Chapter 2
Innovation in Product/Process Development

Abstract Innovation is currently understood as one of the most critical factors for success in manufacturing firms. How to achieve real innovation in very demanding industrial environments is actually a very tough challenge. In this chapter, the concept of innovation is going to be discussed, analyzing the main implications of human beings since innovation is clearly coming out of human brains when triggered with some specific motivations or challenges that are not yet well understood from a psychological perspective. Another key issue is the concept of Extended Enterprise (EE) and how to manage innovation within this frame; the change of working paradigm and the new tools needed to enable people from different companies, sometimes distant locations and definitely different cultures to work together, is a new quite important field of research. How to achieve real innovation in new product/process development is also discussed in this chapter. Finally, a section is devoted to the analysis of the risks in innovation in product/process and how to deal with them.

2.1 Being Innovative

In current global markets, innovation is generally one of the most critical factors for success in industrial firms. Former advantages based on aspects such as costs reduction, local natural resources, geographical situation, and so on are not so relevant today since globalization is flattening these issues, and furthermore, needed natural resources are usually coming from outside, thus obliterating benefits of localization. It is a real must to be always aware of the need to foster innovation, fighting against the usual themes such as: “cut your costs”, “get focused.” Nowadays motto should be “innovate or lose.” This new situation needs the introduction of relevant changes in the way the companies work. One of these changes has to be accomplished in the field of new product/process development that is the basis of the success of industrial companies.

Focusing on that, it is very important to know exactly what the discussion is about and a good reference is the Green Book on Innovation of the European Commission (1995) that has elaborated the definition of innovation given in Table 2.1.

Table 2.1 Definition of innovation

To produce, to assimilate and to exploit successfully a novelty in the economic and social spheres in a way that provides inexistent solutions to the problems and allows fulfilling necessities of the people and the society.

This definition, apart from the idea of "introducing something new," brings it the very important concepts of:

- To exploit it successfully
- In the economic and social spheres; that is to say: the market
- Fulfilling necessities of the people and society

The three points could be reworded and summarized to: *to fulfill the necessities of the market* meaning that the real success of any commercial activity will only arise from a good fitting to the market. In summary, innovation may be defined as: "The transition from a novel idea to a successful product in the market" (see Fig. 2.1).

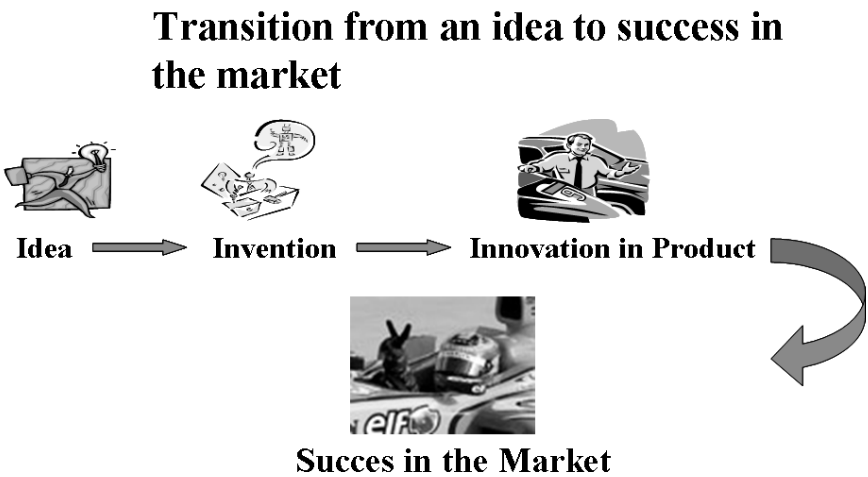

Fig. 2.1 Innovation

Two variables can be distinguished in relation to innovation: *range* and *type*:

- *Range.* Actually there are only two possibilities that may be applied to different aspects of the organization:
  - *Innovation on business management.* It implies working on business processes and covers all areas including strategic management, human resources, marketing, *etc.*
  - *Innovation on product/process.* On the other hand, product and manufacturing (or delivery) processes are currently so interwoven that there no longer seems to be a need to treat them differently.
- *Type.* Two types of innovation:
  - *Radical or breakthrough innovation*
  - *Incremental innovation*

Breakthrough or disruptive innovations should have a significant impact on the business through their impact on the market either by creating a new category of products fulfilling a previously nonexistent demand (Walkman, mobile phones, *etc.*) or by increasing performance level of existing products (injection engines, plasma video screens, *etc.*).

Incremental innovation in its way is very close to the quality field of continuous improvement. Any change in the right direction, adding value to the customer, can actually be considered as an innovation.

Small minor changes in the company's internal processes are difficult to understand as becoming "a successful product in the market" but they are actually also to be considered as "inventions" since, provided they do not have any negative impact through the product to the final customer (better if they have it positive), at least they result in adding value to society in general through such aspects as reducing production costs, improving working conditions, *etc.*

Invention and idea. The origin of innovations is clear: "the great idea (wow)." Even though it may appear obvious, the first main step is to know what are you generating ideas for.

In the industrial world, focusing on product, the right sequence comes from Quality Function Deployment (QFD – see Sect. 1.4.3) (Sorli and Ruiz 1994) as shown in Fig. 2.2.

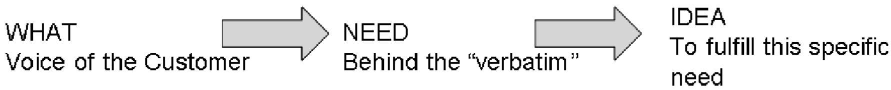

Fig. 2.2 From customer's needs to idea

It may also happen the other way round: the spark for innovation starts with internal dissatisfaction (sales drop, business opportunity, internal/external problems, *etc.*) which through a change plus an improvement becomes an external satisfaction to the customer. From this approach two clear conclusions can be extracted:

- The front end is always the same: *the customer.*
- Innovation means "*change to improve.*" If the change does not bring any improvement it will usually not be harmless; most likely it will carry on disturbances somewhere in the system or, in the best case, will be "good for nothing."

The process for *what's* collection and translation to *needs* is well handled and resolved by QFD. The real gap and challenge is *how to arrive at the breakthrough idea.*

Where do ideas come from? Ideas actually arise only from human brains (Osborn 1942, 1949; De Bono 1967; Altshuller 1992). Good sources (seeds) for them can be found:

- In nature *but* we are unable to notice them
- In tools, artifacts, and devices we use in our daily life *but* are "invisible" for us
- In normal things we are used to do *but* we do not care about them
- In children *but* we do not listen to them
- In other universes *but* we think there is only one: ours
- On the dark side of the moon *but* we always travel to the same side of the moon
- At the end of a long series of "why's" as children use to ask *but* we have lost curiosity a long time ago
- Behind stupid, Utopian, or unrealistic suggestions *but* we dismiss stupid ideas with a frown. Quoting Albert Einstein: "If at first the idea is not absurd, then there is no hope for it"
- Everywhere……but we do not recognize them

Invention. Usually a link is needed between an idea and its practical tangible application to a product or service: the invention.

Without a clear practical objective represented by a "need" from the market place, the application of the "idea" may result in an *invention good for nothing.* This is frequently the case of a technology driven innovation; someone gets attracted by a new technology and immediately looks for where to apply it without really thinking on the key question: "What for?" On the contrary, if the answer is clear, the "invention" will immediately fit into the product/service, achieving the innovation.

2.2 Human Aspects

In the information and communication technologies (ICT) market there exist tools for supporting innovation (*e.g.,* tools supporting collaborative working or idea generation, *etc.* – see Chaps. 4 and 5). New interesting ones are continually emerging; it is for sure that ICT tools will continue growing and will ever increase capabilities and performance.

However, innovation is a serious job that can't rely only on software tools as sophisticated as they could be; there is a real need for methodologies helping people to innovate. Furthermore, innovation means team working which means sharing information. People are in general very reluctant to share information unless they obtain something in return.

Creativity and innovation do not arise directly from the tool itself. As has previously been said, creativity stems only from the human brain and becomes an innovation when applied to solve specific technical problems that will increase the added value to the final consumer. Never forget that only a combination of the three factors (new, successful, adding value) is the real way to achieve innovation.

One of the key resources for creativity is "spare time" to think creatively. Notwithstanding, in current industrial arenas most of the time people are devoting their efforts to perform low value added tasks, fire-fighting, coping with small repetitive problems and nuisances, and in many cases working only for the shake of the organization itself in a much endogamous way. Furthermore, if you try to be creative, the organization may tend to believe that you are wasting your time, a time the company is paying for.

Within this framework, the increasing introduction of ICT tools and the expanding Web facilities combined with the increasing automation of most processes (productive or not) are facilitating the transfer of people's activities from hard manual tasks to soft ones more dependent on intellectual abilities.

As a final consequence, people exercise their mental skills and get more free time, becoming more and more liberated from manual repetitive tasks. The next step is to use this time to be really creative (personal assumption) and to be rewarded by it (company commitment).

2.2.1 Barriers to Innovation

Innovation is not easy to deal with; it has a high level of risk, has to face many difficulties, and needs to be bred and nurtured within a special environment including cultural aspects, means, and systematic approaches.

Some of the generic barriers that have to be overcome for innovating (Piatier 1984) are going to be discussed in this section, while the general approach to "risk in innovation" will be analyzed in Sect. 2.5.

Barriers to Idea Generation. The idea generation process should be divided into two quite distinctive phases as it is graphically shown in Fig. 2.3.

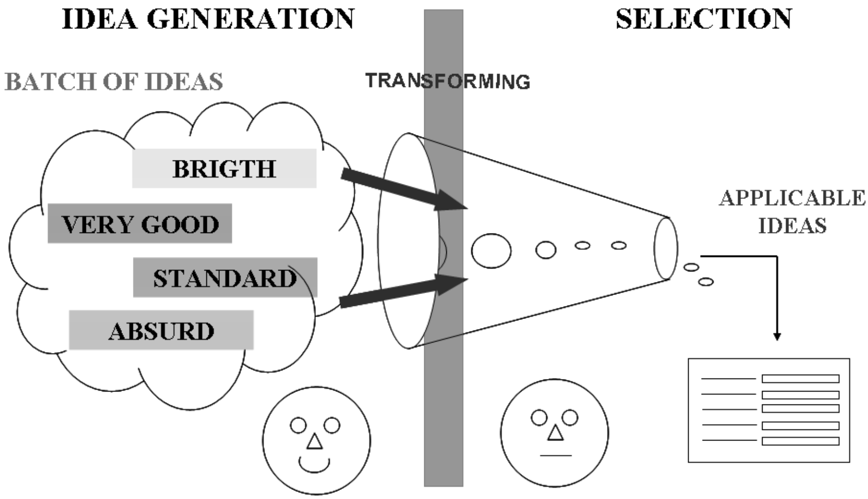

Fig. 2.3 Process for idea generation and selection

The first phase on the left side of the bar is a typical exercise for creativity aiming to free idea generation that could be managed by using a wide range of existing tools (lateral thinking, thinking hats, brainstorming, think tanks, 6-3-5, nominal group techniques, TRIZ, *etc.*) (Osborn 1979; De Bono 1985; Altshuller 1988). It has to be conducted in a freewheeling way, previously creating an open atmosphere, trying to let people evade the day to day routine, and transporting them to a new environment not only in relation to the subject matter but even physically[1], in summary to jump "out-of-the-box." On this approach, people are expected to behave openly, launch a lot of "crazy" ideas,[2] combine, and build upon previous ones, *etc.*

In contrast, the second phase (on the right side) has to be a serious well controlled selection and evaluation process to filter ideas that could finally be applicable. This second part will be discussed in further detail in Chaps. 4 and 5, in relation to the ICT tools supporting this process.

First phase of the innovation process (left side of the figure) has several problems related first, to the difficulties of conducting the process — a good facilitator is a must, and second to the psychological barriers humans build internally to

[1] It is recommendable to use a special room isolated from working areas where some elements fostering idea creation are introduced: colorful painting on the walls, *ad-hoc* furniture, special lights, soft music, *etc.*

[2] As mentioned before: "If at first, the idea is not absurd, then there is no hope for it." Albert Einstein.

block their creativity. These barriers may be of several types (Michalko 1991; Sternberg 1999):

- Perceptual
- Emotional
- Cultural
- Environmental
- Intellectual
- Others

and may appear in different ways such as:

- Self-limitation (perceptual)
- Using stereotypes (perceptual)
- Fear of appearing ridiculous (emotional)
- Not discussing rules (cultural)
- Changing is dangerous (cultural)
- Superficial analysis (intellectual)
- Unique approach (cultural)
- Distractions, monotony (environmental)

Barriers to knowledge sharing. The second phase is a quite longer process (to be discussed in Chap. 5) which needs knowledge handling in order to enable idea analysis, evaluation, combination, and selection of the most promising ones for further analysis and elaboration.

Team work and the use of collaborative tools require knowledge sharing which is one of the main barriers to the process. People are quite reluctant to share knowledge since they feel that it is the main base wherein their values, capabilities and professional status lie. To many persons, sharing and transmitting knowledge mean empowering co-workers (potential competitors) which may eventually imperil their own professional status.

Solutions to foster and improve open knowledge sharing vary greatly depending on the specific circumstances, type of organizations, culture, and other variables. So there are no recipes but a common requirement, a need for an overall cultural change throughout the organization in aspects such as:

- Creating a *win-win* culture: sharing knowledge generates value for all
- Reward systems should be adapted to facilitate *team working* instead of focusing just on individual performance
- *Rewarding innovation* and initiative and *accepting failure*. People should be fostered to try new ways and the organization has to accept they will commit errors
- Empower teams to make their *own decisions* and endorse them from management

Barriers from inside the organization. Organizations need to create a special breeding ground, first to become innovative and second to continue being innovative. Starting a long-distance race – achieving an innovation – though difficult, is easier than keeping on running – achieving an increasing number of innovations in time – which is the brand mark of excellent organizations.

Some barriers hindering innovation will always exist in the organizations. The more innovative an organization, the lower these barriers will be. However it is important to be aware that the barriers can be demolished but if the debris is not cleaned up someone may reuse it to erect the barriers again. If the company's innovation system fails or is neglected, the barriers will grow out of control.

For instance, IBM[3] identifies five barriers to innovation (Andrews 2006):

- *Inadequate funding.* Related to the facts that 1) funding is never enough for innovation; 2) budget time frame does not keep the same pace that potential innovations from ideas arising at any time out of budget
- *Risk avoidance.* People in general do not like changes, are conservative, and are not prone to assume risks
- *"Siloing".* Companies tend to create their own "box" to be enclosed inside and feel protected against the outer environment.
- *Time commitment.* Time (usually long) is really needed for innovation and management hardly accepts that "time for innovating" is paying off. Time is probably the only factor that can never be recovered: "Time is a scarce and valuable commodity."
- *Incorrect measures.* Usual indicators and measurements are not such valid for innovation: payoff is usually longer and there are many intangibles involved.

In fact, some other barriers can be identified as:

- *Organizations not conducive to innovation.* Different types of organizational culture (Kotter and Heskett 1992) greatly influence the disposition of the companies to be or not to be innovative. This in turn, has an impact on the way the organization behaves in relation to innovation on its different levels (management, groups, and individuals), the way the resources are allocated for innovation, how the rewarding systems foster or hinder innovation, *etc.*
- *Leadership.* Innovation starts at the top management level. Since organizations are steered by "persons," the way management behaves and pull the rest of the organization greatly condition the overall company performance (Collins 2001).
- *Employment policy.* Profiles of the people recruited by the organizations will clearly condition the culture of the organization and the working atmosphere which are key issue in the innovation capacity of the companies. For instance Google,[4] renowned for being one of the most innovative companies in our time,

[3] http://www.ibm.com

[4] http://www.google.com/intl/en/about.html

looks for a special kind of people to join in which they call "Googlers" – We're always on the look-out for new Googlers – as can be seen in the recruitment Web site of the company.[5]

- *Level of awareness.* Four rising levels of innovation awareness in companies can be considered (Christensen *et al.* 2008). Knowing their own level of awareness allows the companies to shift from one level to another until reaching the highest one:
  - *Unconsciously not innovating*. Not even thinking of needing to be innovative at all
  - *Consciously not innovating*. They know of the need to innovate but….
  - *Consciously innovating*. Slowly innovating without any system
  - *Unconsciously innovating*. Having a system for innovation so innovating without being conscious

Barriers outside the organization. Some barriers can also be encountered outside the organization:

- *Environment not conductive to innovation.* Some environments may hinder innovation though some others may be more prone to innovate more depending on aspects such as:
  - *Characteristics of the company.* For instance, an emerging new technology-based firm (NTBF) (Leonard 2001; Oakey 1994), due to its own characteristics, *must be* more innovative than traditional companies at least in the first years of life
  - *Size.* SME have in general more difficulties in innovating due to scarce resources and time constraints (Pihkala *et al.* 2002)
  - *Sector.* ICT companies, defense, new business (*i.e.,* windmills), *etc.* tend to be more innovative than other traditional sectors.
  - *Regions.* Geographical areas in which the companies are based condition their behavior related to innovation. Silicon Valley in USA is a good referent on how it attracted entrepreneurs from all over the world and launched the "big bang" of ICT companies. In Europe, the Stockholm region in Sweden, Oberbayern in Germany, *etc.* have been classified as advanced regions according to the "Regional Summary Innovation Index" (RSII) (Hollanders 2007).

    These kinds of clustering of companies would generate "The Medici Effect" (Johansson 2004) gathering people with different profiles, expertise, background, training, *etc.* which in general generate a high potential for innovation by taking advantage and great benefits from the synergies out of the "Intersection of Ideas, Concepts and Cultures".

[5] http://www.google.com/intl/en/jobs/

- *Administrative and legislative regulations.* Regulations, laws, tax systems may have a relevant impact on the level of innovation of the resident companies.
- *Competition.* Pressure from competition or weak competition has also an influence on the behavior of companies in relation to innovation.
- *Knowledge.* The lower the knowledge on a specific technology, the higher level of innovation is needed to cope with it.

2.3 Extended Enterprise

New ways of working move strongly towards Extended Enterprise (EE). The Extended Enterprise concept in parallel with concurrent enterprising looks for how to add value to the product by incorporating knowledge and expertise from all participants in the product value chain. The semantic difference between both terms will be discussed in the following paragraphs.

Industry needs to benefit from Extended Enterprise techniques by involving all people throughout the product life cycle (suppliers, customers, design, production, servicing, *etc.*) enabling them to provide their product knowledge to enhance product development and support. This knowledge needs to be saved and managed; loss of this knowledge results in increased costs, longer time-to-market, reduced quality of products and services. By improving products and customer support manufacturing companies will be more competitive, and employment will increase.

Industrial companies need to shift towards the use of EE technologies and knowledge management for customer/product support. This paradigm implies a quite new scenario: knowledge capturing and sharing, new forms of interrelationship between companies and persons, *etc.*

Companies need to be able to extend their own enterprises (by removing barriers of geographic location and human related problems) to encompass the customer's operations where the supplied industrial products are being used. They need to provide the expertise to support the products *in situ* (including problem solving support, and diagnostic analysis of customer feedback), just as if the company's expert was there with the customer solving the problems. This involves EE models of the technical expertise of the company in supporting their products at the customer's site.

The key idea behind the EE concept is to develop means supporting the collection of all useful knowledge throughout the EE for new and existing process and product developments, and to develop this knowledge into a means of fostering industrial innovations. Innovations are achieved by combining the ideas and feedback from all parts of the product life cycle, including customer interaction with existing products and new product ideas, customer service and field engineers, including suppliers, and including also a pooling of knowledge between multiple sites.

This new paradigm addresses an issue of significant importance to industry: the use of "e-business technologies"[6] for EE product knowledge systems permits ubiquitous human interaction, across and beyond industrial organizations, getting organizations to work better with each other (see Chaps. 4-5). This on its side produces a significant impact on competition, employment, working conditions, internal market and free circulation of goods, health, environment, transport, innovation, and long-term sustainable growth.

The main approach is to focus on product knowledge which comes from the agents in the Extended Enterprise (EE) involved in the development, support and use of products. These agents may come both from the external EE (suppliers, customers, *etc.*) and internal EE (involved functional areas of the company) in the form of tacit or informal knowledge generated by employees. It represents the next evolution of product information systems, taking standards and practices forward to support co-operative working and partnerships.

The main business benefits arising from this new paradigm are:

- Reduction of product innovation cycle-time
- Reduction of time and efforts for solving product/process problems
- Improvement of process efficiency and reduction of wastes

The means needed to support the Extended Enterprise paradigm are:

- Means of stimulating the creation of innovative ideas and collecting them from people involved with the products and processes. Specifically to increase the number of innovative suggestions for new concepts and reducing the time ratio for new designs in the companies
- New ways of processing these ideas and storing them into a structured knowledge repository to ensure that all useful knowledge (innovative information) is saved
- Means of analyzing innovative knowledge to determine which is useful, and which is not. That is, to enable the viability of ideas to be assessed
- Means of delivering the innovative ideas to product and process designers for maximum effect

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[6] The term "e-business" encompasses a variety of ICT tools aiming to enable many different business processes among companies through Web based ICT applications.

2.3.1 Creativity in the Extended Enterprise

Creativity is defined as the "Ability to produce something new through imaginative skill, whether a new solution to a problem, a new method or device, or a new artistic object or form" (MacHale 2002).

This can actually be done on an individual basis but it is not easy. In fact people are very creative in childhood but most of them bury their creativity in time under layers of rules and norms, counter-creative education, boring tasks and corporative restrictions as well as a growing (with age) fear to fail.

Most of the scholars agree that team work fosters creativity by adding extra value to the simple addition of the individual skills of the team members. Moreover most of the existing tools for creativity though they could be used in an individual pattern (but not all) are actually intended for team working.

The real challenge on a collaborative environment (Sorli and Stokic 2008) through the EE is how to "re-invent" these tools in order to enable them to be used within the new virtual working frame, create new ones and eventually integrate all them (see Chap. 4). A very important drawback is that virtual environments fail to create the warm, human, freewheeling atmosphere necessary in any "creative process."

2.3.2 Managing Product/Process Knowledge in the Concurrent/Simultaneous Enterprise Environment

On this framework industry in the twenty-first century has to face these challenges by using techniques to deal with aspects such as:

- *Extended Enterprise.* As already discussed, enterprises are surpassing physical boundaries and are establishing durable links with other companies — engineering, sub-contractors, providers — but are mostly at a loss on how to deal with customers at both ends of the chain. The customer is clearly a very relevant actor at the conceptual phase of the product life where the designer has to understand customer's needs and feelings as well as at the other end of it when the extended product has to live together with the user along its operating live.
- *Concurrent enterprise.* As the idea of EE refers to a longer time frame, concurrent enterprising focuses more on the specific relationship among companies to set up new operations, new product development and launch, marketing activities covering a wider range than only the physical product by itself (extended product), and others.
- *Extended product.* The concept of product is rapidly changing from the physical tangible product to the idea of providing an overall function, for example

Rank Xerox[7] became a provider of document services from being a manufacturer of photocopier machines through following a business change of paradigm in the decade from 1980 to 1990 (Stim 2006). This new focus may imply an overall strategic decision on changing the business orientation but at the very least it represents a plus of intangible assets related to fulfilling requirements, fitting the right product to the right needs, servicing the product and maintaining it through its life, empowering the user to get the best from it, and lastly facilitating the product retrieval and eventual replacement in an environmental friendly manner.

- *Support of ICT.* Besides some psychosocial changes, the technical challenge is related to the massive use and incorporation in industry of the new ICT tools and Web based technologies. There is a strong human implication in the users about getting used to the new technologies and changing the way the work has to be performed.

From this basis, the new trends should be to extend the e-working[8] systems to the whole life cycle of the extended product. In such a way, new working methods will be capable of supporting the Extended Enterprise to monitor and capture knowledge from the "extended product" throughout its life cycle. This will cover from the conception of the product/service to its disposal and back to "re-incarnation," that is to say, launching improved new extended products based on the knowledge collected from the existing ones.

As it has been mentioned above, that knowledge useful to design engineers comes in many forms and useful knowledge can come from many sources inside and outside the company. A common need amongst companies is for them to be enabled to acquire and process this knowledge so that a greater, richer, centralized knowledge and information repository is available to produce better designs, faster, with greater innovation, and with less re-inventing of the wheel. The most important needs of industrial companies with regard to design are to get good products to the market place quicker, and to reduce costs related to design.

2.4 Innovation in New Product Design

Nowadays, high rates of innovation and dramatically reduced product development lead and cycle times have been shaking both practitioners and researchers of product development management. An array of ideas have been introduced under various labels: "cross-functional teams," "design for manufacturability," "concept to customer," "computer aided engineering," "black-box engineering," "platforms," "networked development," and "knowledge management" are just exam-

[7] http://www.xerox.com

[8] Same as mentioned before for "e-business", "e-work systems" stands for the ICT tools to perform different working operations

ples of such labels some of which are discussed in several parts of this book. Such concepts have created new challenges to the organization and management of the technical functions in the firms.

Product development plays an increasingly important role in the competitiveness of the companies basically through introduction of new technologies and product customization. Therefore the product development and engineering functions have an active role to play and must step out of their traditional place as a somewhat isolated expert organization. Thus, the product development organization is more directly exposed to the competitive forces facing the business and more directly involved in the strategic development process in the firm. For that reason, the product development function will continue to attract more attention by management. The traditional boundaries of the function have changed beyond recognition becoming increasingly complex and new forms of relations and direct integration of functions have been developed.

Strong and continuous efforts have been made to reduce time to market, to implement cross-functional teams, and to support project leaders. Co-development with suppliers and extended industrial networks are on the agenda of many companies. During the same period, a strong development of the “soft” area with ICT both as products and integrated with traditional products has also occurred, accompanied by the development of ICT infrastructures for product development.

Innovation in the design of new products is one of the most critical aspects for enterprises. It is really a difficult job to innovate in an industrial environment characterized in general for the urgency, the scarce resources and within a managers’ culture greatly limiting creativity. Furthermore, as has been discussed in Sect. 2.2, there exist several barriers to creativity. Likewise, one can often hear “killing phrases”, expressions such as: *enough of that nonsense, it is a waste of time, do not come telling tales to me…*

In consequence, another very important issue in any new product design and development is the manufacturers’ capacity to add innovation in their new products and designs. The relentless race to develop new, higher quality products and simultaneously reduce time to market and reduce product cost is a major challenge for all companies, especially for small and medium sized enterprises (SME). Notwithstanding, actually there is a lot of knowledge throughout the company that is very difficult to reuse in practice: it is in old forgotten drawings, it is in the brains of employees and may be spotted in old experiences from which the “lessons learnt” have not actually been learnt.

And, on the other hand, many authors agree that innovation ability is one of the most important competitive keys in the current enterprise because to innovate implies advantages like:

- To increase market share
- To enlarge markets and open new ones
- To overpass and take advantage over the competition

- To introduce specific features in the product making a differential from the competition
- To reduce costs

The main difficulty is then to balance these two aspects apparently so opposite: difficulty to innovate and the need to be innovative.

It seems obvious that innovation cannot be left in the hands of any "illuminated inventor's initiative." In real life there are very few people really able to invent (not too practical people by the way) and furthermore just a few companies can afford to contract any of them.

Experience up to now indicates that innovation is difficult to achieve and usually arises from the ideas that some especially brilliant persons are able to generate. However, Genrich Altshuller (Altshuller 1988, 1996, 1997) the father of TRIZ methodology (see Sect. 1.4.4), and his followers concluded that it is possible to systematize innovation. But given there are few really creative people and these persons function in an intuitive manner, some tools to "systematize the innovation" are needed. People have to be provided with tools helping them to generate creative and original ideas which build up the basis for the innovation process. This is the origin of TRIZ, a methodology helping to resolve any kind of "inventive problem"[9] providing innovative design concepts and fostering innovation.

2.4.1 Understanding the Meaning of Innovation

Though previously mentioned, it is important to agree on a common understanding about some of the expressions used in this book.

It is intuitively known what "an invention" is. Anyway it can be defined as the ability to develop a new idea either creative or different, aiming to improve a specific situation in any field: product, process, service…

However, "innovation" is only achieved when this idea ("invention") is successfully implemented. In manufacturing companies this is usually referred to as "industrialization of the idea."

Finally the level of creativity should be described as the difference that makes an idea be considered as an invention.

To complete these definitions the following contribution from Altshuller (1988) is quite relevant. By conducting an exhaustive patents research, he concluded that the technical solutions involved in the patents had a wide range of creative content. Based on that approach, he established a semi-quantitative scale to "classify" creativity. This scale, not quite scientific but very useful, is shown in Fig. 2.4.

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[9] The concept of "inventive problem" within TRIZ philosophy means the kind of problems for which there isn't any known solution. These problems can actually foster innovation.

- **LEVEL 1. STANDARD**
  Routine-type solutions.
- **LEVEL 2. IMPROVEMENT**
  Permanent improvement
  New characteristics
- **LEVEL 3. INVENTION INSIDE PARADIGM**
  Providing solutions from other fields
- **LEVEL 4. INVENTION OUTSIDE PARADIGM**
  Scientific solutions
- **LEVEL 5. DISCOVERY**
  Beyond scientifc borders

Fig. 2.4 Levels of innovation

- *Level 1 Standard.* This level represents solutions of routine-type design problems, obtained using methods well known within the particular field of expertise. In solutions at this level the existing system is not changed, although particular features may be enhanced or strengthened.
- *Level 2 Improvement.* These are solutions that, while basically leaving the existing system unchanged, do involve new features and lead to definite improvements. Inventions at this level are achieved by methods well know within the same industry.
- *Level 3 Invention inside paradigm.* These are those that constitute an essential improvement of an existing system. Level 3 inventions usually involve technology known in other industries but not widely known within the industry in which the inventive problem arose. Solutions to level 3 problems thus create paradigm shifts within their industries; they are found outside the range of accepted ideas and principles of that industry.
- *Level 4 Invention outside paradigm.* Level 4 inventions are characterized by solutions found, in Altshuller's words, "not in technology but in science," through the utilization of previously little-known physical effects and phenomena.
- *Level 5 Discovery.* These solutions are usually beyond the limits of contemporary scientific knowledge. The solution requires the discovery of some new phenomenon that is then applied to the "inventive problem." Level 5 inventions usually lead to the creation of wholly new systems and industries. Lasers, aircrafts, and computers are good examples here.

Obviously enough, words "invention" and "creativity" can only be considered from level 3 upwards.

2.4.2 Industrial Design

The increasing technical complexity of new products, besides a reduced life in the market – in addition to other characteristics as can be seen in Table 2.2 – puts into question the traditional old design process (based on independent and sequential phases) and forces the companies to choose new alternatives.

Juran, a renowned total quality "gurú", in his classic book "Quality Control Handbook" (Juran 1962; Juran *et al.* 1983) made a still valid clear distinction between *traditional* products and *modern* products, as can be seen in Table 2.2.

Table 2.2 Comparison between traditional and modern products (Juran, Quality Handbook)

	TPYE OF PRODUCT	
CHARACTERISTICS	TRADITIONAL	MODERN
Simplicity	Simple, static	Complex, dynamic
Accuracy	Low	High
Interchangeability needs	Limited	Extensive
Consumable or durable	Basically consumable	Basically durable
Using environment	Natural	Artificial
Product understanding by the user	High	Low
Importance for human health, safety and life continuity	Rarely important	Usually important
Life cycle cost for the user	Equal to purchasing price	Bigger than purchasing price
Life of a new design	Long: decades or even centuries	Short: less than a decade
Scientific base of design	Empirical in large measure	Scientist in large measure
Reliability, maintainability, availability issues	Scarce	Quantitative
Production volume	Usually low	Usually high
Usual causes of failure in service	Manufacturing failures	Design failures

Traditional products can be shoes, garden hardware, bread, or aspirins. Modern products are printed circuit boards, computers, aircrafts *etc.* The first telephones and cars were traditional in their simplicity, but now they are modern in their complexity.

Following this idea, two processes are needed for launching new products: *traditional processes* for traditional products and *new processes* for new modern products. Traditional methods are inadequate for modern products. They have been tried but they fail. Besides, use of modern methods for traditional products appears to be uneconomical.

So, following Juran, companies with traditional products should not have too many problems with their current design processes whereas those incorporating modern products should revise them.

However, by now, this may be considered as not completely true. Both continuous improvement and innovation have room in either of the two processes and furthermore can be applied both to the product development and to the correspondent production processes.

In general, the most outstanding and urgent needs industrial manufacturing companies must cope with are:

1. *Reduce time to market.* Most of the design activities are still based on "pen and paper" work. However, providing the right knowledge at the right time can increase competitiveness by reducing project timescales, avoiding repeating mistakes, and enabling solutions to be generated faster.
2. *Reduce costs arising from design.* Design costs amount in general to a significant share of the company overall costs and can be reduced by improved working, better access to information, less time to look for information or search for ideas, and more people focused on solving design problems. Companies need to re-use good design ideas from the past designs (less re-inventions).
3. *Make better products.* Innovation is a critical factor in the success of industrial companies. They need to develop innovative products and solutions and simultaneously reduce the design time, comply with regulations (national and supranational), take into consideration recycle-ability and energy consumption issues, *etc.* This is very difficult for companies, mainly SME, which are in general less able to translate ideas or knowledge into innovations.
4. *Increase involvement in design.* By increasing the number of people (with a structured system) involved in providing design inputs and knowledge, it is possible to enrich the design process, and also improve motivation by involving people. The knowledge of the product/process is distributed across the whole company. This know-how represents an essential resource for successful competition in the market and should therefore be preserved and used as efficiently as possible. There is a risk that this knowledge is lost when key persons and engineers leave the company.
5. *Right first time.* Companies need to get it right first time. Reworking designs and recalling products are every company's nightmare, particularly so for SME.
6. *Reduce maintenance.* By making better products and incorporating the knowledge of maintenance engineers (feedback from maintenance to design, which is not often present in a structured way), maintenance costs can be reduced.

There exist means providing practical methods for capturing, storing, reusing, and developing knowledge into innovative and quality designs. New ICT-based approaches (see Chaps. 4 and 5) of processing knowledge are required to manage all the diverse forms of knowledge that design engineers are exposed to. It will help them to make best use of the extended knowledge resource of companies, increase the development rates of innovative ranges of products/solutions, reduce design time and costs, increase customer satisfaction, improve the process of new products/processes development, and achieve an overall business success.

2.5 Risks in Innovating in New Product

2.5.1 Main Difficulties for Innovation

Innovation is a risky business as well as design of new products, as will be discussed in Chap. 3 (Sect. 3.1.1). Combination of both – "*Innovation in new product design*" – should very likely increase the risk level. In consequence, there are some aspects that have to be considered in order to minimize these risks, which are going to be discussed in this section.

In the product design process, people involved within the product life cycle and the production processes have to be encouraged to generate innovation. Team working between people from different sites (and working off-site) and between organizations, customers, and suppliers along the Extended Enterprise (EE) also needs to be encouraged. *Systemic Innovation* in Chap. 3 (Sect. 3.4) and *Open Innovation* (Chap. 6, Sect. 6.4) will discuss these issues in more detail.

The accelerated pace of technological development continuously increases time and market pressures on manufacturers' capacity to innovate new products and designs and to develop the manufacturing processes that produce these products. As said before, there is a real need for companies to develop new products with higher quality, reducing time to market, product cost and improving quality, but many companies lack the financial capacity either to invest in the latest technology as it reaches the market or to hire specialists to integrate new methodologies and systematically to improve their products.

Many companies would achieve the required corporate breadth-of-experience to improve their products and improve their processes if they could only make best use of their knowledge resources internally and in partnership with their suppliers and customers. Stimulation of "innovation" is a means by which these knowledge resources could be channeled.

Major difficulties for innovation are related to three main topics (which are addressed throughout the book):

1. *Intangibility of the inventive knowledge.* The inventive capacity is usually considered more as an inherent property of the genius than something that may be learnt. Intangibility makes the inventive knowledge difficult to accumulate and transfer. Emerging theories say that the capacity for innovation observed in some inventors is no more than an instinctively applied methodology for abstraction, which gives sense to the words "inventive knowledge" (or "innovative knowledge"), defined as "the knowledge necessary for finding solutions at any abstraction level." Therefore intangibility will be overcome by establishing

rules, methodologies, and tools first for abstraction (general rules or solutions) and then for concretion (applying the general rules and solutions to the specific situation) of problems, allowing accumulation of them and their solutions in a hierarchical database with the abstraction level as hierarchy separator.

2. *Individualization of the innovation process.* Investigations performed during the last 20 years have demonstrated that innovation is better achieved by working as a team. In the first conceptualization steps the working teams should include the best experts in several fields available world-wide which becomes quite impracticable in the current stressed and time limited working environments for most industrial companies (mainly for SME). Due to this problem, innovative thinking is hardly tried by individuals on their own and the results are generally poor (geniuses are not so frequent).
3. *Information overload.* (Goldratt 1990) Nowadays there is a huge amount of information coming from many diverse sources but finding the needed information and knowledge in the right moment is becoming a real problem. Traditional methods like looking for and directly contacting the right person for the right knowledge are becoming almost impossible in the increasingly isolated and time driven working environments of today. Team working among stakeholders in the product value chain is then the only reasonable way of overcoming this difficulty.

Such problems could be minimized by employing innovation methodologies during the development process and incorporating tools to support innovation along the way. However, even when enterprises try to incorporate new methodologies, many problems appear due to human – and methodology – specific factors.

Human factors include problems of encouraging and convincing people to use new and innovative methodologies. It is noted that new methodologies, however enthusiastically received, are frequently discarded in favor of familiar methods shortly after they are taught and personnel are trained. Implementation of new methodologies is also frequently inefficient in time-management terms due to complexity, dependence on worker experience and interpretation, as well as processing of results.

Methodology factors, *e.g.,* available engineering methodologies, are frequently theory-overloaded and do not integrate well with one another, if at all. In the chain of methodologies there is lack of transparency in planning, cost, and technological and quality data.

Key aspect to shift from the current ways of working to the "New Paradigm" as it is going to be presented in Chap. 3 (Sect. 3.1), is the Extended Enterprise (EE) concept previously addressed in the book. The main challenges to be faced under this paradigm are:

- Developing practical means of developing ideas into innovations in products and processes. This will involve taking what is currently available and producing methods of rapidly taking many creative ideas, and assisting people to work together in a structured manner to develop these ideas into innovations.
- Capturing and structuring of innovative ideas over EE in such a way that they can be best used for product/process innovation; this is typical "difficult to structure knowledge" which asks for high level "innovation" meta classification – on one hand the structure must not restrict creativity of the people, on the other they must be structured in such a way as to be easy to assess and re-use.
- Providing means for team development of innovative ideas over EE is a tough challenge and asks for generic approach for development of ontologies applicable in the context of specific products/processes.

Specific innovations that have to be incorporated to the company's culture are:

- *Stimulating the creation of ideas* about products and processes throughout the EE, empowering all people coming into contact with the products or processes to provide their thoughts on improvements and original ideas
- *Interactive solution to be able to take basic ideas* and develop them (by *collective working* throughout the EE), into product and process design innovations
- *Development of diverse ideas from multiple sources* into workable innovative designs (for industrial products and processes)
- *Assessment of innovative ideas* to analyze their likely success, and thereby evaluate the viability of ideas/designs
- *Development of specific ontologies* needed to enable efficient exchange of ideas between different experts/actors within an EE
- *Combination of methods* for creating innovative ideas with "classical" methods for collection of knowledge on products/processes and problems
- *Development of a combination of repositories* with innovative ideas, products-processes knowledge, and information/knowledge on problems, and/or improvement potentials
- *Fostering new forms of organizational learning* within the EE by collecting and storing innovative ideas and making them available over long time period

Since the basis is sharing innovative ideas from different actors within EE the involvement of the end-user is critical. This provides a good basis for efficient specification and testing of methods and tools, taking into account critical human related aspects.

2.5.2 Risk Management

2.5.2.1 Risks

Definition of risk varies widely mostly depending on the context in which it is used. In the case of innovative new products development, risk can be considered as "any event that provokes undesirable effects in the process which will finally result in economical losses for the company."

It is relevant here to consider a distinction between "uncertainty" and "risk" (Knight 1921) in the sense that a risk can to some extent be assessed (measured) while an uncertainty is almost impossible to measure.

Hubbard (2007) proposes a more detailed definition of both terms and how to measure them as:

> **Uncertainty**: the lack of complete certainty, that is, the existence of more than one possibility. The "true" outcome/state/result/value is not known.
> **Measurement of uncertainty**: a set of probabilities assigned to a set of possibilities. Example: "There is a 60% chance this market will double in five years."
> **Risk**: a state of uncertainty where some of the possibilities involve a loss, catastrophe, or other undesirable outcome.
> **Measurement of risk**: a set of possibilities each with quantified probabilities and quantified losses. Example: "There is a 40% chance the proposed oil well will be dry with a loss of $12 million in exploratory drilling costs."
>
> D. Hubbard

The final idea (according to Hubbard) is that uncertainty may exist without risk (uncertainty in a weather forecast is not risky for office work) but risk always implies uncertainty (risk in navigation may come from uncertainty in weather forecast).

2.5.2.2 Fundamentals of Risk Management

Risk management. This is a key aspect of project management. In any project a risk analysis should be performed beforehand. Furthermore, in a process aiming at innovation in new products design and development, risk management becomes of an utmost importance. Its results will become the input for a decision making "go/not go" gate.

Risk management builds upon three legs that are discussed in next sections:

- *Risk analysis*
- *Contingency plan*
- *Decision making*

Risk analysis process should be a continuous activity throughout the project combined with the decision making gates and a contingency plan intended to mitigate the potential negative impacts of the risk occurrence. The combination of the three constitutes the risk management.

Risk analysis. Risk analysis is an important but highly difficult activity in each project but in contrast, it pays back well since once the risks have been identified and assessed it becomes easier to implement measures to prevent their occurrence or/and mitigate the resultant effects.

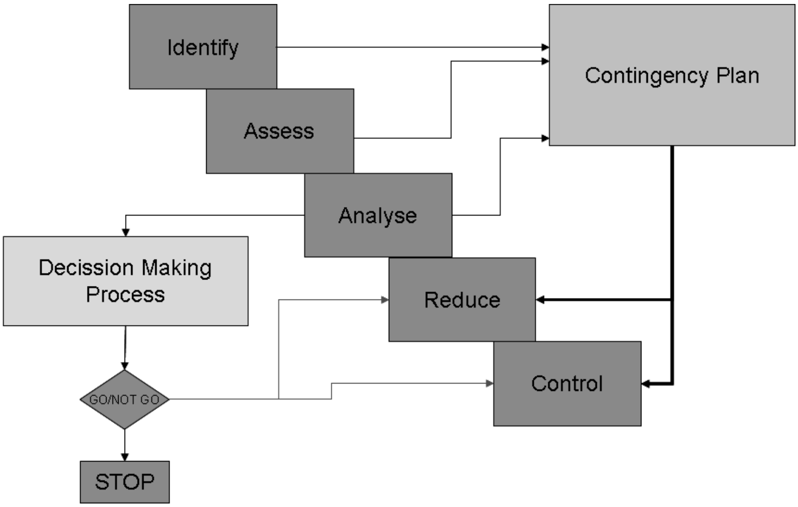

Fig. 2.5 Risk management process

As can be seen in Fig. 2.5 adapted from Roy (2003), the process follows five steps selectively concentrating on those risks with higher probability of occurrence or more serious impact on the process:

1. Identifying the risk
2. Assessing the risk: evaluating the impact and probability of occurrence
3. Analyzing the risk: understanding the process for which the risk may show up
4. Reducing the risk: setting up any feasible means that could prevent the risk occurrence or its impact on the process
5. Controlling the risk: monitoring the process trying to prevent the risk before it actually comes out or to trigger countermeasures once it shows up

These countermeasures (5) should have previously been identified and defined in the contingency plan; meanwhile any of the steps 2, 3 or 4 should derive to a decision making gate.

Contingency plan. A contingency plan must implement all possible preventive actions that should prevent risks occurrence but must also contain alternative plans to be launched upon the appearance of identified risks as well as how to proceed in the case of appearance of non-identified risks. It should follow the form of a flow chart showing the alternatives to be chosen in case of deviations from the original plan ("if…then") with as many branches as possible. A flowchart of the kind can be prepared by using tools such the "Process Decision Program Chart (PDPC)" in which the process flow is represented describing all possible situations with the required actions to correct deviations (see Sect. 1.4.9).

Decision making. Decision making gates have to be pre-defined in time related to the standard flow of the project but also an agile decision making mechanism has to be developed in order to deal with risks appearance. Whenever a risk is becoming unmanageable, the contingency measures show ineffective, the risk is higher than expected, or a new unexpected risk is showing up, the decision making mechanism has to be triggered, and a decision on the project continuation or on changes to be implemented in it has to be made.

2.5.2.3 Identifying and Assessing Risk

Risks are evaluated by means of allocating weight to them in a numeric form. In general a risk equals the product of its probability of occurrence times the value of the impact on the process (*i.e.,* potential losses):

$$\text{Risk evaluation} = \text{Occurrence} * \text{Impact}. \qquad (2.1)$$

The result of such an equation provides a priority number enabling the analyzer to concentrate its work on those with higher priority number (third step: analyze). In this equation, occurrence means the statistical probability of the appearance of the *cause* (event) that will trigger the process resulting in an undesirable *effect*. A serious drawback lies in the difficulty of evaluating both concepts; there are several tools that allow one to estimate them.

Tools to calculate the probability of occurrence can be grouped under the general umbrella of Probabilistic Risk Assessment (PRA studies):

- *Fault Tree Analysis (FTA).* FTA (Mobley 1999) by using logical gates (and, or, not) represents in the form of a tree the sequence and combination of failures that chain up to the final effect.
- *Human Reliability Analysis (HRA).* Methods for evaluating and modeling human errors (Pekka 2000). Detailed breakdown of human tasks allows the assignation of probability of failures to "human systems" in the same way as FTA works for technical systems. This method is most related to processes with heavy safety implications (Gertman and Blackman 2001).
- *Common-Cause Failure Analysis (CCF).* Methods for evaluating the effect of inter-system and intra-system dependencies which may tend to cause simultaneous failures so increasing the overall top effect.

Following any (or a combination) of these techniques, the effect or final result of the failure is traced down to the individual causes at bottom level for which in many cases there are statistical data of probability of failures: information from databases catalogues from the providers, bath-tube graphs, reliability analysis, *etc.* Tree hierarchical structures allow calculating upwards of the probability of occurrence of the effect.

Impact evaluation. The impact is related to the effect caused by the failure and has to be considered as the "cost" of the undesired result. It can be estimated in monetary units as the expected cost of the failure for the company allowing sorting by their level of magnitude. In cost engineering (Roy 2003) economical evaluation of risks helps to estimate better the overall costs of the development and to decide if they are assumable by the company.

Nevertheless it should not be forgotten that the final goal of this evaluation is to sort the risks by order of priority, so in practical terms (as the following tools show) impacts can be evaluated by means of assigning them just a neutral figure which represents the "value" of their effect. Those which may eventually cause damage to persons or properties have to be taken up to the higher level of priority independently on how the cost of a human being could be evaluated (*i.e.,* by insurance companies).

The following tools support both identification and assessment of the potential risks.

Failure Mode and Effect Analysis (FMEA). In which an experienced team develops an in deep analysis of all possible failure modes and assigns to each of them, three factors (see Sect. 1.4.5):

- Probability of occurrence of the cause of failure (O)
- Severity of the effect of the failure (S)
- Probability of the failure being detected before the occurrence of the effect (D)

$$O*S*D = RPN \tag{2.2}$$

The product of the three factors (D in inverse mode) provides the "risk priority number" (RPN) in order to sort out the list of failures according to their expected impact. The three factors, independently of how are they calculated, have to be conversed to a common rank in order to have a consistent result.

Preliminary Hazard Analysis. It is similar to the FMEA in its method but focuses in greater detail on the hazardous incidents related to industries potentially dangerous for the human being and/or the environment.

Anticipatory Failure Determination (AFD). AFD is an interesting approach arising from TRIZ methodology (see Sect. 1.4.4) which systematically employs ARIZ-TRIZ algorithm to "invent" any possible mode of failure in the system. Similar to FMEA, it helps to develop an exhaustive list of failure modes and then to evaluate its probability of occurrence by means of logically analyzing the combination of events that may be produced in determined circumstances. AFD does not utilize numeric calculations (like FMEA) nor logical sequential chains (as FTA) but just rational inventive thinking (TRIZ).

2.5.3 The Human Factor in Risk

It can be clearly seen that the evaluation of both factors of the risk equation – mostly the impact – is highly subjective though the contribution of the team and the use of the above-mentioned "neutral techniques" tend to minimize the subjective influence. Affect, emotion, personal perception, "gut feeling," and other factors (Slovic *et al.* 2004) form part of what Epstein (1994) named "Experiential System" which has been built up over years of human evolution largely based on affections.

The experiential system will then have a preeminent role in the twofold decision making process involved in risk management: decision on the assignation of priority to the risk and decision on how to manage it through the contingency plan and the decision-making gates process.

Another important aspect to be taken into account is the fact that the "objective reality" coexists with the "subjective reality." On one side, each person has or may have on his mind a different perception of the reality and on the other the way reality is described by someone will actually built up a new one in the minds of the hearers.

Some interesting facts to highlight from Slovic's work (Slovic *et al.* 2004) on the experimental system are:

- People base their evaluations not only on what they think of it – which can have a sound technical and scientific basis – but also on how they feel about it. Previous experiences, misjudgements, and prejudices may bias the decision to the direction of the feelings.
- The way data are provided has an utterly influence on the decision. Percentage, probability, and statistical figures have a quite different meaning to different evaluators since rough absolute figures are difficult to compare.
- Insensibility to probability. In determined circumstances people tend to dismiss probability ranges, for instance playing the lottery expecting to achieve huge winnings against the very low probabilities of such a thing happening.

It can be concluded that "experiential" decision making is important as it is based on intuition, affections, feelings, and other personal aspects that may help to make a good decision more quickly. On the other hand, rational, analytical decision making based on data and facts is usually more time consuming but the results should be sounder and more reliable.

The important point to highlight is the fact that no matter how accurate the information and available knowledge might be, there always will be the variable influence of the human factor in the form of feelings, prejudices, intuition, and so.

Being aware of this and, depending on the required agility and importance of the decision to be made, a good balance between experiential and rational systems should be achieved.

2.5.4 Risks in Innovation

The following risks may be the most serious possible risks that can be present in the development and launching of any innovation in product. These can be considered as the upper level risks arising from different combinations of smaller risks at lower levels:

- Innovation is not accepted by the market
- Costs increase out of control swallowing expected benefits
- Development time exceeds all forecasts
- Innovation turns out to be a bad solution
- Product failures show up once the product is on the market

The three domains economic, technologic and societal have to be well balanced in order to mitigate the revolution caused by a breakthrough change in the market.

Innovation may not be accepted by the market, usually because it comes out at the wrong moment for some reason: it is too revolutionary for the time, it is blocked by the economic situation, not in tune with the societal culture and time, *etc.*

The De Lorean case is a paradigm in that sense but there are more examples such as Sony's Beta video system, the Citröen SM model launched in 1970 that failed completely in the market, Apple's electronic agenda "Newton" launched in 1993 with the right technology (incorporated later in the modern PDAs) which also failed in the market until being discarded in 1998. Nowadays it can also be seen in the market penetration problems of the hybrid vehicles, being very reluctantly accepted by the customers.

A comprehensive analysis of the market trends, the use of prospective tools (Delphi, expert's consultation, surveys, *etc.*) combined with clinics and pilot testing with friend-users can help to minimize this risk. QFD (see Sect. 1.4.3) supporting the identification and whole analysis of customers' needs and requirements also helps one to understand better how to fit the products to the market but fails in predicting if the innovative solutions adapted to fulfill some requirements would be too "scaring" for the market.

Another interesting tool for this purpose is "Direct Evolution" (one of the TRIZ applications – see Sect. 1.4.4) that provides a good methodology to analyze the historic evolution of technological systems and predict their future trends.

Risks of uncontrolled increase of costs, excessive development time, or inappropriate solutions can always occur but their appearance is fairly reduced with a solid and well managed development process as that described in Chap. 3.

The case of failures showing up once the product is on the market is the most dangerous for any industrial company due to the costs not only in monetary units: warranty, reposition, post sales service and maintenance, *etc.* but far more important, the intangible costs of loss of brand image, and customer dissatisfaction with the very dangerous (for the company) "mouth to ear" propagation of the complaints that is estimated to multiply by more than five the number of potential customers that will be eventually lost by the brand. The proposed new development process also pays special attention to this specific problem.

From a study realized in five small and creative companies in the UK in 2008 (Jerrard *et al.* 2008) the following risks categories were identified inside and outside the company:

- Financial: operational finance, access to working capital, pricing
- Personal: personal finance, family circumstances
- Intellectual Property: developing and protecting ideas, research needs
- Regulatory compliance: policy changes, safety issues, new standards
- Markets: competition, consumer/customer response
- Technical: manufacturing processes, new technologies, components
- Partnerships/collaborations: networks, cross-functional teams, formal/informal partnerships, *e.g.,* suppliers, specialist input, distribution networks
- Organizational: capacity, skill, support/commitment to NPD

R. Jerrard

Summarizing this list, the key points related to risk in new process development (NPD) are related to:

- The way risk is assessed in decision making
- Communication between the design team and the decision makers
- Acceptance of the risk as inherent to the creativity process
- Balance between the risk assumed by designers and the risk accepted by consumers (are they willing to assume any risk at all?)

2.5.5 Minimizing Risk in Product/Process Development

The overall innovation process, described in Chap. 3 as the "*New Paradigm in Product/Process Development,*" is focusing upon the minimization of these risks. This solid and coherent development process allows one to take into account most of these risks from the early stages of the process, so minimizing the risk occurrence.

Categories of risks defined by Jerrard above (Jerrard *et al.* 2008) can be summarized by grouping them into four categories:

- *Financial.* Company's financial resources and Intellectual Property Rights (IPR) issues
- *Human related.* Personal situation, personal behavior (teams, partnerships, networks, *etc.*) and organizational
- *Technical.* Including regulatory aspects
- *Marketing*

Save for financial aspects, the rest of the categories are analyzed and dealt with in Chap. 3 as well as mentioned again in several points in the other chapters. Financial aspects are clearly out of the scope of the book since it is another domain; nevertheless, a well controlled process such as the one to be described next has the advantages of being quite accurate in the costs estimations and providing high confidence to potential investors and financial entities.

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