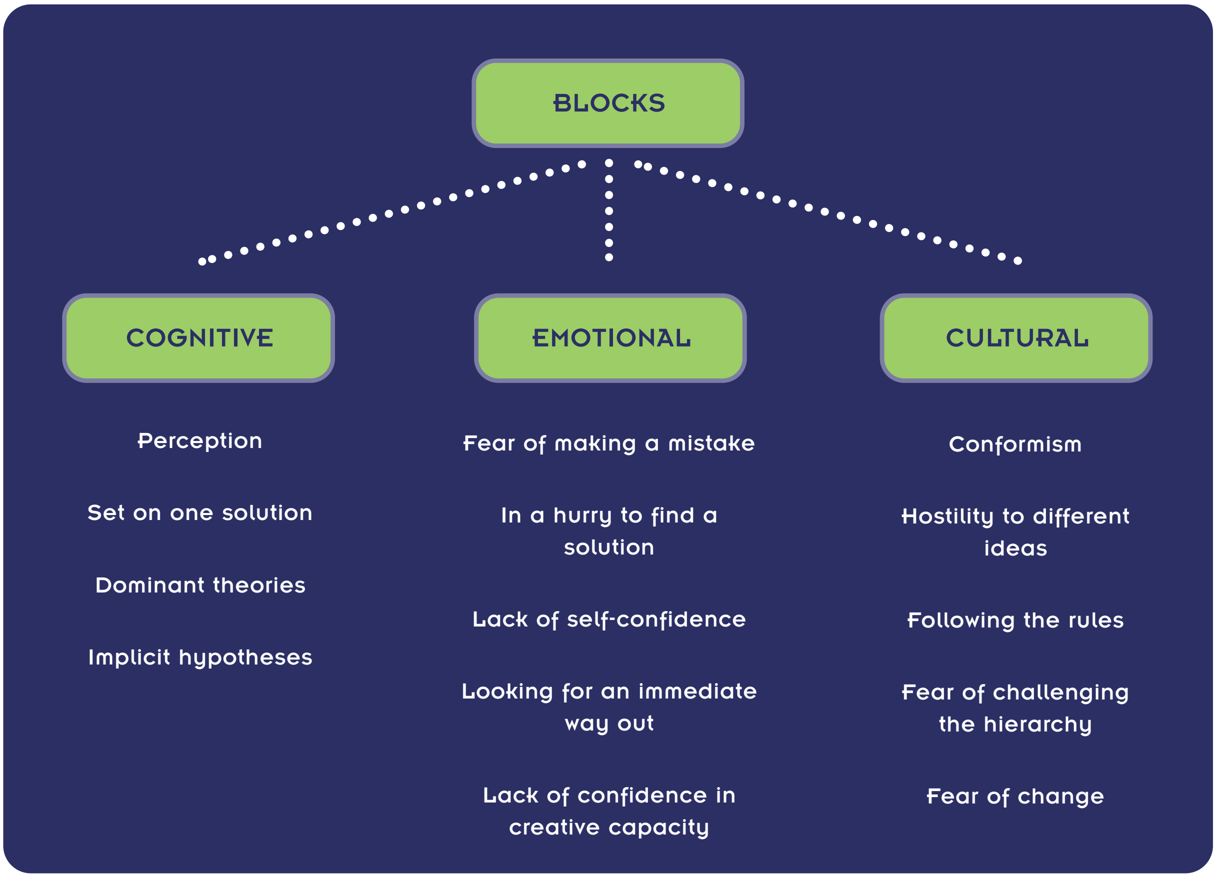
g) Challenge conventional thinking (see the following box)

5.6 Creativity blocks

There is a series of conscious and unconscious mechanisms that impedes the fluent generation of new ideas. These may be COGNITIVE (problems of perception that prevent the extrapolation of other situations or solutions), EMOTIONAL (individual concerns, fears and insecurities that get in the way of creative freedom) or CULTURAL (rules and values which are transferred socially from generation to generation or which belong to the organizational culture itself).

It is important to be aware of their existence so that creative capacity can be consciously uninhibited. It is essential, therefore, to create the proper relaxed atmosphere.

There is a series of conscious and unconscious mechanisms that impedes the fluent generation of new ideas.



PHASE 2: PROJECT SELECTION

IDENTIFICATION

A
B
C

NEW PROJECTS

+

PROJECTS IN PROGRES

1
2

PROJECT PORTFOLIO

Visualization

PROJECT MAP

Offers a graphic representation of how projects are distributed and diversified, showing areas where they are lacking.

SELECTION

A B C

COMPANY STRATEGY AND A VISION OF THE FUTURE PROVIDE THE **SELECTION CRITERIA**

- What are the organization's key competencies
- Which businesses to we want to have a presence in?
- What is our market position (competitors, suppliers, customers)?

~~B~~

A C

APPLY QUANTITATIVE AND QUALITATIVE CRITERIA IN ORDER TO **EVALUATE RISK AND ASSESS PROJECT FEASIBILITY**

- Expected cost-to-profit ratio
- Size of company
- Technical complexity

~~A~~

C

THE PROJECTS SELECTED MOVE ON TO THE NEXT PHASE

6 PHASE 2: PROJECT SELECTION

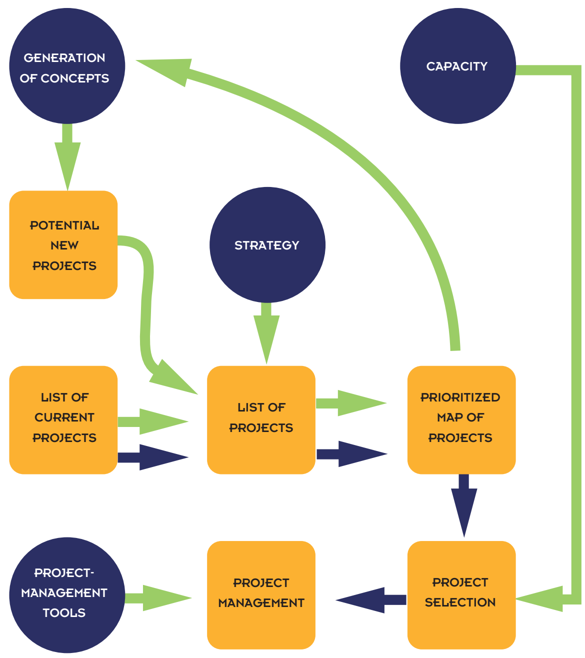
6.1 Introduction

The selection of suitable projects to which the company is to allocate significant resources is the first and most critical stage in project management. If the proper selection is not made, then however perfectly the project is managed, it will not provide the company with the results it requires. We must ensure that what we are doing actually needs to be done before we ensure that we are doing it correctly.

This is the first and most critical stage in project management.

Selecting projects by evaluating them one by one as they arise should be avoided. Projects should be managed in an integrated PORTFOLIO and they should all be compared with one another.

When selecting projects we must first identify the projects on which the company is working and those on which it should work in accordance with its own strategic alignment. Projects are selected on the basis of project specifications or formulas (specific information), planning that allows projects to be prioritized according to their strategic importance for the company and the company's own capacity to develop them. Selecting projects by evaluating them one by one as they arise and making decisions about each of them individually should be avoided. On the contrary, projects should be managed in an integrated PORTFOLIO. It is important to prioritize projects, compare them with one another and keep them all in view and prepare an annual or at least five-yearly plan.



There are several reasons why a project may be attractive for an organisation:

- Strategic reasons
- Profitability
- Survival
- Learning
- Etc.

To be able to do this, it is useful for a company to pursue the following steps:

1. Make a list of all current and proposed projects. This list can be prepared on the basis of a review of the projects currently under way at the company and the concepts generated by the process outlined in the previous section (see Chapter 5: “Generating ideas”). It should be pointed out here that this doesn’t have to be an exhaustive review. The time allocated to “discovering” what the company is doing should be limited, thus leaving more time available to describe what needs to be done.

2. Create a map or portfolio of potential projects. This will include both existing and proposed projects. It is useful to visualize them in graphic form, including values such as their expected impact, difficulty of execution (or probability of success), the degree of innovation involved in the product or process and an estimate of the resources required.

3. Establish the areas in which projects are lacking. Make an effort to define new projects in these areas, where they are considered relevant (principle of risk diversification).

4. Review company strategy, placing special emphasis on technological and innovation strategy, in order to establish which values are important for project evaluation and with the aim of being able subsequently to select those projects which are most closely in line with the company’s vision.

5. Make a careful selection from the projects presented as a result of the preceding steps, bearing in mind any limitations in the company’s capacity and the different criteria followed (strategic, economic, environmental, etc.).

We will now outline a series of concepts and useful tools for implementing the tasks described above.

It should once again be recalled that the innovation unit is the project itself (and not necessarily the new product!) and this may lead to confusion in many companies. We are thinking of projects in which the aim is to develop technological platforms or new manufacturing or marketing processes, which could be decisive innovation projects even though they do not necessarily result in new products.

6.2. List of projects

Many companies do not have a clearly defined idea of the projects on which they are working or the projects to which they intend to allocate resources. In order to select the projects in which resources are to be invested, it is essential that they are properly identified and continue to be clear to anyone involved in them (within the limits of required confidentiality). For this to occur, it is necessary to create a list of specifications for the project, with its identifying characteristics, its projected aims, its conditions and any preliminary development costs (see Chapter 3).

6.3. Selection criteria

There are several kinds of criteria that assist in the selection of innovation projects. They can basically be divided up into qualitative, quantitative and mixed criteria.

Qualitative criteria are used when it is considered that an investment must be made for strategic reasons (though the return on this investment may be difficult to estimate), in order to ensure future competitive advantages for the company, to ensure new emerging markets or to reinforce key competencies.

Quantitative criteria are those that result from calculating the estimated levels of resources required and returns on investment with a minimum degree of certainty.

example

Examples of criteria used to select innovation projects

Estrategic
Strategic alignment. Does it conform to the future vision of the company?
Way in which the company competes (cost or differentiation).
Competitive advantage offered by t he project.
Exclusive benefits to customers.

Market attractiveness
Size of market.
Rate of market growth.

Key competencies
What can the company provide that is individual and attractive in comparison with its competitors?

Technical feasibility
Size of technology gap.
Technical complexity.
Reliability of results.

Return v. risk
Expected return.
Financial criteria: IRR or ROI.
Period of return.
Reliability of estimates.
Level of risk.

6.4. Strategic criteria

In order to select projects it is important to be aware of the factors that are decisive for the company's current and future competitiveness. In other words, what are the critical elements in the company's strategy? It is easy to understand that different strategies will encourage different innovation projects. In this section we will review some of the strategic definition tools that can be useful for companies.

6.4.1 A company's strategic vision or aim

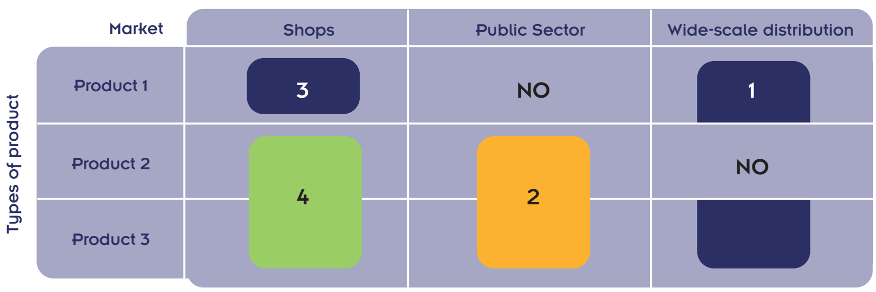
One way of selecting strategic projects is that of setting out a future VISION for the business, a hypothetical picture of how the company would ideally wish to position itself vis-à-vis its customers, its shareholders and society in general. This vision will condition the way it competes in the marketplace, the way in which it operates and the procedure it uses to allocate resources and select projects.

example

Metalquimia, a Girona-based company that manufactures machinery for the meat industry and received the Catalan Government's Technological Innovation Award in 2001, undertook the strategic challenge of transforming itself from a company that built special machinery into a worldwide reference centre for meat studies. Its vision of the future led the management team to develop innovation projects which encouraged this market positioning, while implementing powerful knowledge-management systems that became a reference point in the sector (as a service to its clients), outsourcing low-value activities (manufacturing) and reinforcing areas relating to the study of meat and improvements in meat processing, with the aim of becoming specialists in the design of meat-processing machinery.

6.4.2 Product-market focus: business areas in which we want to be involved

Another tool used in strategic decision-making is identifying the business areas (product, market and technology combinations) in which the company is competing. To do this, we can take an abstract of the actual situation, separating customers (markets) and product lines into similar categories in order to obtain a map of our **business units.** Each of these units will potentially have its own different sales, marketing, production and financing strategies. It is a question of deciding which business unit or units will be allocated more resources in the future. The innovation projects selected should reinforce these business units.



In the example shown, a hypothetical company sells three different products in three different markets. The processes supporting each product are different, as are the methods used for distribution, sales and production financing in each market. The company opts to combine business units with common synergies and to prioritize them according to their strategic policy.

6.4.3. Reinforcement of essential competencies

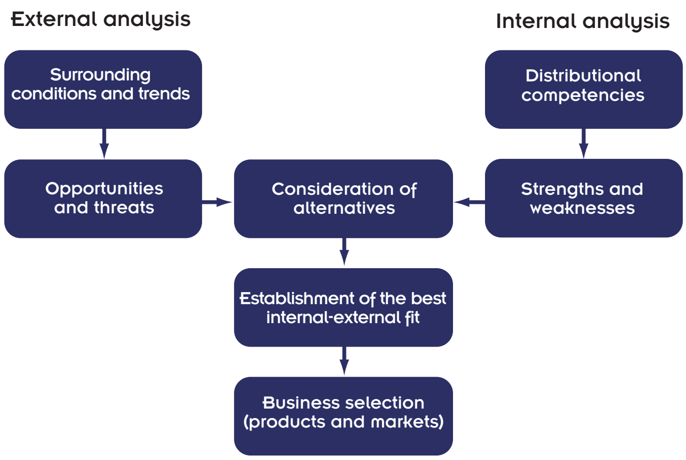
One basis for strategic decision-making can be to identify the organization's key or essential competencies and propose that any innovation project developed be aimed at strengthening one of these key competencies.

A key competency is a combination of abilities that underpin a company and contribute to generating exceptional value for its customers in a way that is unique as compared with the company's competitors and can be extended to new products or services[15].

CANON defines itself as a leader in three science and technology fields: the optical sector, microelectronics and precision mechanics. Any projects it launches are therefore aimed at reinforcing its leading position in these three areas. The products that it may manufacture at any one time are chosen on the basis of demand, while maintaining its leading position in these three combined fundamental competencies.

6.4.4 The Andrews model (SWOT)

Analysis of STRENGTHS, WEAKNESSES, OPPORTUNITIES and THREATS

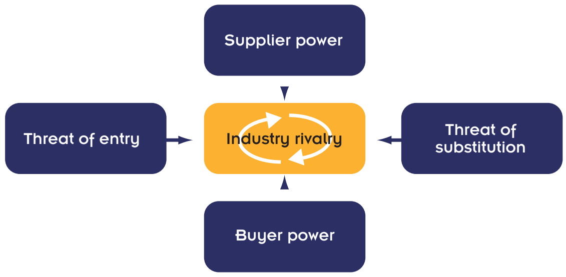


This model suggests analysing the company's external environment in order to identify opportunities and risk, as well as analysing the internal environment to identify any strengths and weaknesses. On the basis of both analyses, potential strategic alternatives are considered (future scenarios), and those with the best internal-external fit are the ones that will determine the businesses (products and markets) in which the company should position itself.

6.4.5. Porter's five-forces model

The essence of this model lies in an analysis of the company within its environment. A company's competitive advantages are strongly linked to its capacity to understand and manage external forces in the sector correctly.

The level of competition in a particular sector depends on five basic competitive forces, as shown in the diagram.



15. Gary Hamel and CK Prahalad, *Competing for the Future,* 1995.

The behaviour and evolution of these forces as a whole determine potential profitability in a sector in which potential profits are measured in the long term, based on the return on capital invested.

a) What level of internal competition is there in the sector? What advantages have been gained by companies in the same sector (differentiation, price wars, etc.)?

b) Supplier analysis: Are there dependent relationships between suppliers and our company? Do we depend on them? Do they depend on us? Could they join forces? Can we obtain discounts for volume purchases?

c) Customer analysis: What determines a purchasing decision? Are we dependent upon our regular customers? What power do they have to make demands? How satisfied are they?

d) Analysis of the potential entry of new competitors: What obstacles are there to the company's entry? How can we protect them?

e) Analysis of the potential entry of substitute products: What are the chances of our products becoming obsolete?

6.5 Quantitative criteria

6.5.1. Decision tables

Managers responsible for projects that are to be implemented usually make their final decisions with a large amount of business intuition. However, to ensure that their intuition is well founded, they must take a series of quantitative estimates into account. To do this they mainly use decision tables and spreadsheets on which financial forecasts can be laid out.

The following sheet illustrates a decision table used to evaluate a project on the basis of three main areas and their corresponding sub-divisions:

	EVALUATION						
Criteria	Weighting	1 Very poor	2 Poor	3 Normal	4 Good	5 Very good	Score
Production	40%						
Uses existing processes	10%	1					0,1
Short launch period	15%		1				0,3
High learning curve	5%				1		0,2
Supplier availability	10%			1			0,3
Marketing	30%						
Size of potential market	15%					1	0,75
Market share	10%				1		0,4
Cannibalization	5%		1				0,1
Financing	30%						
Investment NCV	5%		1				0,1
Recovery period	10%					1	0,5
Cashflow requirements	15%			1			0,45
	100%						3,2

6.5.2. Financial criteria

The following criteria are frequently used in order to make a financial evaluation:

- Recovery period: the time the project will take to recover the initial investment.
- Profitability index: anticipated profit as a percentage of required investment.
- Net Current Value (NCV): current value, discounting net cashflows (positive and negative) over time, throughout the life of the project.
- Internal rate of return (IRR): the discount rate that makes the current net value of discounted cashflow equal to nil (i.e. zero).

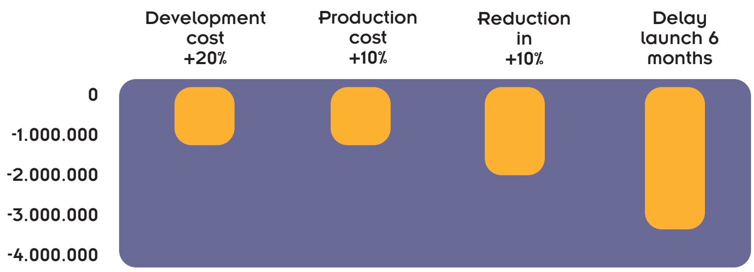
Spreadsheets are extremely useful for making a financial evaluation, since they not only allow a specific situation to be analysed, but also permit one to analyse how sensitive the results obtained may be to individual variations in the initial hypothesis.

Below is an example of a spreadsheet showing projected sales and costs:

		YEARS							
	Hipothesys	1	2	3	4	5	6	7	8
Unit sale price				7.000	6.300	5.670	5.130	4.593	4.133
Annual reduction	10								
Size of market				10.000	20.000	40.000	60.000	40.000	20.000
Market share				10%	10%	10%	10%	10%	10%
Sales (units)				1.000	2.000	4.000	6.000	4.000	2.000
Sales ( )				7.000.000	12.600.000	22.680.000	30.618.000	18.370.800	8266.860
Unit cost				3.500	3.430	3.361	3.294	3.228	3.164
Annual reduction	2%								
Cost of products sold				3.500.000	6.860.000	13.445.600	19.765.032	12.913.154	6.327.446
Gross margin ( )				3.500.000	5.740.000	9.234.400	10.852.968	5.457.646	1.939.414
Gross margin (% of sales)				50%	46%	41%	35%	30%	23%
Engineering		2.000.000	2.000.000	1.000.000	100.000	100.000	100.000	100.000	100.000
Marketing (% of sales)	16%			1.120.000	2.016.000	3.628.800	4.898.880	2.939.328	1.322.698
General (% of sales)	5%			350.000	630.000	1.134.000	1.530.900	918.540	413.343
Operating costs		2.000.000	2.000.000	2.476.000	2.746.000	4.862.800	6.529.780	3.957.868	1.836.041
EBT		-2.000.000	-2.000.000	1.030.000	2.994.000	4.371.600	4.323.188	1.499.778	103.374
Accumulated BIA		-2.000.000	-4.000.000	-2.970.000	24.000	4.395.600	8.718.788	10.218.566	10.321.940
Recovery period	4								
10% NCV	5.320.317								
ROI	39%								
ROS	10%								

It is also very useful to incorporate uncertainty in any project analysis. This can be done by simulating various scenarios (by changing the parameters of the evaluation model) or by using certain spreadsheet applications that allow for the direct entry of uncertainty in different fields on the sheet itself (probability distributions instead of fixed values). This also then gives the results in the form of probability distributions.

With the help of these tools it is possible to identify the areas in which the project is most sensitive. In the particular case shown in the above example, we can see the impact that different events might have on accumulated profits. Thus, we can see in this case, as is true of many projects, that variations in production costs or sales volumes do not have as great an influence as variations in the product's launch period.



6.5.3. Zero-base budgeting: simple and effective

Zero-base budgeting is an effective way of defining which projects should be prioritized and which should be postponed until the following financial year.

List of projects

Project	Cost
Update catalogue	5.000
Advertise product C	15.000
Internal e-mail system	20.000
New logo design	5.000
New corporate video	10.000
Extend paint section	40.000
Buy new warehouse	40.000
Replace furniture	15.000
Update CAD system	7.000
Industry show	15.000
New demonstration video	5.000
New bridge crane	25.000
Stand, Expo Barcelona	10.000
Stand, Expo Seville	10.000

Make a list of potential projects for the WHOLE year and give each project an approximate cost.

List in order of priority

Project	Cost
Extend paint section	40.000
Buy new warehouse	40.000
Industry show	15.000
Internal e-mail system	20.000
Update catalogue	5.000
Update CAD system	7.000
Advertise product C	15.000
New logo design	5.000
Replace furniture	15.000
New demonstration video	5.000
Stand, Expo Barcelona	10.000
Stand, Expo Seville	10.000
New bridge crane	25.000
New corporate video	10.000

Prepare a new list in which these projects are listed in order of their importance for the company.

Adjustment to budget

Project	Cost	
Extend paint section	40.000	
Buy new warehouse	40.000	
Industry show	15.000	
Internal e-mail system	20.000	
Update catalogue	5.000	
Update CAD system	7.000	
Advertise product C	15.000	
New logo design	5.000	= 147.000
~~Replace furniture~~	~~15.000~~	
~~New demonstration video~~	~~5.000~~	
~~Stand, Expo Barcelona~~	~~10.000~~	
~~Stand, Expo Seville~~	~~10.000~~	
~~New bridge crane~~	~~25.000~~	
~~New corporate video~~	~~10.000~~	

Now add up the individual estimates from top to bottom and draw a line above the annual budget amount available for projects.

Projects selected

Project	Cost
Extend paint section	40.000
Buy new warehouse	40.000
Industry show	15.000
Internal e-mail system	20.000
Update catalogue	5.000
Update CAD system	7.000
Advertise product C	15.000
New logo design	5.000
Total	147.000

Any projects below this line are set aside, at least for this year, unless available investment funds are increased. This is what is known as zero-base budgeting. Money available = money to be spent.

6.5.4 Other restrictions: analysis of capacity

In addition to budget limitations, as dealt with using the method set out in the previous section, it is essential to include the limitations dictated by the capacity of the company's personnel, departments or other necessary resources, since no matter how willing the workforce, if there are not enough hours available, the job will not be done.

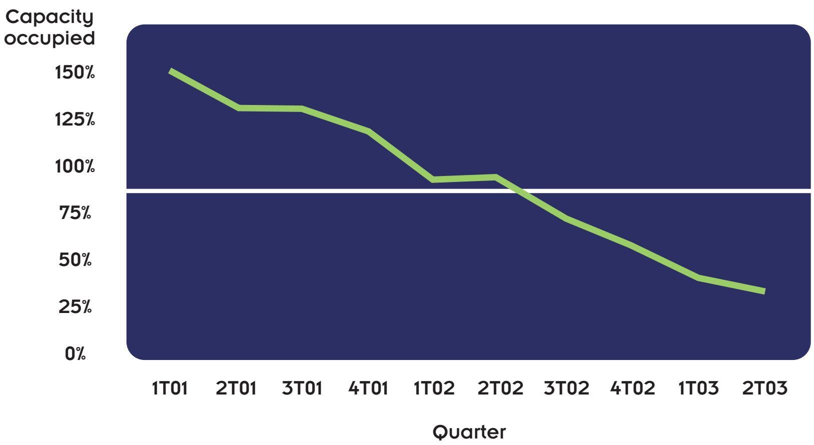
A simple way of analysing the capacity committed by a department to a group of projects is to use a diagram of aggregate capacity, which can be prepared by each department on the basis of the work the department estimates it will have to complete or has already been assigned in each of the projects approved.

Operations Department

Project	Activity	Hours allocated (pending)	Deadline
F27	New control software for cutting machinery	80	30/11/01
Miramar	Evaluation of new logistics operator	25	8/11/01
...	...	...	...

Working from this table, it is possible to group together the items required within the relevant time periods and complete a graph showing the accumulated capacity required. In this way it can be ensured that the company is not calling on more resources than are actually available, thus offering the possibility of adapting these tasks over time so that the capacity of the elements involved is not exceeded, or passing the task on to another, less busy department (wherever possible).

It is important to note that overstretching a particular resource normally results in **delays to all the projects** allocated to this resource, since in the absence of any prioritization, it is usual to distribute the time available among all the projects, meaning that they will all suffer significant delays.

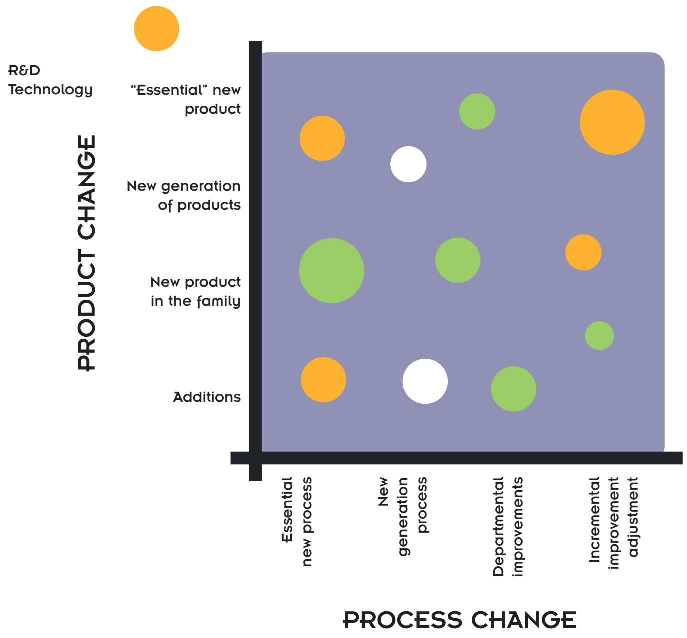


6.6. Visualizing the portfolio: project maps

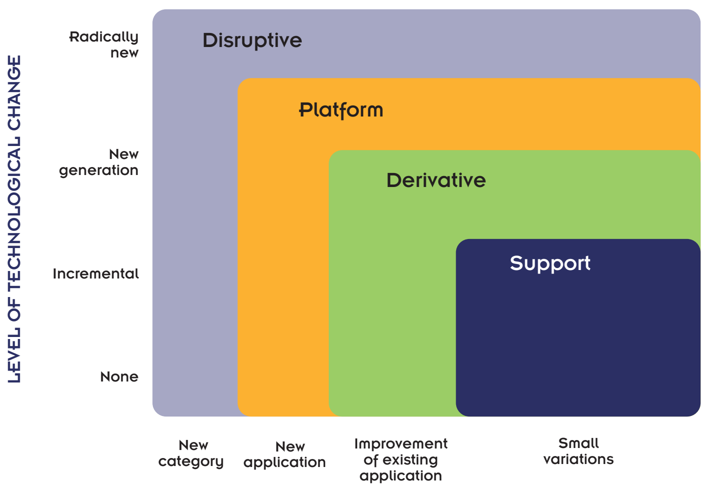
To assist in making a final decision once this quantitative analysis is complete, it is very useful to display the results in map form, usually in two dimensions, in which the projects are shown as circles, with colours signifying a particular type of project and the diameter of each circle indicating the resources allocated. These maps are useful management tools when evaluating the opportunity costs of carrying out projects of a single type and observing the portfolio's level of diversification.

The following are among the most common diagrams used:

Product/process-change diagram



Classification of projects according to the diagram



PHASE 3: PROJECT SPECIFICATION (PS)

WHAT IS THE PS?

A document listing

The steps to take

The needs the project has to meet

What must the PS CONTAIN?

IDENTIFICATION
Title and sponsors

RESPONSIBILITIES
For controlling, monitoring and analysing results

MISSION
What the project aims to do and in what context (What needs does it address?)

AIMS
Sets out the mission in measurable terms

DESCRIPTIVE REPORT
Containing the criteria used for selection, the problem to be solved and level of innovation achieved

SCOPE
Scope of project (What it does and does not aim to do)

PLANNING
Detailed sequence of activities including: phases, deadlines, leaders, budgets and control of risks

EXPLOITATION PLAN
Description of the economic scenarios that make the project economically viable

APPENDICES
Graphs, drawings and market surveys

7 PHASE 3: PROJECT SPECIFICATION

7.1 Why specify projects?

When the project manager is given the responsibility for setting up a new project, many of the company's resources – including personnel, facilities and budgets – will be affected. To use these resources effectively, the project manager must have a well-defined list of the needs to be met and the aims to be achieved, as well as the action phases and the decision points needed to monitor the project.

The specifications are used as the formal medium of communication between the various people, departments and suppliers involved in the project.

No project should ever be started without specifications clearly defining and documenting the requirements to be met. In the case of development projects, there may be some uncertainty in the different stages, not only in terms of their duration, but also in their structure, meaning that the structure of the project's activities and tasks are not decided in detail until the project is under way. There is still, however, always a clear definition of what the project aims to achieve and its scope, even though these may be modified as the project progresses.

The project specification (PS) can be defined as a working document detailing the requirements to be met and the steps to be taken to obtain a project or process that is commercially valid or affords the company competitive advantages

The PS can be defined as a working document detailing the requirements to be met and the steps to be taken to obtain a project or process that is commercially valid or affords the company competitive advantages.

It sets out the situation and the requirements that must be met if the project is to be successful.

The PS is the document that contains all the data connected with the project or process to be designed or innovated. It is the best tool with which to clearly establish the scope of the project.

It is a dynamic document that evolves as the project progresses

7.2 What form does the PS document take?

It is a dynamic document that evolves as the project progresses. It should also be shared amongst all the company's departments involved so that all of them feel constantly involved in and committed to the project. All areas have to play their part in this evolution, especially at the start of the project.

The starting point for any innovation project is an idea that gradually evolves and becomes more sharply defined as results from research, analysis of the competition, preliminary studies and similar work become available. With this information, the PS gradually takes shape and is constantly updated, as products that arise from a mere outline of an idea on a sheet of paper – stemming from basic ideas that have not been jointly agreed upon, shared among departments or developed from contributions from different people and departments – are unlikely to lead to competitive and original projects.

If the requirements change during the course of the project, the specifications have to be formally revised to keep them up-to-date with the latest modifications.

The PS has to be broad-based and clearly written in language that can be understood by all the departments involved.

The PS must develop in detail the initial datasheet prepared to select the projects. This datasheet (see Chapter 3) contains the product identification, aims, and anticipated resources and deadlines.

The PS must develop in detail the initial datasheet prepared to select the projects

7.3. Basic requirements of the PS

List to serve as a guide for preparing a PS (minimum requisites)[16]

1. Identification
2. Responsibilities
3. Introduction / Mission (opportunity or problem to solve)
4. Aims
5. Descriptive report
6. Scope
7. Planning
8. Exploitation plan
9. Appendices

1. Identification

Gives the project a title, identifies its sponsors and locates it within the organization.

2. Responsibilities

The organization will appoint someone to take responsibility for preparing, controlling and monitoring the project and making use of its results.

16.See standard UNE 166001, "Requirements for an R&D&I project".

3. Introduction

This is aimed at people affected by the project but not familiar with it, as well as all those directly involved. It sets out the problem or situation that prompted the project and gives any relevant past aspects useful for carrying it out. Fundamentally, it provides a shared vision of the master plan of the project and puts it in context. It must succinctly express what the project aims to achieve (in thirty words or fewer).

4. Aims

The project aims

set out

the project mission

in measurable terms

The project aims set out the project mission in measurable terms and must be:

- Specific and clear enough for everyone to interpret them in the same way when reading them.
- Measurable – with information on how results are to be measured – so that afterwards we can determine to what extent they were met.
- Realistic, i.e., not utopian, but demanding enough to motivate the team carrying out the project.
- Relevant to the project mission.
- Defined within a timeframe, with a clear timetable and deadlines.

A set of well-defined aims that are shared within the organization is one of the keys to a successful project.

5. Descriptive report

This provides a reference of past experiences so the reader can understand the selection criteria followed by management when deciding to launch the project. It includes:

- The problem to be solved: it defines the specific issue that the project aims to resolve.
- Opportunities provided and their significance for those involved.
- The strategy to achieve the envisaged aims: summary of the main activities, estimation of resources and allocation to the participants.
- A description and quantification of results: the results are described and quantified, with forecasts as to their ownership, mechanisms for their use and release.

A set of well-defined aims

that are shared

within the organization

is one of the keys

to a successful project

- Specification of the product or process, in the case of development projects (technical and market specifications). It is useful to have a formal document containing these specifications (a “contract booklet”) and approved by technical managers and representatives of the customer the project is being prepared for. For an example of the methodology used to combine these two foci, see Appendix 1, *“Two Parallel Visions: Technology and the Market”.*

• Standards and legislation that could affect the project, at both national and international level and from any country that may be involved in carrying out the project. Reference should also be made here to the quality standards being followed17, as well as any aesthetic aspects to consider.

• The level of innovation the project aims to achieve for the organization: a study of the state of the art, description of what the project provides that is new, the current technical situation, kind of project (see Chapter 3) and how it differs from usual ones, technical limitations on achieving the aims, scientific and technological advances created by the project (if any), its originality and justification.

In the case of the development of new products or processes, when beginning specification and planning, it is important to consider any constraints on scaling up the project up or limitations of the production plant where the project is to be produced industrially (see Appendix 2: Project Industrialization).

6. Scope

This clearly defines the project's scope and is crucial for marking its start, end and any deviations that might occur in developing and implementing the project. Both the positive side (what the project aims to achieve) and the negative side (what is not considered) should be defined. Right from the start an effort has to be made to clear up any ideas project members may have that could be the cause of later disagreements. Avoid giving in to the temptation of progressively extending the scope of the project to solve problems that turn up as the project progresses. The initial definition of the scope should be continually revised and other independent projects defined to deal with aspects not included in the project in hand.

Correctly identifying the scope of the project will aid in the process of determining the execution and coordination phases to be followed, as well as allocating the necessary resources and personnel to ensure the project is a success.

Both the positive side (what the project aims to achieve) and the negative side (what is not considered) should be defined

7. Planning the allocation of resources and deadlines[18]

This is the most substantial specification section and basically specifies the actual work sequence to be carried out. It contains:

• A detailed sequence of the activities to be performed and the phases that make the sequence up, as well as the targets for each stage and the corresponding resources allocated.

17. The project should be covered by the organization's quality system.
18. For more detailed information on tools for planning projects, see the following chapter.

• The structure of the organization and personnel. Definition of responsibilities for each phase of the project. It includes the profiles and responsibilities of the main team members and clearly defines the functions of each person and department.

• Timetable for activities. Interplay between project phases or tasks. Flowcharts (Gantt, PERT, etc.). Estimated duration of each phase and the associated degree of uncertainty.

• Control structure. Defines the decision points and the decision-making process as the project develops. Quality and control steps to be taken, how often data will be gathered and monitoring meetings held. Records and their connection with the organization's quality system. Mechanisms and responsibilities to ensure targets are met at each stage.

• Identification of risks and critical points that may be relevant when developing the project. Forecast for managing changes and contingencies.

• Budget allocated and how it will be controlled. Description of resources needed for each task.

• Quality plan. Identification of similar projects carried out, connection with the organization's quality system (if any) or that of any other organization taking part in the project, mechanisms for identifying and recording the information and documentation generated.

8. Exploitation plan for results

This includes a description of economic scenarios associated with the project that make its preparation economically viable, especially:

• Action to make use of the project and publicize its results.

• Impact of the new product or process (if this is the result of the project). Possible applications, public aim, potential market, description of the product's features, policy on pricing, distribution and sales.

• Mechanisms to protect and publicize results.

• Use of results: players involved, policy on protection of intellectual property, ways innovation can provide a return. Quantification of the return (business plan).

• Investment and financing mechanisms.

• Provisional operating account.

• Industrial and economic benefits generated by the project: how the project's results contribute to economic growth and improving the organization's and the industry's competitiveness.

The exploitation plan for results includes a description of economic scenarios associated with the project that make its preparation economically viable

For a more detailed description of the documentation recommended for preparing the PS, see standard UNE 166001, "Requirements for an R&D&I project"

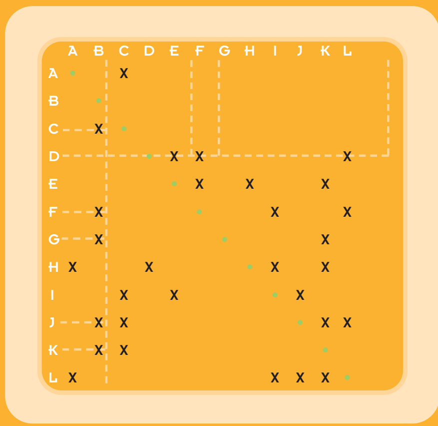
9. Appendices

Any kind of appendix that accompanies the specifications and makes them clear and more explicit. Graphs, figures, drawings, market surveys, etc.

Clearly, the level of development of the set of specifications may well be simpler in less complicated projects. Nevertheless, we must stress once again how important documentation is to set out explicitly the views of the different managers and departments involved.

PHASE 4: PROJECT PLANNING

Splitting the project into tasks (subprojects) and work packages



Assigning responsibilities

Estimating duration, resources and costs

Work-package and delivery control plan

Diagramming the project

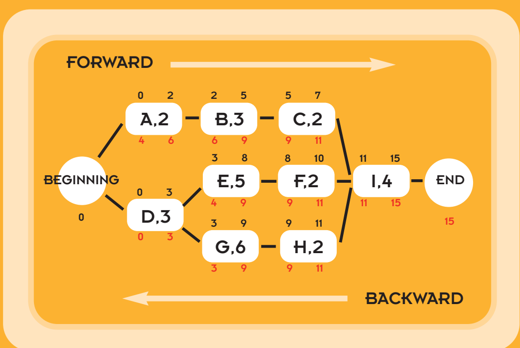
Activity and disbursement plan

Risk management

Balancing resources

Activity and disbursement plan

Communication and documentation



8 PHASE 4: PROJECT PLANNING

Innovation projects should be planned in the same way as any other project that we decide to carry out. The fact that most innovation projects have a high degree of structural uncertainty does not invalidate the need for planning, but rather makes it all the more necessary. This also guarantees frequent and fluid planning of the process of monitoring everyone involved. If a project is not planned, it is, by definition, impossible to control.

Project planning may include the following activities. However, it is not necessary to use all of them for all projects, or to complete each step meticulously.

1. Splitting the project into work packages.
2. Assigning a coordinator for each work package.
3. Estimating duration, necessary resources and costs.
4. Work-package and delivery control plan.
5. Diagramming the project.
6. Risk management.
7. Balancing resources.
8. Establishing the critical chain.
9. Activity and disbursement plan.
10. Communication and documentation.

The project-specification and project-planning phases are closely related. When planning, therefore, it may be necessary to change specifications as initially unforeseen restrictions arise. It may be necessary to repeat both phases several times until they are coherent and feasible.

We will now briefly describe each of the activities involved in planning.

8.1 Splitting the project into tasks and work packages

Projects tend to be too large to be integrally controlled and must be broken up into subprojects. Subprojects are then split into work packages and tasks.

Tasks should be defined in such a way as to leave no room for ambiguity, and their scope should be clearly defined in order to later establish and control the time and resources needed for their completion.

Projects tend to be too large to be integrally controlled and must be broken up into subprojects. Subprojects are then split into work packages and tasks

Each group of related tasks will be included in a “work package”, to be overseen by one individual who will keep track of its progress throughout the project.

The five basic stages of project planning.

I. Define the work as independent tasks that can be arranged sequentially, assigned and traced.
II. Define the tasks with a level of detail appropriate to the length and complexity of the project.
III. Arrange the tasks in a general sequence with a beginning and an end. This will involve combining tasks in “work packages” (also known as subprojects).
IV. Present the sequence of tasks in a way that can easily be explained to all members of the project team.
V. Ensure that the resulting tasks are carried out and verify that the project’s objectives and requirements are met.

The more time we devote to the planning stage, the more time we will save once we begin to execute the project.

Likewise, it is important to define (tangible) deliveries related to the different tasks, in order to be able to determine the moment in which each task has been completely finished. This point is essential to the preparation of progress and project-monitoring reports. The stage-gates model (Chapter 4) can be used for this purpose.

8.2 Assigning a coordinator to each work package

According to the relationship between the different tasks, work teams will be assigned to the different work packages. These teams, which are usually multidisciplinary, are supervised by a single coordinator who is responsible for the completion of the work package.

It is a good idea to make sure that no one is overloaded with responsibilities while others have no responsibilities assigned to them. It is impossible to guarantee that individuals will be able to deliver what they have promised, even with the best of intentions, if the commitment is too great.

Work teams will be assigned to the different work packages according to the relationship between the different tasks

8.3 Estimating duration, necessary resources and costs

We must estimate the duration (in calendar days) of each task or work package and the exact commitment required of each person, department or team in order to complete it. It is important not to confuse these two concepts. It may take a couple of weeks to complete a task, even though it only requires a few hours of work (because a permit authorization has to be requested, for example).

We can calculate the buffer time needed to achieve a certain degree of assurance that deadlines will be met.

It is just as important to know the uncertainty of the expected duration of an innovation project as it is to know the duration itself. In order to do this, estimates should be expressed as ranges rather than precise time periods. That is, instead of estimating that an activity will take approximately 3 weeks, it is more useful to know that it will take between 2 weeks (if everything goes well) and 5 weeks (in the worst-case scenario), with 3 weeks being the estimate with greatest probability. The greater the range, the greater the uncertainty.

The work plan is then prepared, based on the most probable estimates. Using the degree of uncertainty (the range in the estimates), we can calculate the buffer time needed to achieve a certain degree of assurance that deadlines will be met.

Regarding resources, we must estimate the time that each resource must be dedicated to the project in order to complete a task. This estimate will assist us in making sure that we do not overload resources beyond their capacity and will help make sure we meet the established deadlines.

Finally, we can estimate the costs associated with each activity, either overall or by budget items, depending on the company's preferences. Obviously, greater detail allows for better monitoring and subsequent learning, but also requires more data-collection effort.

8.4 Work-package and delivery control plan

For newer projects where the company or different coordinators do not have very much experience, it is important to define what it means to "meet needs" and how to guarantee that needs are met. Precise quality standards should be defined for work packages and deliveries as required. If possible, a checklist should be also prepared in order to verify that the different steps are being completed. For each work package, it is necessary to define the conditions that determine its completion, decide who will be responsible for verifying its completion and establish an appropriate way of recording what takes place.

Precise quality standards should be defined for work packages and deliveries as required. If possible, a checklist should be also prepared in order to verify that the different steps are being completed.

8.5 Diagramming the project.

Once we have defined the estimated tasks and their durations, we can put them on a time scale to determine when each of them can and must begin. In order to do this, we must define the dependencies that exist between them. That is, we must establish which tasks must be finished and provide information before other tasks can be begun. It is very useful to do this definition exercise as a team, with the different task coordinators, so that they can share their different perceptions of how the project is going to be carried out. The ideas about dependencies that come up during this discussion can be represented using symbols in a dependency matrix, as shown in the figure.

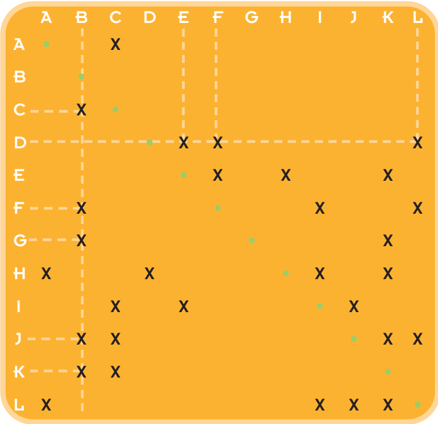


fig.1

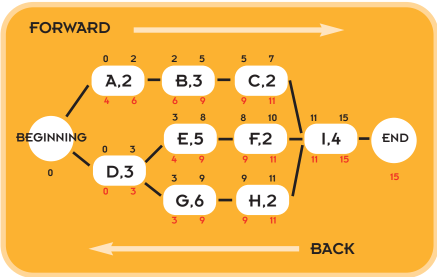


fig.2

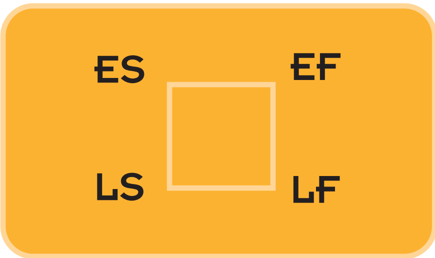


fig.3

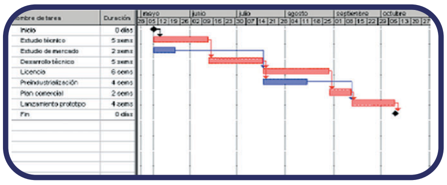


fig.4

This project is split up into twelve tasks, represented by the letters A to L. The Xs indicate the dependencies. Therefore, task D requires information from tasks E, F and L, and task B provides information that is needed for tasks C, F, G, J and K.

Ideally, a coordinator should be in charge of each task in order to ensure the flow of information.

Once the priorities have been established, the project can be diagrammed.

The starting point is drawn first, followed by the activities that are not dependent on any others. We then draw the activities that are dependent on the activities that have already been drawn, and so on until all activities have been drawn. Activities that are not followed by any other are connected to the ending point.

Based on this diagram and the estimated duration of each task, we can calculate the earliest date that each activity can start (ES) and finish (EF) and the latest date that each activity can start (LS) and finish (LF) and still complete the project as quickly as possible.

Figure 2 shows a project made up of 9 activities, A, B, C, D, E, F, G, H, and I, where activities are represented sequentially as boxes showing the name of the activity and its expected duration. As we can see, activity F can start when E is finished. In a best-case scenario, it will begin on day 8 and finish on day 10. Keeping in mind that the longest path of activities, which represents the minimum time needed to complete the project under ideal circumstances (**the critical path**) is D-G-H-I (15 days), task F has to be finished on day 11 and begin on day 9, at the very latest.

Planning large-scale projects can be extremely complicated. Project-management software can simplify this stage significantly.

Once we have prepared the diagram and calculations, we are ready to draw a Gantt diagram. This is the most commonly used type of diagram for communicating plans and monitoring projects, because it is easy to prepare and read (Fig. 4).

The diagrams for the first projects are likely to be very detailed, while those for later projects are much more vague. This is not cause for concern. As the project advances, more information will be generated and new activities will be more clearly defined.

8.6 Risk management

However optimistic we may be while planning a project, reality is still very unpredictable, and things may not turn out as well as we had planned. For this reason, it is a good idea to systematically go over all of the events that could have a negative impact on the project. It may be possible to avoid them or at least mitigate their consequences. This can be done by using the following five-stage approach:

However optimistic we may be while planning a project, reality is still very unpredictable, and things may not turn out as well as we had planned

a) Identify risks: Create a list including everything that could happen.

b) Determine impact and probability: Classify the events according to the impact that they could have on the project and by the estimated probability of their occurrence.

c) Possible actions: For risks with high impact or probability, analyze possible actions that could be taken to improve the chances of the project's success:

- Changes to eliminate or reduce the possibility of occurrence.
- Contingency plans designed to reduce impact.

d) Control and monitor: Implement the agreed-upon actions.

e) Documentation: For use as a learning tool and in later projects.

Specific techniques exist within this general outline that can help to better prevent and systematically minimize some risks by using a system that evaluates the possibility of occurrence and impact and prepares for contingencies according to their seriousness. One technique used is FMEA (Failure Mode and Effects Analysis)[19].

In the event of incompatibility of resources within a project, it may be necessary to change plans to resolve conflicts

8.7 Balancing resources.

Resources are not usually assigned exclusively to innovation projects, especially at SMEs. That is, individuals work on innovation projects while at the same time carrying out other tasks related to their functional responsibilities. Therefore, the problem of balancing resources does not usually arise from the tasks that make up a project. Instead, it is a matter of freeing resources from everyday tasks in order to be able to dedicate the necessary amount of time to the project. However, assigning resources is vitally important to innovation projects. For this reason, the sponsor, a top manager who guarantees that resources are assigned and dedicated to the project, is an essential figure.

19. See *Eines bàsiques de qualitat*, Catalan Quality Centre, CIDEM.

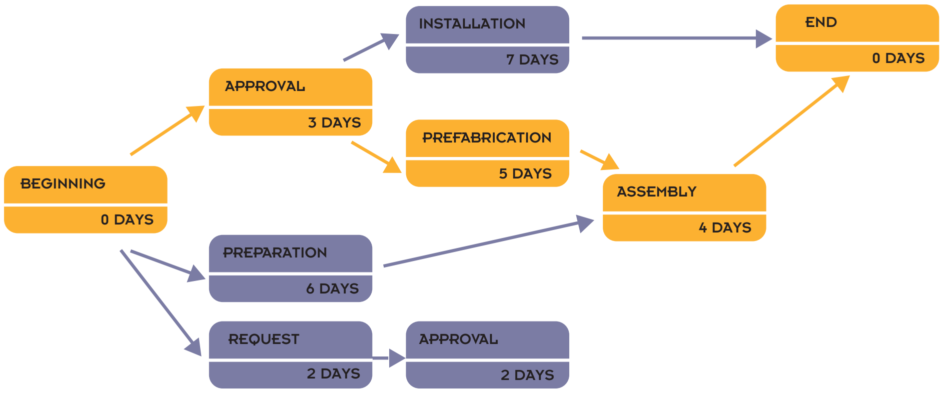
In the event of incompatibility of resources within a project (one person assigned to different tasks at the same time), or with another project, or with everyday tasks, it may be necessary to change plans to resolve conflicts, which could delay some activities and cause the whole project to fall behind schedule.

8.8 Establishing the critical chain

Once the diagram has been prepared, risk-prevention or contingency actions have been implemented and resource conflicts have been resolved, we can see that the total duration of the project is determined by a series of tasks that are usually linked and sequenced (although they may also be related because they use the same scarce resource). The sum of the individual durations of these tasks equals the total duration of the project.

The **"critical chain"** is made up of the activities that determine the total length of the project. If no conflict of resources exists, the critical chain will be the same as the critical path seen in example 2.

The project manager should concentrate on managing the critical tasks. It may also be prudent to include time buffers at the end of the critical chain, as well as at the end of the task chains that are not critical yet have an influence on the critical chain. Controlling the critical chain is essential to controlling the project. The incorporation of time buffers protects the critical chain from being influenced by the other activities.



8.9 Activity and disbursement plan

After planning and making adjustments, we are ready to decide when each task will be started and when it will be finished. With this information, along with the definition of the resources involved and other costs related to the tasks, we can prepare an activity, resource-use and disbursement plan similar to the one shown in the following figures.

Starting and ending dates for the project activities:

Tasks	Starting date	Ending date
A	15 January	20 March
B	15 January	30 April
C	10 February	31 March
D	3 March	20 April
E	15 March	15 June
F	1 January	25 June

Hours that Department X is assigned to the project:

Tasks	January	February	March	April	May	Total
A	25	40	25			90
B	10	10	10	30		60
C		50	100			150
D			25	100		125
E			10	20	35	65
F				15	60	75
Total	**35**	**100**	**170**	**165**	**95**	**565**

Anticipated project costs:

Tasks	January	February	March	April	May	Total
A	7,900	12,600	7,700	2,500		30,700
B	3,700	3,000	3,100	9,900		19,700
C		15,400	30,600			46,000
D		2,000	8,000	30,200	1,500	41,700
E			3,700	6,900	10,500	21,100
F				4,800	18,200	23,000
Total	**11,600**	**33,000**	**53,100**	**54,300**	**30,200**	**182,200**

8.10 Communication and documentation

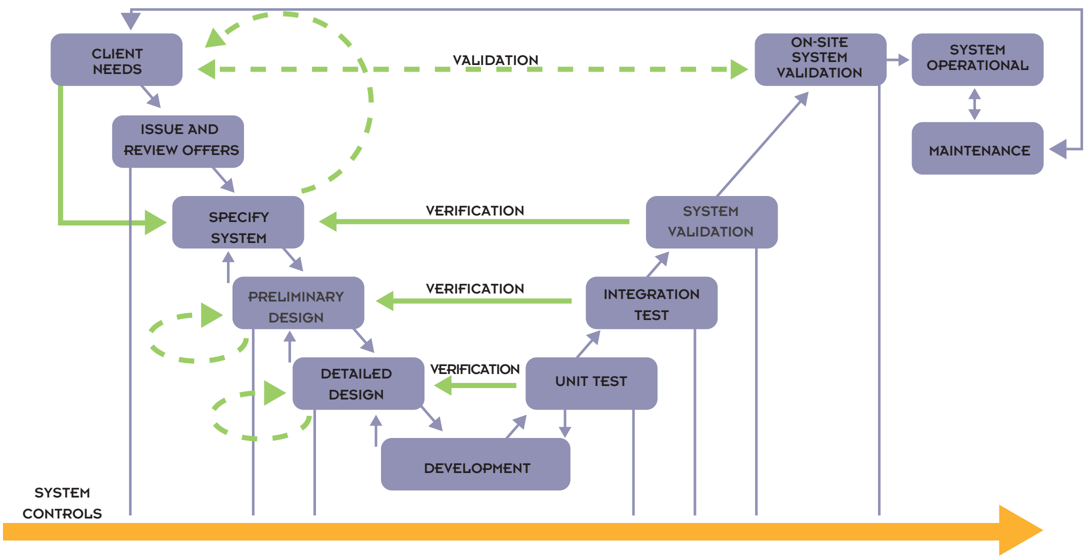
The results of the different planning stages described in the previous sections are useless if not documented and communicated to everyone involved in the project. Obviously, the participation of everyone involved in the planning process is essential, but they must also be informed of the final result of the planning and the responsibilities that they will have to assume.

This communication should be maintained throughout the execution and monitoring of the project.

example

Project planning at GTD

GTD, winner of the Catalan Government's Technological Innovation Award in 2001, is a control-software company that uses a V-shaped project-management system that is defined starting the moment a client need is detected. As the project progresses, the company documents and audits every step in accordance with the UNE-EN-ISO 9000:2000 standard.



PHASE 5: PROJECT EXECUTION

WHEN EXECUTING THE PROJECT, IT IS VITAL TO **MONITOR** IT CLOSELY AND CONSTANTLY **UPDATE** THE INITIAL PROGRAMME.

WHAT IS MONITORING?

Being on the lookout for any unavoidable **DEVIATIONS** from the programme in order to control the programme's development and regularly **UPDATE** it.

WHAT DO WE MONITOR AND HOW?

EFICIENCY AND TIME

(Do we get the anticipated results within the time allocated?)

Through regular **MEETINGS** to exchange information that is then recorded in the minutes.

BUDGETS AND RESOURCES

Is the expenditure forecast on target? (Person-hours are also a resource allocated to the project.)

Through regular **REVIEW OF THE EXPENDITURE BALANCES** and control of the time to carry out tasks.

9 PHASE 5: PROJECT EXECUTION

9.1 Project monitoring and control – sticking to the time and cost forecast

All projects inevitably experience deviations; the important thing is to know whether they are significant or not. Thorough monitoring allows us to determine how important these differences from the foreseen situation are so the necessary decisions can be taken.

Steps for successfully controlling the project:

1. **Use the project programme** (Gantt chart) as the main tool for coordinating the project. This is why this guide puts so much emphasis on the planning stage.

2. **Monitor the programme and constantly update it.** The programme pinned to the office wall does not in itself guarantee the aims will be met. To be of any use, it must be regularly updated so that it shows the current state of progress

3. **Remember** that communication/information is the key to effective control. It is never good to have too much or too little information. Everyone within the organizational structure of the project needs information at different levels of detail. Top management requires progress reports, whilst the working team members need much more detailed information. See the section entitled Review Meetings below.

4. **Regularly monitor project progress** and check it against the programme to identify and anticipate deviations from the budget, deadlines and tasks defined in the initial programme.

5. **Get involved.** Although you might have highly sophisticated monitoring systems and methods at your disposal, always check every last detail yourself. Every successful project needs the project manager to make a special effort above and beyond the work of other team members.

6. **Be flexible when faced with changes** in execution time, budget and work plans to keep the project within its original parameters.

7. **Document project progress and the changes that have occurred.** Ensure this information is made available to all those involved, from management to all the working team members.

8. **Make the most of finishing activities** early to start others ahead of schedule, i.e., do not be bound by the programme deadlines if there is the chance of starting an activity ahead of schedule. This will enable you to take advantage of positive deviations to compensate for later negative ones.

All projects inevitably experience deviations; the important thing is to know whether they are significant or not. Thorough monitoring allows us to determine how important these differences from the foreseen situation are so the necessary decisions can be taken

9.2 Project Review Meeting

Regular review or monitoring meetings provide a unique opportunity to transfer information and clear up important points. These meetings coordinate teams and members working on the same project.

They take place at regular intervals and are chaired by the project manager, who tries to focus on the areas that are most important at the time of the meeting.

They take place at regular intervals and are chaired by the project manager

These meetings serve to solve problems and must be efficiently run to avoid becoming the source of new activities that complicate the project. Therefore, they ought to be short and sharply focused and minutes should be kept and made available to all team members.

9.3 Budget monitoring and control

Review meetings are normally good for monitoring efficiency and time, but budgets and costs call for special monitoring techniques.

As an example, three kinds of budget monitoring and control follow:

1. Activity-by-activity control

In the Gantt chart, tasks are monitored individually, their development is checked and the amount spent thus far is compared with that budgeted. The best way to control this kind of monitoring is to draw up a graph or spreadsheet of the expenses generated by each task.

2. Control of all project contingencies

This control is based on the creation of a safety margin for costs and time, once the project is defined. That is, once all the activities without a safety coefficient are added up, the resulting total is given a margin of N days and X amount of additional budget resources to cover unforeseen turns of events and deviations (contingencies account). Contingencies should be divided into three warning levels. The first concerns safety, the second serves as an alarm and the third requires action if the project is to be completed within provisions.

Contingencies should be divided into three warning levels. The first concerns safety, the second serves as an alarm and the third requires action if the project is to be completed within provisions

Consequently, when starting monitoring and passing through each of these levels, we will have to carry out a series of actions designed to deal with these contingencies.

3. Earned-value method

In many projects, regularly updated controls of expenses are often carried out and compared with the initial plan. However, cost is not the only variable of interest and in many cases just because a project sticks to the expense plan does not necessarily mean it is controlled. The earned-value method allows for additional monitoring of project progress and the resources used.

Below is a short example to illustrate these concepts. Imagine a project in which activities are scheduled to be completed by a certain date, e.g., activities 1 and 2 must be done by 1 January 2002.

example

The forecast consumption of resources was:

RESOURCE PLAN

Execution of activity 1	*20 person-hours (ph)*
Execution of activity 2	*30 ph*
TOTAL PLANNED	*50 ph*

However, when the results are revised, we decide that the first activity is finished, but the second is only half done. The project's progress, measured in the same units as those used for planning, would be:

Review day: 1 January 2002

CONTROL OF WHAT HAS BEEN DONE (1 January 2002)

Execution of activity 1	*100%*		*20 ph*
Execution of activity 2	*50%*	→	*15 ph*
		→	
TOTAL CARRIED OUT	*50%*		*35 ph*

The project is 15 ph behind schedule (equivalent to 30% [15/50])

Let's look at the total person-hours actually spent on the project:

RESOURCES CONSUMED (1 January 2002)

Execution of activity 1	*18 ph*	
Execution of activity 2	*25 ph*	
TOTAL CONSUMED	*43 ph*	
TOTAL PLANNED	*40 ph*	*100%*

As 35 ph was budgeted for what has been done, we can also see that the project is over budget in terms of resources, as it has consumed 43 ph, corresponding to a 23% [(43-35)/35] deviation.

These deviations can be extrapolated to the rest of the activities and used to redefine the finishing date and the resources needed to complete the project.

PHASE 6: CONCLUSION AND REVIEW

1 PROJECT COMPLETION

- Administrative conclusion (accounts, etc.)
- Subsequent monitoring plan
- Gathering of information from team members and preparation of report

POST-MORTEM ANALYSIS 2

- Self-criticism
- Comparison of execution with plan:

  Were aims met?

  Within deadlines?

  Using the forecast resources?

3 KNOWLEDGE MANAGEMENT

- Information and communication technologies provide the means to make the knowledge generated by the project available to all those who might need it

10 PHASE 6: CONCLUSION AND REVIEW

Once a project is completed, its development has to be evaluated to document the positive and negative experiences so they can be borne in mind in future projects.

Right from the start of the project, it is important to have a view of the final tasks and also incorporate the evaluation tasks and the possibility of cancelling the project or putting it on hold before it is completed.

When a project is completed, there are three different stages to be considered:

1. Project completion
2. Post-mortem analysis
3. Knowledge management

> Right from the start of the project, it is important to have a view of the final tasks and also incorporate the evaluation tasks and the possibility of cancelling the project or putting it on hold before it is completed

6.1 Project completion

When a project is completed, we have to check that the requirements and deadlines were met and at the same time carry out administrative and contractual closure to ensure the internal or external customer is satisfied. The list of activities includes:

- Administrative conclusion, closing accounts, etc.
- Conclusion of the contract with suppliers, if necessary
- Subsequent monitoring plan
- Gathering information from team members and customers
- Calling a meeting to review the project with the sponsor
- Acknowledgement of each member's contribution
- Preparing a report on project conclusion

6.2 Post-mortem analysis

The post-mortem analysis is carried out when the project has been completed with the aim of reviewing everything that took place during project execution to draw lessons to improve future project planning and execution.

This review must include all those involved in the project, including areas or departments that experienced problems and participants who might be critical. Self-criticism should be encouraged, keeping personal aspects (which should not be addressed) separate from those connected with the project: hard facts and data should be used; supposition and rumour ignored. The review should be carried out professionally and everything documented in a brief written report. Sometimes, especially in the case of projects that created tension or problems in the organization, an external facilitator may be extremely useful.

The review can be carried out chronologically, from the start of the project to its completion, by stage, by department or by following any other sequence that allows for an ordered, exhaustive review of the project. Project execution should be compared with the plans for achieving aims, meeting deadlines, the use of resources and other expenses and the quality of results. The analysis must include a list of the positive aspects and achievements that the team is proud of, as well as anything that went wrong (including trying to work out the causes of the problems and giving the team's responses), situations that were frustrating and a set of recommendations for future projects.

The post-mortem analysis is carried out when the project has been completed with the aim of reviewing everything that took place during project execution to draw lessons to improve future project planning and execution

In the case of projects that created tension or problems in the organization, an external facilitator may be extremely useful

example

Learning from experience

A leading international supplier of designs for train interiors that carried out turnkey projects for builders and operators of railway lines decided to formalize this activity within its organizational processes in two stages. The project manager first called one or more meetings when the project was finished, which were attended by all the departments involved in the project (Sales, Engineering, Purchasing, Production, etc.). The point of these meetings was to analyse the main wise moves that had been made and the difficulties that had arisen in the different phases of the project, including the bid, the engineering solutions adopted, the material suppliers, carrying out the sketches and models of the interior and the logistics of delivering the interior modules to the customer. The result of the meeting, duly documented in a series of records containing all these critical elements, was then incorporated into the project specifications, internally referred to as the Basic Project Requirement Specifications (BPRS), thus allowing this valuable information to be used in future projects. However, the most of important point is that these elements now form the core of a knowledge-management database designed by the company. When it comes to producing any final bid for interior-decoration projects, this database now provides a complete BPRS containing engineering and production solutions, potential suppliers and the delivery logistics from successful past projects, thus avoiding repeating any mistakes.

All the information from innovation projects should be compiled and referenced so that it is accessible and can be advantageously used in new projects. Companies that transform information into useful knowledge are able to learn from their experience. For more details, see Appendix 3 (Knowledge Management in Innovation Projects).

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APPENDIX 1

TWO PARALLEL VISIONS: TECHNOLOGY AND THE MARKET

Background

Developing high-quality, successful new products and processes calls for policies to encourage creativity and innovation within the organization, market information to be transferred to design tasks and the ability to develop products quickly, which is only possible by working with concurrent engineering.

The desire to include both the market and technological visions right from the stage of designing new products and processes has given rise to very useful management tools to combine these two concepts. The idea is to incorporate – right from the early stages of conception and design – market features through work practices and not to try to force this process in the case of products with complicated designs and highly complex processes.

Designing products and processes based on concurrent engineering always aims at obtaining simple, solid products to optimize and control the most suitable parameters and achieve maximum customer satisfaction at minimum cost.

In other words, it aims at duly identifying the needs of internal and external customers and translating these requirements into product and process specifications, which are completed and controlled by a set of parameters that enables them to be continuously corrected and improved upon.

The key to these methods is including the concept of the quality of the finished product in the conception of the project and having all the multidisciplinary team members involved from this early stage so they can express their opinions and validate the needs, risks and possibilities offered by each option.

How can we work simultaneously?

A very useful tool in this context is Quality Function Deployment (QFD), a specific tool for carrying out concurrent-engineering tasks.

QFD is a structured process that aims to identify customer needs and turn them into project requirements in each development and implementation stage of a product or service, with the participation of all company departments involved in the process.

QFD involves interdepartmental teams from Marketing, Design Engineering and Production and has been used by the Toyota Motor Corporation, which has managed to reduce production costs for its cars by 60% thanks to significant streamlining of its design processes.

The process starts by studying and listening to customers to determine a product's differentiating features. Market research is used to define the needs and preferences of the product's consumers, which are then divided and classified into categories labelled "client preferences". One example20 could be a vehicle manufacturer who wants to improve the design of one of its car doors (see the following figure). The surveys and interviews carried out with customers reveal that the two most important requirements for the car doors are that "they should stay open on a slope" and "they should be easy to close from the outside".

20. *Production and Operations Management,* R. B. Chase, N. J. Aquilano and F. R. Jacobs. Irwin McGraw Hill, 1998, adapted from *The House of Quality* by J. R. Hauser and D. Clausing, Harvard Business Press, 1988.

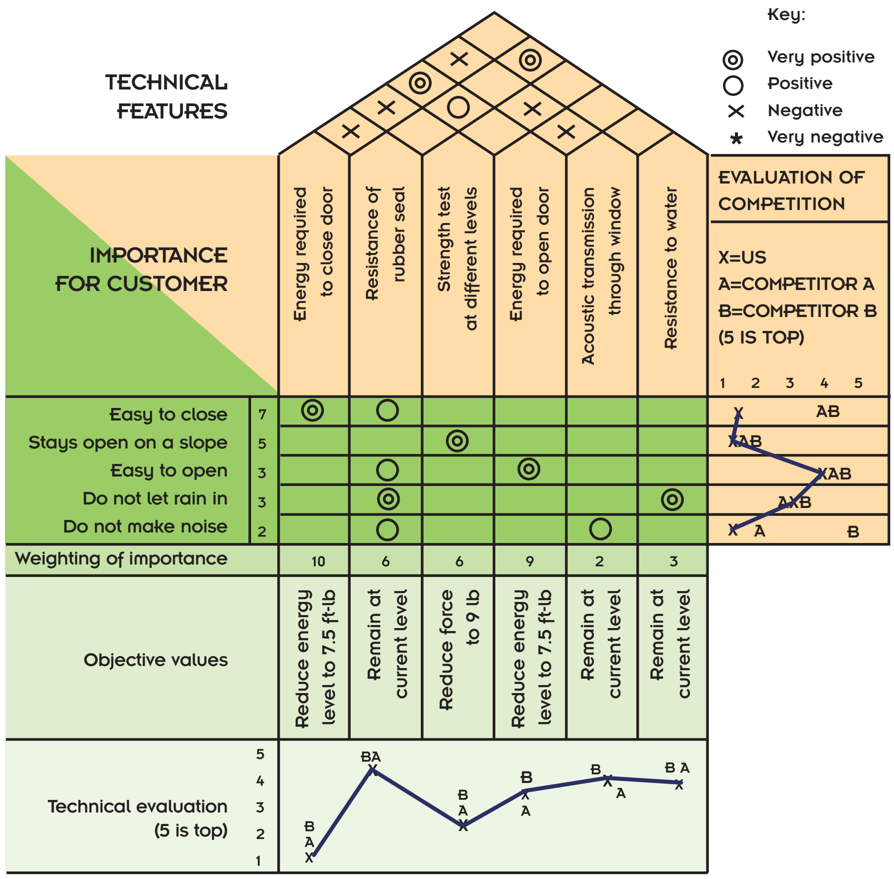
Once they customer requirements are defined, they are weighted in accordance with the relative importance they have for the customer. Customers are asked to compare the company's products with those of the competition and rate them accordingly. This process helps the company determine which features of the product are most important for the customer and evaluate its product in comparison with others. The final result is a better understanding of and greater focus on the product's features that are relevant for satisfying the customer.

The information required forms the basis of the matrix called the "quality house". This matrix enables the multifunctional team responsible for carrying out quality functions to take decisions in accordance with technical and market criteria simultaneously. The matrix helps the team translate customer needs into specific decisions. The product's important features and the aims for improvement are both decided together and detailed in the "house". This process encourages other departments to work together and provides a better understanding of the aims of and restraints on the departments involved. Nevertheless, the main advantage of the "quality house" is that it helps the team focus on developing a product aimed at satisfying market needs.

The first step in building the "quality house" is to produce a list of a product user's needs, which are then weighted according to their importance.

Customers are asked to compare the company's products with those of the competition. It is important to identify lead users, i.e., the most innovative ones that have most experience and are most demanding when it comes to spotting defects and demanding product requirements.

The series of product technical features is then considered and these features are also weighted according to the importance awarded by the customer. The evaluation of these features must sustain or refute the customer's perception of the product. This information is used to evaluate the products' strong and weak points in matters connected with the technical features.



In the example given, the most important ease-of-use criterion for the customer would be how easily the door closes and the most important technical one would be the reduction in energy needed to close the door (these are not unrelated). Technically, the company in the example is at a low level as far as the aim is concerned, but the competition is no further ahead. However, the market perception is that the doors of competitors A and B have better closing features. The project ought not perhaps to focus on improving technological capabilities, then, but on improving the market image.

Some important considerations:

– QFD is not just a tool, but also a methodology that helps us systematically structure a series of phases and operations that traditionally have been done somewhat disorderly.

– It involves a change in mentality in business culture in a twofold sense: the mentality of customer satisfaction and of teamwork.

– QFD calls for an interdisciplinary team that includes personnel from Marketing, Engineering and Production.

– information management. QFD uses information, and helps structure it, classify it, set priorities and, above all, identify gaps to be filled.

QFD achieves aims such as:

– Having a global vision of overall development.

– Analysing all the parameters and positive and negative influences.

– Helping follow a path focused permanently on customer needs. All the project's requirements throughout its life are foreseen as far as possible.

– Strengthens team members' creativity.

– Promotes the coherent and systematic use of other management tools (FMEA, functional analysis, etc.).21

Key factors for successful QFD:

– Unequivocal support of management. This comes in two forms: making resources available and giving the project free reign.

– Suitable subjects to obtain results.

– Sufficient motivation.

– Proper planning. Selection of a suitable project is vital, especially for the first few times.

– Training.

21. See *Eines bàsiques de qualitat, materials didàctics sobre la planificació de qualitat,* Catalan Quality Centre, CIDEM.

APPENDIX 2

PROJECT INDUSTRIALIZATION

What is industrialization?

Industrialization of a new product or production process is without a doubt the moment of truth for manufacturing companies. All the effort made during the stages of product conception, design and development now have to be transferred to the factory to obtain the anticipated improved efficiency.

There is no point in developing a product which, although functionally excellent, cannot be produced with a sufficient profit margin or whose quality cannot be guaranteed to match that expected by the customer.

Industrialization can be understood as turning a concept into a product and, to be successful, requires the product definition to be constantly compared with the capabilities of the anticipated production process during all the development phases.

Learning from current production processes

Every production process naturally evolves over the course of time22 towards a point of equilibrium between several competing forces. The effort made to increase productivity (e.g., greater production rate, full use of production capacity or reducing the workforce) contrasts with the quality levels demanded by the market through non-quality costs. This balance is a compromise that ensures a high quality/cost ratio in a specific economic context and market.

Analysing the current production process and identifying and understanding the factors that led to it is an excellent starting point for designing new, improved products and processes.

Incremental improvement of processes

Incremental improvement based on partial changes that are limited in scope and have a low implementation cost allows processes to be strengthened and filtered until the background noise of incremental inefficiencies is eliminated.

This incremental innovation is often applied using the concept of Total Quality Management and continuous improvement (Kaizen) using systematic tools such as quality circles and improvement teams.

They may be supported by statistical models such as Statistical Quality Control (SQC) or design of experiments (DOE), with the Taguchi method being a particularly relevant example.

Applying these models allows the variables present in the process to be identified and ensures the range of variation leads to an optimal point.

DOE techniques are based on the idea that current values of the critical variables are not the optimal ones. By modifying them in a planned and controlled fashion and analysing the results of the process, the primary relationships and interactions between the variables can be established and their optimal values thus calculated. Possible actions arising from applying these techniques might be: making some old variables new control variables, extending or reducing the range of variation of old and new control variables and redesigning the process (or product), and rejecting any variables that cannot be kept under efficient control.

22. Although the process of continuous improvement is not always a formal one, it should operate more or less implicitly

In the medium and long term, incremental actions usually end up using up all the economically efficient improvements and, consequently, radical changes have to be considered to continue making progress.

Radical process innovation

New underlying technologies make it possible to radically rethink the production processes de rigueur up to now. These kinds of innovation can bring about revolutions in the market and result in significant social changes (e.g., mass assembly-line production of cars made them affordable and this has given large sections of the population a degree of freedom and independence unthinkable in the recent past).

These radical innovations in the process lead to the appearance and market launch of new products that would have been previously unthinkable (e.g., miniaturized integrated-circuit technology has given us PCs and mobile phones). In this way, industrialization becomes the driving force for product innovation.

Industrialization during product design

Lack of foresight is still a very common problem during the stages of product conception and design. This means that when the design reaches the factory, production managers discover features of the product that can be criticised or improved upon.

How can this be avoided? Prevention is always better (and cheaper) than cure and several effective tools can be useful here:

- **Design for Manufacturing and Assembly (DFMA)**

As suggested by its name, this process involves laying down certain principles or basic rules which can be applied to the conception and design phases to allow the designer to select from all the functional solutions available the one that will make for easy future industrialization. A well-known example of this tool is Poka-Yoke or geometric characteristics that prevent assembly errors.

- **Statistical Design or Design Margin**

During the design stage, a quantitative characteristic of the product (e.g., a dimension) ceases to have a theoretically fixed value and can instead vary between maximum and minimum tolerance limits. It is then treated as a random variable governed by a law of statistical distribution with a nominal value and a distribution (e.g., the mean and standard deviation of a normal distribution). The distribution values used in the design-phase statistical analysis must consistently reflect the intrinsic distribution of the anticipated manufacturing process and therefore use past results from the statistical process control (SPC) theoretically in place in the factory.

The behaviour of the physical units manufactured through the anticipated production process can be predicted in the medium term in that a specific functional parameter can be modelled according to its various basic quantitative characteristics, its distribution and, therefore, fulfilment of the functional specification (which must ultimately reflect the needs of the end user).

This tool has a twofold purpose: to classify the aptness of the various design alternatives from the point of view of the industrial process and to widen as far as possible the acceptable margins for the process' critical characteristics to make it intrinsically stronger through design.

APPENDIX 3:

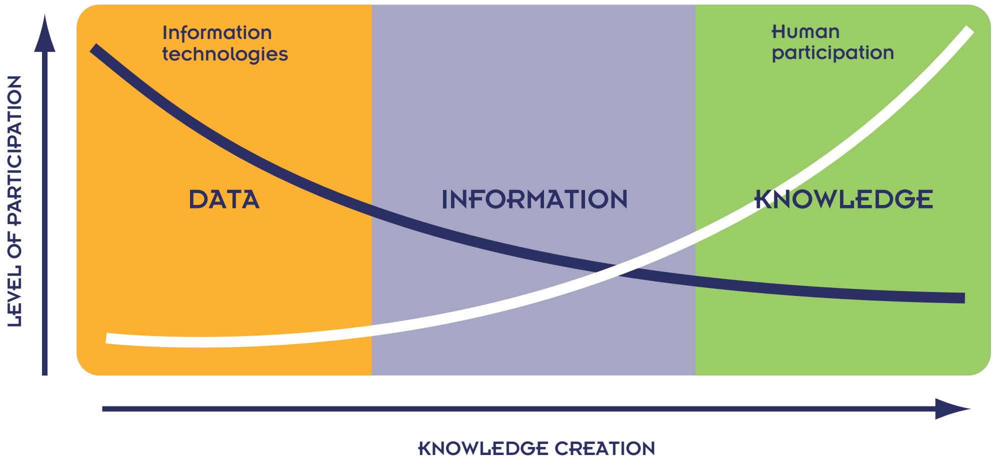
KNOWLEDGE MANAGEMENT IN INNOVATION PROJECTS

No one is interested in rediscovered something they already know, making the same mistake twice or forgetting valuable information that took a great deal of effort to acquire in the first place, especially when it comes to innovation projects. Knowledge is one of the most relevant economic factors of our time and proper management of knowledge is a key part of competing in the so-called **"knowledge society".**

But knowledge is also intangible, given that it is found in people's minds, which makes it difficult to hold on to, classify and reuse at the corporate level. In order to be managed independently, knowledge must be explained, documented and made accessible. However, some parts of knowledge do not respond to this rational scheme (intuition, creativity, experience and skills) and can only be managed by managing the human resources responsible for producing them.

In the broadest sense, knowledge encompasses everything from simple data and information to the comprehension of the human mind itself. The first rung includes **data**: letters, numbers and words without context or meaning. Such data is easy to structure, gather and transfer. The second rung is **information**: data organized in a context. The third rung is **knowledge** itself: information organized with meaning. This may be first-level knowledge if it is geared towards action and answers the question how? (**know-how**); or it may be second-level knowledge if it answers the question why? (**know-why**), thus fitting into the category of true comprehension.

When going from data to information and knowledge, the level of human participation increases, whereas the feasibility of the use of information technologies (IT) decreases, as shown in the following figure:



Knowledge management in innovation projects

Three kinds of knowledge are used and generated during the execution of an innovation project:

- **Explicit knowledge:** This is knowledge that can be formally structured using logical or rational rules, thus making it accessible to anyone. It can be taken out of its original context and generalized so that, in the future, problems can be solved like the one responsible for generating the knowledge. At the lowest level, this knowledge may take the form of a database or similar structure, whereas at higher levels it is materialized as theoretical knowledge, procedures, design guides, trial protocols, etc.

- **Implicit knowledge:** This basic knowledge is contextualized in the form of day-to-day work, but no explicit reference is made to it (it is not formalized). The fact that it exists, however, is clear from the results.

- **Tacit knowledge:** Each individual has this knowledge about a specific task (skill or experience) and it cannot be explained, given that it corresponds to non-rational qualities (intuition, creativity). This kind of knowledge makes each individual unique and different. Its existence is a challenge when it comes to managing knowledge.

Managing knowledge involves codifying and converting as well as possible the knowledge of each individual in the organization into explicit knowledge for the whole organization by applying the right techniques, thereby increasing the group's capacity to solve problems.

- **Applied knowledge:** This knowledge is demonstrated in the structure of the tangible results of innovation projects and is partly the embodiment of explicit knowledge and partly the result of the implicit and tacit knowledge of the people implementing the project. **This knowledge is externalized and classified through such things as reports, documents, plans, etc.**

The coexistence of these four kinds of knowledge in the context of the development of innovation projects makes it necessary to use different methodologies and tools to successfully manage knowledge as a whole.

Methodologies and tools for knowledge management

Following are some of these tools and methodologies. However, pay close attention because one of the most common errors when implementing knowledge-management programmes is going into the process with unrealistic expectations about what new technologies can do. It should also be stressed that **sharing knowledge can be perceived by some people as a threat.** In this regard, an atmosphere of trust and treating people the right way is essential for success. Shared knowledge must necessarily be complemented by the non-transferable knowledge each individual possesses.

Document-management systems (EDM: Enterprise Document Management)

As mentioned above, knowledge should be converted into explicit knowledge as far as possible, which generates the need to store this knowledge (reports, instruction manuals, databases of materials, design methods, product descriptions, processes descriptions, etc.) so it is **accessible** to all users. To this end, tools should be used to classify, research, store and extract it. The fact that information is stored in digital format makes it easy to use IT tools.

Knowledge-based engineering (KBE)

Knowledge-based engineering is a technology that allows companies to gather and develop the explicit knowledge of their engineers, as well as best manufacturing practices, legislation and costs, etc.

A KBE system provides a software environment in which experienced development engineers can create new applications, which are then used by engineers and designers (end users), for whom the KBE application provides a structured approach to design. Geometry generation is automated and controlled by rules codified by the KBE development engineer. This allows users to concentrate on the functional needs of the product and not on details of engineering analysis. Successive developments in the KBE system make it possible to include new knowledge and experience.

It is a very useful tool in the context of incremental innovation (continuous improvement of a range of similar products), but is not completely suitable for radical innovation projects.

Concurrent engineering (CE)

Today, the general consensus is that concurrent engineering is the most efficient way of working on engineering in an increasingly competitive environment. Concurrent engineering can be defined as a set of techniques aimed at cutting down on the time to market, while incorporating the customer's opinions and also guaranteeing product quality during its entire life cycle (from design to recycling) by simultaneously carrying out activities and working in multidisciplinary teams.

One of the distinctive features of concurrent engineering is precisely the integration of knowledge through the use of multifunctional teams (Marketing, Technical Office, Production, etc.). This makes it possible to minimize one of the major problems of the classic approach to engineering: the division of work in poorly communicated, sealed compartments. Integration between departments is fundamental, especially between product engineering and production, and between the company and suppliers, which reduces the impact of dividing work into specialization and management areas. Only by means of integration is it possible to consider all the knowledge of the important disciplines in each phase of product development, even tacit knowledge.

Concurrent-engineering tools were discussed in Appendix 1 (QFD). The basic point is that the concurrent system generates customer-oriented knowledge and not just knowledge of the functional area.

Besides improving communication, integration prevents tasks from being repeated unnecessarily due to differences of criteria or omissions and keeps suboptimal solutions derived from excessively partial approaches from being accepting.

PDM/EDM systems

Product Data Management (PDM) and Engineering Data Management (EDM) are two notions that could be considered synonyms or even equivalents. However, some authors feel that EDM manages data as part of the development of an engineering project, whereas PDM not only manages data, but the process as well.

The aim of PDM systems is to support applied technological knowledge and consists of maximizing the benefits of the concurrent-engineering application in terms of the time to market while maintaining complete control of the data and automatic data distribution to all the people who need it when they need it. PDM systems achieve these aims by managing data, which is saved in only one place, where its integrity is guaranteed and any changes made can be monitored, controlled and recorded.

Data-management systems must be capable of handling product data in the form of documents and their attributes, not to mention the relationships between them. Classification is fundamental in PDM systems. All similar information should be grouped together by attribute. Besides product-data management, some PDM systems also manage design and development processes as well as data flow.

Specific systems for knowledge management (KM)

Specific systems are currently being developed for knowledge management, mainly based on the use of Internet technology. These systems are large-scale, formalized and structured warehouses of basically explicit knowledge in digital format. The fact that they are accessible from an intranet facilitates access to the system, as well as interaction with users. These systems therefore make it possible to carry out a good deal of the functions involved in knowledge management, i.e., storing, classifying and locating to ensure the entire company has access to knowledge.

These tools are expected to become more important in the future and will probably include the functions of the other tools described here. They provide considerable support for the efficient execution of innovation projects.

The economic value of knowledge

The final point to be considered is that the knowledge generated during innovation projects has an economic value that should be measured, dealt with and suitably protected. It forms part of the company's intellectual capital and represents one of its chief competitive advantages. It will be necessary in each case to analyse the need to protect this knowledge through patents, copyrights and other instruments designed to protect intellectual property. The most important thing is that the successful innovation project will give the company a lead over its competitors that will allow it to consolidate and take advantage of the knowledge generated by launching new projects in the future.