Chapter 13

Change Management

The depletion of natural resources, particularly fossil fuels, population growth, and pressure that it puts on the environment, climate disruption, globalization, and the emergence of "giants" such as China, India, and Brazil which result in imbalances, and the vital issue of water will lead to unprecedented social upheavals especially in developed countries. The changes required will result in technological challenges that researchers, engineers, and technicians must solve; *process engineering* has a major role to play.

The 21st Century will be a century of transition!

The company in this changing world must constantly adapt and look for forms of reliability, set up a protective "shield" both organizational and technological. The "technological shield" is one of the tools provided by the SMS (Safety Management System) described in Chapter 2.

Running a business is managing risks.

In the 1980s, Change Management was developed/created in the United States. It is the basic package of many consulting firms that offer companies "support" in what can be a perilous exercise. Any major change is difficult and results can be disappointing or even contrary to the objectives set.

Chapter written by Jean-Pierre DAL PONT.

13.1. The company: adapt or die

The turnover of a company consists of sales of its various products, each in their respective phase of their lifecycle, which is illustrated in Figure 13.1. The products are born, and reach their plateau of maturity, whereas others die of old age or of sudden death as they are dethroned by competing products more popular among the consumers. The life of the product only decreases in this competitive world of ours.

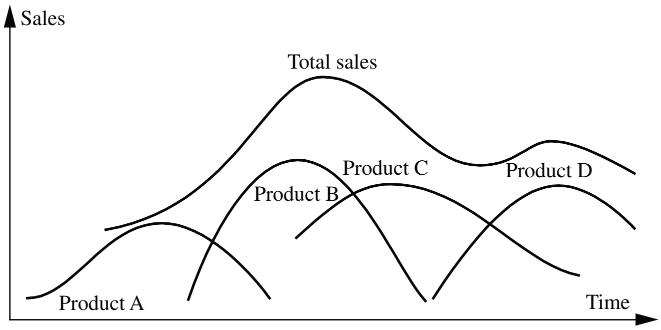

Figure 13.1. *Contribution of products to the total sales*

The company is therefore obliged to develop new products; research, engineering, and production have contributed to innovating, adapting, creating, and editing of the existing system. It is the same with the production tool, as we have discussed in Chapter 3, from which Figure 13.2 is extracted.

Since 2006, M. Goshn, CEO of Renault, said that his company lacked new models. In 2010, Renault focused its strategy towards electric cars and small cars.

The contribution to turnover and profit generated by new products is a good indicator of the quality of the research of a company and its innovative spirit.

13.2. The company: processes and know-how

Management of change requires knowing the business processes, and assessing its expertise and *core competencies*.

13.2.1. *The company, a multitude of processes (processes, methods, procedures)*

A *process* can be defined as an activity implemented by people with the help of a means to achieve a certain goal (e.g. payroll or hiring an engineer). *Everything is* a *process*!

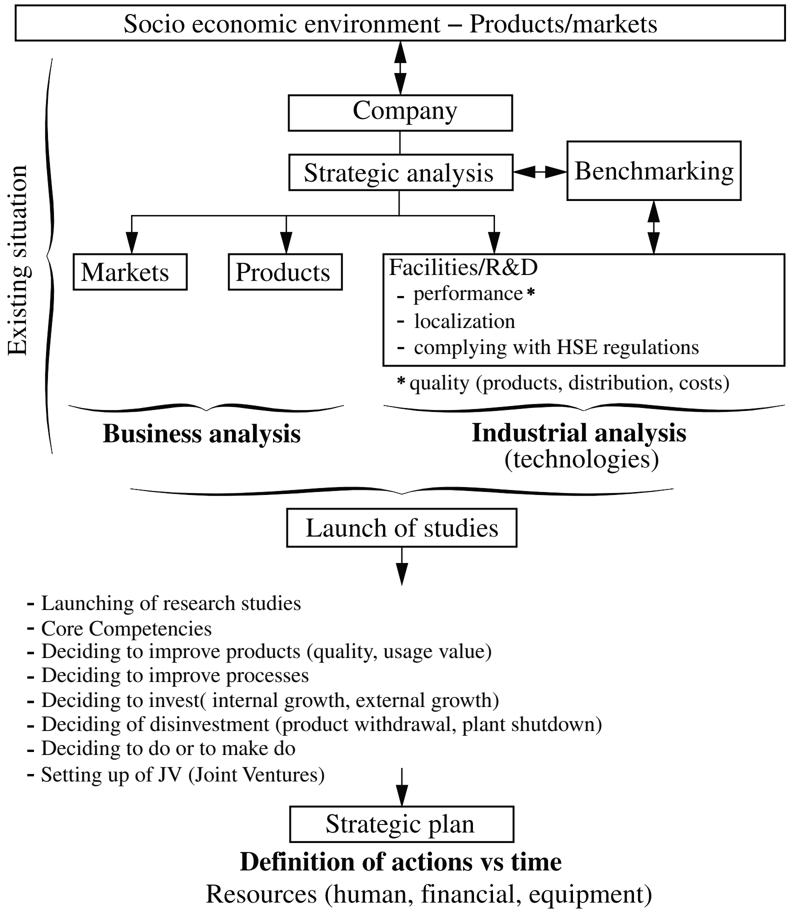

Figure 13.2. *Strategic plan of the company – industrial aspects*

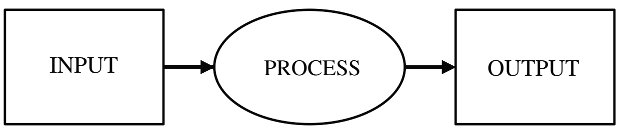

Figure 13.3. *Illustration of a process*

The goal of process industries is to transform raw materials and energy into finished goods and services. Let us cite chemical industries, companies involved in energy supply, pharmacy, metallurgy and so on. All of them make use of a process, i.e. a set of skills of methods and technologies.

A procedure is a *written* document that reports specifically on how to perform an activity. A production manual recollects all SOPs (Standard Operating Procedures), i.e. methods involved in a specific process like manufacturing phthalic anhydride, sulfuric acid etc.

Let us consider an example of a repair process of an electric pump in a plant.

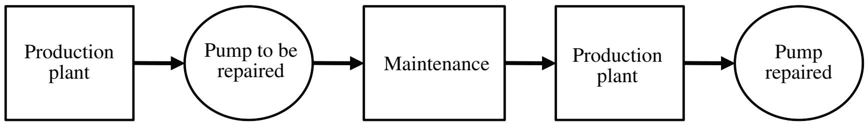

Figure 13.4. *Repair process of a pump (very simplified)*

Such a process is a sequence of operations which brings into play a number of services. A person qualified in electrical servicing isolates the motor of the pump and shuts off the supply from the motor control center (MCC). The production service isolates the pump, drains it, cleans it, and documents the work order (WO). The maintenance department dismantles the pump, repairs it, sets it back, allocates the cost of the expense, and maintains/updates the pump record data sheet. The production department puts the pump into service, and signs the WO after the performance review.

The oversimplified process above involves different trades. The difficulties arise at the *interfaces* as shown in the following example.

The *Piper Alpha disaster*: the oil platform Piper Alpha in the North Sea exploded followed by a fire accident on July 6, 1988. One hundred and sixty seven men died, and 61 saved their lives by jumping into the sea. The platform was destroyed. The cause of the disaster was the routine repair of a pump. The investigation report accurately determined the cause: poor general organization, maintenance processes of poor quality, lack of written procedures, lack of staff training, and so on.

13.2.2. *The expertise of the company – core competencies*

The expertise of the company is its greatest asset, and is its first capital. This is the greatest wealth of companies in developed countries which are quantified as *science- and technology-based societies*. *This is their chance of survival*.

Ikujiro Nonaka [NON 98] made the following observation: "*In an economy where the only certainty is uncertainty, the one sure source of lasting competitive advantage is knowledge*".

Knowledge management (KM) is a set of practices meant to assess the knowledge of individuals, organizations, and identify the essential knowledge of the company to maintain its technological lead. The protection of know-how is an essential component of KM; years of work and research can be squandered in a few moments especially in recent times where information can be exported at the click of the mouse.

KM uses the cognitive sciences, sciences for understanding the mechanisms of human or animal thinking and includes among other disciplines, psychology, linguistics, organizational theory, anthropology, neuroscience, artificial intelligence and so on.

One goal of KM is clearly to ensure the continuous training of employees knowing that "Every 5 years half of the technical knowledge base becomes obsolete" (AIChE, American Institute of Chemical Engineers). Another of its missions is to spread knowledge at the company level, knowledge that must be adapted to those who receive it; a maintenance worker does not need the skills of a CPA (Certified Public Accountant).

The know-how of the company is diffused and is not confined to its boundaries. It may include:

– an external part: KM within its customers, suppliers, business partners, and so on;

– an internal part: KM within its patents, trademarks, company structures, production, sales, and so on.

The know-how may also be classified based on the nature of the knowledge:

– *explicit* knowledge encompasses all that is formal, written, and these are the procedures, protocols, and operating manuals. In an analytical laboratory, operating procedures are described step-by-step and the materials brought into play are perfectly defined; these methods can be exported without any difficulty;

– *tacit* knowledge covers the skills that are often the result of a long time of learning in the field or the ability of people; it takes years to train a glass blower, and he can't become one over night. The quality of a dish depends more on the quality of the CHEF than of a cookbook.

The know-how of a plant can be scattered between:

– the researchers who developed the process;

– engineering firms that built it, with a special mention for process engineers, key players of process review meetings, and process safety reviews. They are at the beginning of the process flow diagrams (PFD), process and instrumentation diagrams (PID) and process equipment specifications (see Chapter 9);

– successive manufacturing personnel (engineers, supervisors, employees) (*special mention to those who started the plant*);

– maintenance and laboratory personnel;

– the actors in the *supply chain* who have knowledge of suppliers, customers, the use of products, and distribution channels;

– the after sales service, the applications laboratory.

13.2.2.1. *Core competencies*

The term core competencies includes the knowledge that the company cannot do without because they are part of its expertise. They can be handled by an individual, with the risk that this represents, a set of individuals with very similar skills, or group of people with complementary skills.

In the case of start-up of a process unit abroad, the entity that has exported the technology will be called on to send staff for manufacturing, maintenance, instrumentation, laboratory, and so on.

The *core competencies* can be described as strategic [TAR 98] because the company's future depends on them. In general, the company's business will evolve with its activities; some skills will become obsolete or will become common as the know-how has become widespread; the company can find the equivalent on the employment market. It takes a lot of flair to identify new skills and new competencies that will support the activities from the medium- to long-term.

Focusing its activities on expertise or management is the question that every professional is made to ask in the course of his career by questioning what works best for him, what allows him to grow and reinforce his "employability". The latter reflects the ability of a person to keep his job, and to increase his chances of finding another depending on what happens to his employer or on the evolution of the market. Knowledge about the skills relevant to the job performed, and the new skills to acquire to stay at the "top level" should be part of everyones questions.

Beyond the cliche "an expert is someone who knows everything about nothing and a manager knows nothing about everything", everyone has to question his field of expertise.

13.2.2.2. *Technology transfer*

Let us consider the case of the construction of a plant abroad based on an existing technology. A licensor decides to build a plant abroad following a technology that belongs to him. In general, the licensor has at the beginning of the process one local contact (Figure 13.5).

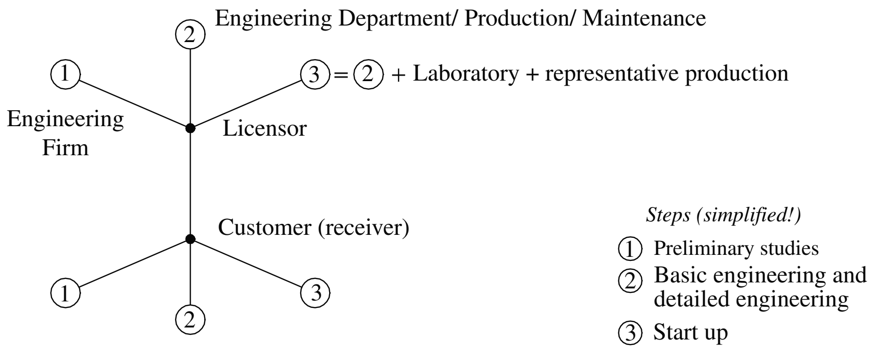

Figure 13.5. *Steps in technology transfer*

The process of transferring the know-how follows the stages of industrialization as described in Chapter 9. The transition from feasibility studies to a "basic plan" will involve increasingly licensor specialists (representatives of the production, maintenance, laboratory, research department, etc.). A multitude of plans and procedures are exchanged. The receiver appropriates all the vast information that is given to him. One day, he will be alone with the industrial tool of which he would have acquired!

Let us note that transfer of *identical* technologies is practically impossible: regulations, quality of raw materials, finished products, plant capacity, weather conditions, the need to purchase equipment different from that used at the licensing agency without forgetting the cultural differences that will require adjustments and changes in the processes. Surprises often occur at start-up, and it is necessary to face them!

Let us see some real-life cases:

– *Plant in Texas*: a large plant lays off a portion of its staff to safeguard its *bottom line* (profitability). Due to numerous breakdowns, the employer is forced to rehire a majority of those dismissed.

– *Buncefield disaster*: on December 11, 2005 (Hertfordshire Oil Storage – United Kingdom), 300 tons of gasoline spilled out from a storage tank within 40 minutes (450 t/hour!!!). The safety features did not work and the damage was enormous.

Trevor Kletzer, a British security expert, analyzed the accident and noted that the feedback did not play a part "*Organizations have no memory*. *Only people have memories and when they leave they take their memories with them*";

– *Transfer of technology from France to Indonesia*: the factory licensor subcontracted the maintenance of his control system to an outside company. He is no longer the master of his expertise! It is in the hands of a very small company whose small size makes it vulnerable; licensor put him at risk. The transfer of technology is done in poor conditions;

– *Flixborough accident* (September 1, 1974): the reaction system of the Nypro Works at Flixborough (UK) consisted of six reactors in series [KLE 94], cyclohexane is oxidized to caprolactam, intermediate of nylon 6-6, with air at a pressure of 9 bars and at 155°C. About 250–300 m^3/h of reaction mixture flowed from reactor to reactor: the reactors were connected by a pipe of 28 inches (711 mm). Following a crack in the reactor 5, it was by-passed and a *provisional* 20-inch pipe was put in place to connect the reactor 4 to reactor 6 by using two existing expansion bellows.

This makeshift job was carried out by people who were not aware of the complex technology of expansion bellows. Due to improper mounting, a bellow ruptured. A cloud of cyclohexane spread, lit up and exploded. There were 28 deaths and considerable damage.

The Flixborough accident highlights the expertise inherent in the design of the pipes. In a plant such as Flixborough, given the size of equipment and severe service conditions the *piping* should be considered as a *core competency*. A disaster could have been avoided.

13.3. Human aspects of change

It is difficult to use the name "tools" when referring to humans. However, nothing can be done without methods and without active involvement of the players of the company. It is pointless to discuss the quality if the employees are not motivated and trained. Training affects, among other things, the teamwork. It is the group which needs to be convinced that it is necessary to move forward and challenge the existing way of doing things at the request of "strangers" to the group.

In what follows, we will address matters dealing with a good working ambiance, quality of the visitor experience, and some "tips" that can be useful for first level supervisors.

Change can be seen not only as an opportunity for improvement, progress, and consolidation but also as a source of disorder, and a threat to the future. It can cause anxiety, fear, demotivation, animosity, rejection, and conflict.

The first step is to “unfreeze” a situation, an existing state of mind (unfreezing), and to overcome inertia. The second step is the stage of change itself. In the third and final phase, a new mood sets in, this is the “refreezing”.

Any change requires:

– a fight against the inertia inherent in any system: the NIH (*Not Invented Here*), and the NIMBY (*Not In My Back Yard*) have been proven: these are proven brakes to change;

– the support of most stakeholders (there will always be opponents!);

– interest to be greater than the disadvantages and constraints (there are always some!);

– a favorable “ambiance” and a feeling of trust supported by adequate internal communication;

– the players of change to be accepted and recognized as competent, eager to do well and not seen as inquisitors. They must develop methods and appropriate tools both technical and human, methods of group work, communication techniques, and methods of conflict resolution and problem-solving;

– the change team to be supported at the highest level of the company.

As such, the executive committee must include:

– the establishment of a project team specifically identified and managed by a project director with *appropriate resources*, who must report to the management, is a *sine qua non* condition of credibility;

– the definition of objectives to be achieved;

– monitoring the progress of the project from the cost and time perspective.

Change can be a major source of conflict. There is *ipso facto* the operational management versus entrepreneurial management conflict which was discussed in Chapter 2. One of the first questions asked by the “executives” is whether the business line can lead the change by themselves or whether outside help is needed, thereby generating additional costs and ... conflict.

13.3.1. *Creating a feeling of trust*

Creating a feeling of trust requires a few simple rules (the following list is not exhaustive):

– *respect people*, to recognize what has been done (not all is bad!);

– *define the work* of each to make him/her feel comfortable in the organization;

– encourage each agent of change to ask himself the following question: *what do I expect from the upstream (*information, products, etc.) *and what does the downstream expect from me (information products)*?

This *minimalist* management tool is extremely handy: it allows each person to position himself in the organization and set his added value:

– make the system visible, transparent: the need for change as well as the team in charge of it are announced at the highest level. The process decision must be clear and must define the liability of everyone who is in charge, who is responsible?

Common case: a team "invades" a production plant for making improvements. How to ensure that the manufacturer responsible for the plant, and who has liability, does not feel bypassed; that he agrees to do the tests that are required which can present operational risks and customer risks;

– *inform and involve* all stakeholders at their level; no one should feel forgotten or overlooked.

To create this atmosphere in the manufacturing sites, factories, or plants, it is recommended to use both the techniques outlined below: visual management and *brainstorming*.

13.3.2. *Visual management*

Chapter 10, "Japanese methods", deals extensively with this concept; the following is intended as a simple addition.

Employees spend most of their lives in the workplace, increasingly visited by customers. An architect involved from the outset in the design of the company will give a nice "look"; the paint, green spaces and flowers that will decorate the workplace is only a tiny fraction of the amount of investment.

The company logos, billboards of safety results and site objectives will create an environment that the employees will appreciate, providing them with a *sense of belonging*. Many companies involve their employees in setting-up their environment (offices, cafeterias, break rooms, etc.); an initiative to be encouraged.

The procedures must be known to all. An adequate "*reporting*" takes into account the degree of progress of the successes and challenges and work ahead.

13.3.3. *Brainstorming*

Brainstorming has its own rules, in contrast to what one might think. If, as a first step, it is necessary to leave complete freedom, so excluding the constraints and censorship, the ideas, even the best, then can be organized, reviewed, and reformulated. The flip chart is an essential tool of the organizer or the secretary.

13.4. Basic tools for change management

13.4.1. *Systems analysis*

Von Bertalanffy is considered to be the "father of systems analysis". The Austrian-born biologist immigrated to the United States before the war and in 1945 published his book *General Theory of Systems*. According to Von Bertalanffy, a system is a set of items in mutual interactions.

Figure 13.6. *Ludwig Von Bertalanffy (Vienna, 1901 – New York, 1972) the "father of systems theory"*

During World War II, the American mathematician Norbert Wiener introduced the concept of feedback in ballistic studies. These reflections were the source of his concept of "cybersystems" aimed at "*the study of communications, control, and command in organized systems*".

The French representative of this school of thought was the biologist Joël de Rosnay, who in 1975 published *Le Macroscope*. Joël de Rosnay defines a system as "a set of elements in dynamic interaction, organized according to one goal" [LUG 05].

During the 1970s there emerged a third-generation systems analysis that was made necessary by the difficulties met in its application of cybernetics in social systems. This new approach, developed by P. Checkland and K.E. Weick [CHE 81, WEI 85] in the UK, is particularly suited to organizations regardless of their nature or size: companies, teams, families, economic systems, political systems, the world, and so on.

It is used primarily to build the preliminary projects of organization, development, change (strategy, management, etc.) by providing strategic analysis, construction, and project management tools.

A system can be schematized as in Figure 13.7.

The difficulty in defining the system is to define its borders, components, and their interactions. Everything is a system!

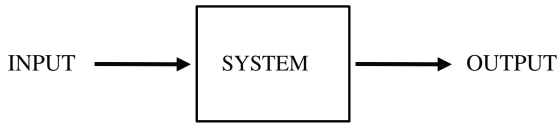

Figure 13.7. *Schematization of a system*

Here is what a representative of the European Parliament says about French agriculture:

"Environmental pollution, pollution of groundwater, monocultures for the production of so-called "green" chemicals, the depopulation of the countryside and quality of life are piled up, and to top it all, one talks about the difficulties associated with the economic calculations of prime costs, European grants, not to mention the climatic changes looming on the horizon!"

If we consider French agriculture as a system, what inputs should we choose? Farmers, the environment, livestock production, tourism; and what scope?

Let us consider the case of *biofuels*. For an agricultural country like France, it is legitimate to consider its biomass as a source of fuels substituted for fossil fuels. This is based on the fact that carbon dioxide, a greenhouse gas, which is released by the combustion engine, will be absorbed by the plant during growth. The systemic approach to this problem involves considering all the environmental impacts of the biofuel industry.

Lifecycle Assessment (LCA) of the biofuel industry shows three major stages or sub-systems: culture of the plant, transport, and plant biofuel processing. A first study done on biodiesel [DEN 98] shows not less than eight environmental impacts associated with the production of biofuel. Moreover, it is observed that the generation of greenhouse gas emissions takes place at each stage and is not limited only to carbon dioxide.

Paul Crutzen, who received the Nobel Prize for Chemistry in 1995 (for his work on atmospheric chemistry in collaboration with Mario Molina and Frank Sherwood), challenged the validity of this industry and has shown that a "systems analysis" which includes the emission of nitrogen oxides associated with the production and use of nitrogen fertilizer gives a negative greenhouse gas balance. Nitrous oxide has 300 times the impact of carbon dioxide!

13.4.1.1. *Systemic analysis of a company*

The company has been analyzed in depth as a system, which is nothing more than normal because of its importance.

It is considered as an economic subsystem of a high level of complexity in the world connected by a multitude of interactions. This is an "open" system whose purpose is the production and exchange of goods in different markets. This allows for better management of the complex transactions in the economy than by single individuals. It consists of elements of different natures: people (staff, suppliers, and customers), materials (raw materials, finished goods), money, information, and so on, which are grouped into subsystems to exchange flows of the same type.

The company-system is subject to different mechanisms of homeostatic regulation ("remain constant") that tend to stabilize it: regulation with the environment, regulation between internal subsystems, and so on.

J. Mélèse [MEL 95], a pioneer in the application of systems for companies and public services calls for "the modular analysis of systems" to represent the company system. The sociologist Edgar Morin is now considered to be an expert in the analysis of open systems, and the reader can benefit from this work [LUG 05].

13.4.1.2. *Control of process modification*

The modification of a manufacturing process can have favorable, desired, or sometimes unfavorable consequences, as can be imagined. Changes to the manufacturing process may represent both a major opportunity and a very high risk, especially if they are performed on the job by the staff who do not have the history of previous activities. The proposed flow chart below (Figure 13.8) comes under change management. It is very simplified. A change in the process may involve the whole company, if the commercial product resulting therefrom is modified (hopefully improved). If so, samples must be sent to the customers, this phase can last for months. In the pharmaceutical industry or in the plant protection industry, a change process gives rise to a protocol very heavy with registration.

13.4.1.2.1. Success story

Rhodia in collaboration with Michelin has developed the "green tire" where precipitated silica has partially replaced part of the carbon black. The reduction in friction leads to significant fuel savings. Given the extreme importance displayed by the manufacturer for safety, control tests lasted for years before final acceptance.

It is very important that any idea of modification for a change, any proposal is the subject of a cross-sectional information that affects all functions of the company concerned. The flowchart in Figure 13.8 can be considered as the beginning of decision-making. Its first merit is to consider the stakeholders. It often requires much to-ing and fro-ing.

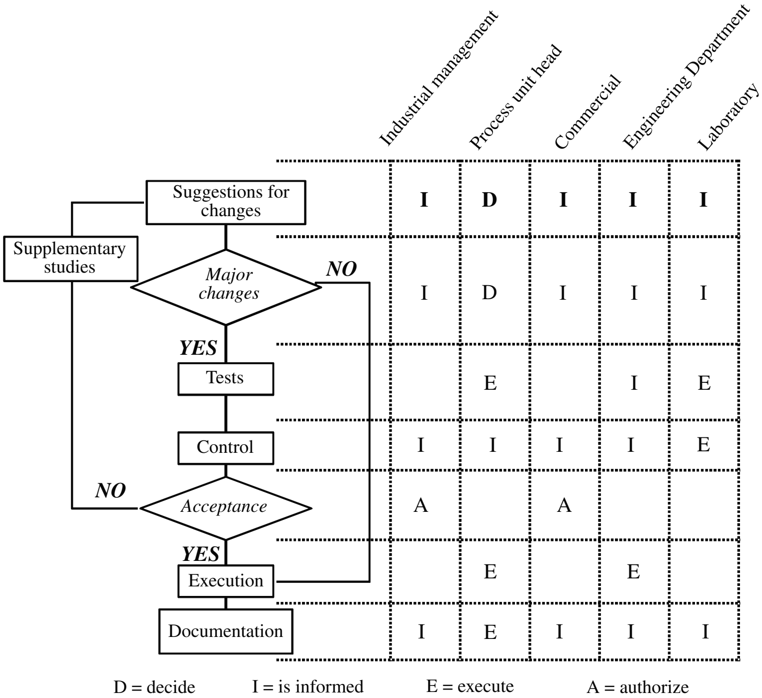

Figure 13.8. *Flow chart illustrating the decision-making process in the modification of a manufacturing process*

13.4.2. *Continuous improvement, the PDCA, the Deming wheel*

NOTE.– An overview of Deming's life and his work is given in Chapter 10.

The company that decides to have a quality approach will establish a quality management system (QMS) an absolutely transverse process involving the support of all business partners (*stakeholders*). It should be considered as a business project because it involves organizational changes, and as such, its objectives, content, scope, and planning must be defined.

Easy to remember, the PDCA (*Plan-Do-Check-Act*) synthesizes its own basic principles of quality management as part of a continuous improvement process. The method involves four stages, each stage leads to another, and aims to establish a virtuous circle. These stages are as follows:

– *P* for *Plan*: first of all, this is a step to choose the targets in accordance with the company strategy and its diagnostics, the requirements of customers (and business partners) and the criteria for profitability and then to implement the resources, adequate financial means necessary for achieving these objectives and ultimately to develop performance indicators;

– *D* for *Do*: this step consists of executing the plans or projects defined in P;

– *C* for *Check*: the results obtained over time should be monitored to assess what will work and what will not work;

– *A* for *Act:* the last step consists of stabilizing parts of the system that work well, especially by writing the procedures attached to the process, as well as correcting or improving the solution implemented.

The *Act* step therefore brings a new project to be realized, so a new planning has to be established. It is a cycle that is represented with a wheel, the famous Deming wheel (Figure 13.9). At each stage, the wheel progresses a quarter turn. This move represents the action forward. A spin can take months or even years.

To avoid "going back", a wedge is placed under the wheel, which prevents it from going back. This wedge represents the system of quality management, integrating part of the overall process of company management including preventive measures and corrective actions.

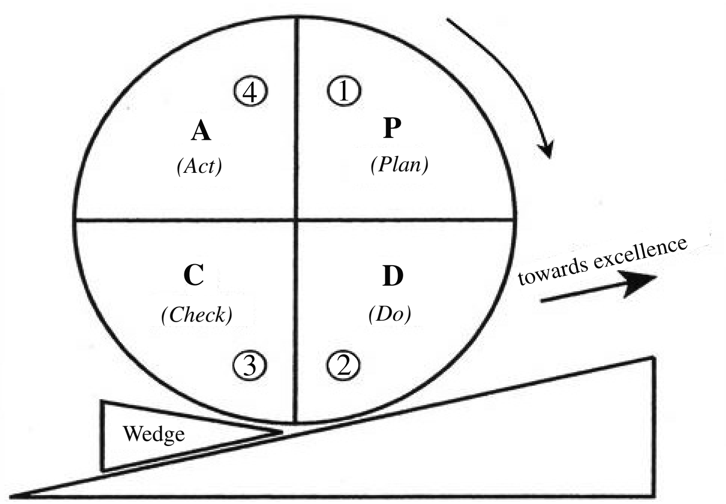

Figure 13.9. *The Deming wheel illustrating the PDCA method*

13.4.3. *Pareto analysis*

This refers to the Pareto law or the 80–20 rule; 20% of the causes produce 80% of effects. For example, 20% of customers account for 80% of sales, 20% of certain faults cause 80% of failures etc.

Vilfredo Pareto was an Italian economist who finished his career as Professor of political economy at Lausanne. During the studies that he conducted in Milan in the late 19th Century, on the distribution of wealth, he realized that 20% of people control 80% of the wealth. Later, this observation was extended to other areas.

Box 13.1. *Vilfredo Pareto (1848–1923)*

The method ranks the causes by decreasing order of importance and measures their contribution to the final effect. Pareto analysis is significant because it determines where to focus its efforts to obtain the best results, thereby creating value with the greatest chance of success.

Figure 13.10 shows a Pareto chart applied to the maintenance cost of a plant. The analysis of this cost shows that rotating machinery (pumps, compressors, and agitators) represent 60% of costs. It is necessary to focus on this type of equipment. Pareto analysis of rotating machines may indicate that it is the centrifugal compressors which represent 80% of the cost of rotating machines; it is this type of machine which is to be considered first.

13.4.4. *External audits*

A method has been used in some very large companies that extensively uses the same technologies in different sites. The manager of plant A audits plant B with a team of people from outside B. The director of B audits Plant C, and so on, as shown in the following diagram.

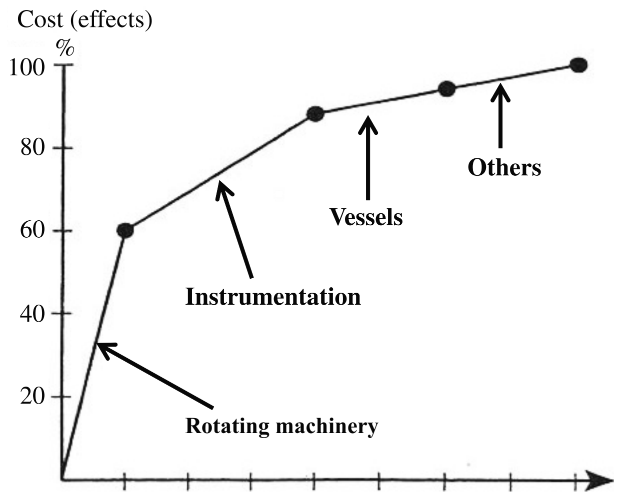

Figure 13.10. *Pareto chart applied to the maintenance cost of a plant*

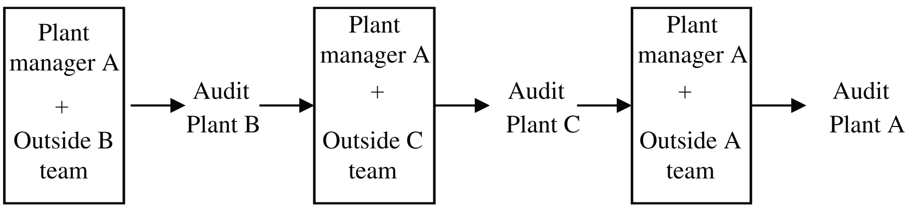

Figure 13.11. *Particular method of auditing valid for large groups*

This is a particular *benchmark*. The practices of each other are compared confidentially, the auditors have access to all the information since they belong to the same company!

Each entity may discover a better practice than it currently uses and use it to its advantage.

13.5. Changes and improvement of the industrial facility

Industrial practice shows that any system can be improved. The process industries are industries, where experience and observation are essential. However, any system has its limitations: it is about whether to continue to improve the existing process or seek new technologies, i.e. look for what is called a technological *breakthrough* [RAN 93].

13.5.1. *Continuous improvement and process control*

The improvement of production tools may include, but are not limited to, the following:

– efficiencies;

– productivity gains;

– quality improvement;

– reduced manufacturing costs.

The process engineer and production assistant are at the heart of the system. They do not have the constraints of the person in charge of the operations. They have time to use the process engineering tools in order to model, simulate the system, check the performance of equipment using computer codes, and carry out the tests on the plant if possible or by using pilot facilities.

The first priority of the plant manager is to take care of his personel day-to-day operations and customer satisfaction, and also to hunt for raw materials misusage, operations improvement, energy conservation.

EXAMPLE 13.1.– A fermentation plant comprises 15 fermentors of 130 m^3 each. A model of the stirring system using CFD (*Computational Fluid Dynamic*) shows that the transfer of heat and matter can be improved. Pilot runs confirm the potential gains. An industrial fermentor is changed; and full scale tests lead to a significant improvement in productivity of around 30%. The modified agitation system is extended to all the fermentors.

13.5.1.1. *Statistical process control (SPC)*

Statistical process control (SPC) was developed and used heavily during World War II. Edward Deming was one of its promoters. SPC has been at the beginning of the development technique called Six Sigma that will be mentioned later on.

These preventive methods are based on sampling and control of raw materials and products being manufactured, finished products, and the analysis of the physical parameters of the process (temperature, pressure, flow rates, etc.).

In the 1920s, the *statistical processing* of these values was the source of quality control. The aim was to ensure that the process did not drift and that the product characteristics remained within acceptable limits. *The ultimate goal is to prevent non-conformities*. This is the basis of SPC.

13.5.1.1.1. Some reminders on statistics

Let us look at any variable of the process denoted by x_i. Sampling is performed and this value is measured n times. If the sample is representative, then the n measured values follow in most cases what is called a Gaussian distribution, a bell curve as shown in Figure 13.12.

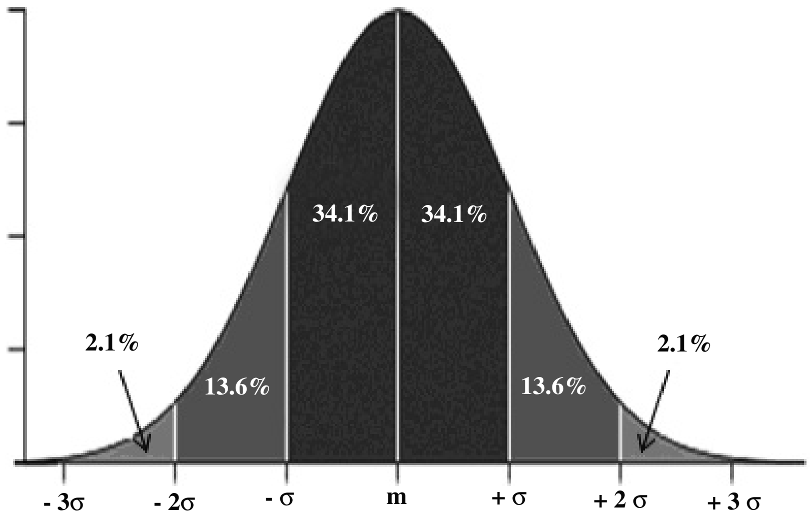

Figure 13.12. *Gaussian distribution and normal statistical law*

The n measured values are distributed around their mean m:

$$m = \sum_{i=1}^{n} x_i \qquad [13.1]$$

A value that represents the distribution of values around this average is the standard deviation σ, which is defined by:

$$\sigma = \sqrt{\frac{1}{n}\sum_{i=1}^{n}\left(x_i - m\right)^2} \qquad [13.2]$$

If the distribution is normal as shown in Figure 13.12, then statistically:

– 68.2% of values are in the range of $[-\sigma, +\sigma]$;

– 95.4% of values are in the range of $[-2\sigma, +2\sigma]$;

– 99.6% of values are in the range of $[-3\sigma, +3\sigma]$, if 6σ.

13.5.1.2. *The SPC in manufacturing*

Any process tends to drift either to identifiable but unpredictable causes (power failure, error of raw materials, setting error), or for random or unknown causes, also known as non-identifiable, which depend on the process (slight variation of raw material composition, malfunction of a metering device, etc.).

The aim of statistics is to collect, organize, and interpret data. Many product characteristics have normal distributions and are plotted by the famous bell curve (Figure 13.12).

The characteristics of a product must be between a tolerance of upper specification (T_S) and a lower tolerance (T_I). The products out of tolerance are reported as defective and rejected by the client.

The *capability* (C_p) of a process defines its ability to focus on the average specification of the product required by the client, between T_I and T_S. The capability is a unitless number indicating the ratio between the tolerance range and the dispersion (variability of the process). It is calculated by:

$$C_p = \frac{T_S - T_I}{6\sigma} \quad [13.3]$$

The greater the number, the more "capable" the process is. As shown in Figure 13.13, one can simply decide whether a process is capable or not.

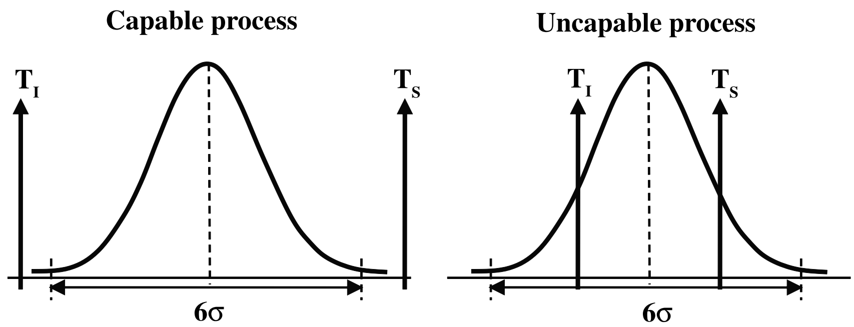

Figure 13.13. *Criteria of a process capability*

Another factor, widely used, is the *Cpk* index. This index reflects the offsetting of the distribution with respect to the average expected value in the range of specifications. It is calculated by:

$$Cpk = \min\left(\frac{T_S - m}{3\sigma};\frac{m - T_I}{3\sigma}\right) \qquad [13.4]$$

Many industries specify a *Cp* greater than 1.33. Motorola goes further and imposes a *Cp* and *Cpk* larger than 2 and 1.5 respectively.

The SPC uses control charts to monitor all the parameters that an Ishikawa-type analysis (diagram causes/effects) has identified as influential on the process. These methods are complex, it takes skill to work with them. Let us not forget the history that claims a statistician who drowned in a water depth of 50 cm on average!

13.5.1.3. *Six Sigma method*

In the 1980s, the Six Sigma method was used and developed by Motorola in the U.S. The fact that General Electric announced that its use had earned them *hundreds of millions of dollars* ensured its promotion to major corporations.

It is structured in five stages called DMAIC, standing for *Define, Measure, Analyze, Improve, and Control.* As its name implies the statistic is at the heart of the technique; Six Sigma means six standard deviations.

Its objective is to eliminate defects and non-compliance of finished products.

99.99966% of the products of a "*Six Sigma*" process meet specifications. In other words, there is *statistically* only 3.4 defective parts per million.

Six Sigma has been extended to administrative processes of large companies beyond the manufacturing process itself. High-profile, it is implemented by experts and *black belts* and assumes a major infrastructure typical of the implementation of a quality system; it is primarily suitable for large companies [BRE 99].

13.5.2. *Looking for a breakthrough*

The analysis of a manufacturing process, *benchmarking* (see Figure 13.2), that is to say comparison with a similar process, can lead to the sometimes difficult conclusion that the process in question has become obsolete.

Continuous improvement often conducted with the means at hand is not enough, one must review the situation and change the scale. The company then has to create a multidisciplinary team, generally constituted of representatives from research, processes, engineering, and general subject matter experts.

This method is cumbersome because it requires the allocation of dedicated resources for many years. It is therefore an expensive method! *It is a method that involves project management techniques.*

In some companies, the team thus formed is called the Process Improvement Team (PIT) The implementation of what can be called a Process Improvement Team (PIT) should follow some basic rules:

– a multidisciplinary team of five to seven people from outside and inside the plant, competent in the subject area;

– a leader selected from the people not inside the plant, recognized and supported by senior management;

– allocated resources (in various required disciplines from specialized laboratories, from engineering departments);

– a budget;

– a well-recognized methodology;

– short-term and long-term challenges clearly displayed (Pareto analysis);

– progress measured, monitored, and coordinated;

– recognition of the success of the team (hopefully!).

Some errors are to be avoided:

– persons engaged in PIT but in fact not available due to other priority assignments;

– people not recognized and accepted by people in the plant;

– a PIT leader with no or little expertise in the domain under study;

– inadequate resources;

– loss of momentum;

– a lack of interest of senior management;

– no budget for the study.

13.5.2.1. *The case of IT*

IT *(Information Technology*) is essential in industrial processes. Its significance is only growing. It may be the best and the worst thing: *there is absolute need to know the process before computerization*. It is particularly recommended to proceed by steps to implement specific “pilots” as far as possible before going to full scale hardware. Benchmarking of similar experiences might of course be of considerable importance and save time and money.

13.5.2.2. *Change impacts – systems reliability*

Again: "*Entrepreneurship is managing risk economically*" [BAR 00]. The *risk management* of the company covers all risks of the company. It has become a business function.

Every business is vulnerable; all its functions are sources of risk. Production tools can be the cause of catastrophic technological accidents (SEVESO, BHOPAL, AZF, etc.). According to insurance companies, 70% of SMEs that have a serious accident such as a fire disappear in the 2 or 3 years that follow.

The safety aspects have been widely discussed in Chapter 2.

The notion of *robustness* of a system can be considered as an extension of the concept of dependability that covers the terms of reliability (R), maintainability (M), availability (A), and safety (S). It is often referred to by the acronym RAMS which can be considered the characteristics of a system that allows us to place justified confidence in it [MOR 05].

In the case of a change, the problem is to assess the "resilience" of the system. The notion of "resilience" stems from metallurgy: resilience expresses the aptitude of a sheet of metal to resist an impact.

It is with this notion of resilience in mind that we will briefly describe some risks involved in change management.

13.5.3. *Corporate risk*

The staff is the primary asset of the company! Changes in people may have different origins; as for example:

– attrition by retirement, resignation, illness, and so on;

– transfers, promotions, social or family issues and so on.

The change in executives or in high level of control is an important source of risk. *A director who runs a plant of 200 people may be ill-suited to manage a plant of 500 employees. The style is different, the atmosphere is no more familiar. It is no longer possible to know everyone!*

The critical mass of an organization is the staffing levels, below which, a company may be at risk by lack of resources in case of key people leaving. Very small plants require special management, one person can be in possession of much of the know-how, have many “hats”; his departure can cause some unpleasant issues.

Time: It usually takes 2 years for an executive to “get a hold” on a position, the first year he is floundering, the second he feel’s comfortable, and he can instigate from the third. Ill-timed transfers do not promote creative stability.

13.5.3.1. *Product-related risks*

Performance products pose the most complicated case: often only the client appreciates the impact of a change in the product that they are buying.

Traceability has become a fundamental concept, in particular, for products of animal or plant origin.

13.5.3.2. *Risk related to changes in the process*

We have already mentioned the need to implement appropriate procedures. Let us consider two real life cases for illustration.

Case 1: the productivity of a plant manufacturing an insecticide is increased by raising the reaction temperature by a dozen degrees centigrade. After a period in which the expected results are achieved, an explosion destroyed the plant and causes the death of two operators. The origin of the accident lies in the formation and the accumulation of an unstable by-product, the accumulation resulted from the failure of the “reactor-loop” recirculating pump. The cause of the accident is the *ignorance of work* during the development process, the formation of an unstable by product beyond a certain temperature was well documented!

Case 2: a manufacturer of allyl methacrylate decides to change his process in order to reduce production costs. Samples are provided to the major client whose testing is very brief. A new plant is built, and the old one is closed. *Ultimately*, the new product is refused, a small difference in composition leads to the products being deemed non-compliant! This example shows the need to know perfectly the use of the product made by the client and assess the impact of any change in quality.

13.5.3.3. *Risks associated with changes in working plants (revampings)*

The project risks were discussed in Chapter 9 “Project Management Techniques: Engineering”.

Changes to existing plants are generally much more difficult than building new plants. This is what is colloquially known as *revamping*.

These difficulties have multiple origins.

The *calculation codes* have their limitations. When “it is new” it is easy to make safety margins in the case of uncertainty. In the case of a *revamping*, it may be necessary to ask the question about the capacity of a distillation column, its capacity can be increased from 100 tonnes to 120 tonnes/day by changing the fractionation trays! Conservation gains of a shell and its annexes are to be compared with the commercial risks if the capacity is not reached!

The determination of the *capacity limit of a WWTU* (waste water treatment unit), and its ability to process a new pollution load is difficult to evaluate. Some specific and at times difficult pilot tests must be performed.

The *cost estimation* is often very approximate. Let us take the case of piping; sometimes pipes, expected to be reused, have to be replaced by new ones due to their state of corrosion.

The *implementation phase* must take into account the issues related to the duration of shutdowns; customers have to be supplied.

It must also consider *safety* issues when changes are made on a working plant; fire orders absolutely mandatory to perform welding raise many questions. Operators are not ready to deliver them!

The *amount of contractor hours* (on workshop) are difficult to assess, everything is subjected to additional cost.

13.6. Re-engineering, the American way

Amongst all others, two American books have ignited the world of management in the 1990s:

– *Re-engineering the Corporation – A Manifesto for Business Revolution* [HAM 93];

– *Liberation Management – Necessary Disorganization for the Nanosecond Nineties* [PET 92].

The following quotes are taken from the two books and allow the reader to get an idea of the explosive content of their contents:

– *forget what you know about how business should work. Most of it is wrong*!;

– U.S. companies operate on the old principles which are 200 years old, mainly on the principle of division of labor highlighted by Adam Smith (1776). It is necessary to replace tasks with processes;

– *a Business Process is a collution of activities that takes one or more kinds of input and creates an output* that is of *value to the customer*;

– *we live in a world regulated by the 3C's: Customers, Competition, and Change*;

– *re-engineering is the fundamental rethinking and radical redesign of business processes to achieve dramatic improvement* such as *cost*, *quality*, *service*, and *speed*;

– *re-engineering* is different from *restructuring, downsizing*, *reorganizing,* and *automating*;

– *why do we do what we do*? *Why do we do it the way we do*?

– *values & beliefs*: the views of employees, those they stick to or those they reject;

– *People, Jobs, Managers & Values are linked together. Processes not organizations are the object of re-engineering*!

These quotes for the less vigorous reflect both a certain "American way of re-engineering" and what we can expect from the re-engineering of some companies run by outside consulting firms. These radical changes spread quickly!

In Japan, it took 10 years for Taichi Ohno to convince his company TOYOTA to adopt His system of JIT. Please refer to Chapter 10 "The Japanese Methods".

Other countries, other customs!

13.7. Conclusion

We are on the verge of unprecedented transition. Sustainable development (the 3Ps) and competition require new concepts, and new technical and managerial approaches for industrial companies. Any company and everyone within it must be prepared to change.

Changes take time, patience and energy, the mastery of technologies involved, and the tools they own.

In terms of stubbornness and tenacity, didn't Edison say: *Invention is 10% inspiration and 90% perspiration*!

The concept of robustness is a fundamental concept: do the changes improve or decrease the robustness of the system? A well-conducted systematic analysis can help greatly to avoid disappointment.

The process engineer has a considerable role to play in these developments. He knows how to make balance sheets (material, enthalpy), he can visualize the process, make it understandable to his colleagues from research, engineering, production and he is the person who can have a systemic approach and therefore see all the aspects of the projects.

He is the person at the interface of multiple disciplines, he has returned to play the role of conductor, and we hope that this will serve to teach him the different parts.

13.8. Bibliography

[BAR 00] BARTHELEMY B., QUIBEL J., *Gestion des risques de l'entreprise*, Techniques de l'Ingénieur, Paris, 2000.

[BRE 99] BREYFOGLE F.W., III, *Implementing Six Sigma: Smarter Solutions Using Statistical Methods*, John Wiley & Sons, New York, 1999.

[CHE 81] CHECKLAND P., *Systemes Thinking*, *Systems Practice*, John Wiley & Sons, New York, 1981.

[DEN 98] DE NOCKER L., SPIRINCKX C., TORFS R., "Comparison of LCA and external cost analysis for biodiesel and diesel", in *Proceedings of the 2nd International Conference on Life Cycle Assessment in Agriculture*, Agro-Industry and Forestry, Brussels, 3-4 December 1998, Vito, 1998.

[HAM 93] HAMMER M., CHAMPY J., *Reengineering the Corporation – A Manifesto for Business Revolution*, Harper Business, New York, 1993.

[KLE 94] KLETZ T., *What Went Wrong – Case Histories of Process Plant Disasters*, Gulf Publishing Company, Houston, 1994.

[LUG 05] LUGAN J.-C., *La systémique sociale*, Que Sais-je?, PUF, Paris, 2005.

[MEL 95] MELESE J., *Approches systémiques des organisations. Vers l'entreprise à complexité humaine*, 3rd edition, Editions d'Organisation, Paris, 1995.

[MOR 05] MORTUREUX Y., *La sûreté de fonctionnement: méthodes pour maîtriser les risques*, Techniques de l'Ingénieur, Paris, 2005.

[NON 98] NONAKA I., *The Knowledge-Creating Company in Harvard Business Review on Knowledge Management*, Harvard Business School Press, Watertown, 1998, 532.

[PET 92] PETERS T., *Liberation Management – Necessary Disorganization for the Nanosecond Nineties*, Alfred Knopf, New York, 1992.

[RAN 93] RANGANATH NAYAL P., KETTERINGHAN J.M., *Breakthroughs*, Mercury Press, Toronto, 1993.

[TAR 98] TARONDEAU J.-C., *Le Management des savoirs*, PUF, Paris, 1998.

[WEI 85] WEICK K.E., *Sense Making in Organizations*, Sage Publications, Thousand Oaks, 1985.