RATIONALITY AND THE MANAGEMENT
OF UNCERTAINTY IN NEW PRODUCT DEVELOPMENT

by

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Abstract

Innovation projects always introduce concomitant elements of uncertainty and complexity; concerning the product to be developed and any technological requirements, the prevailing market and competition, and the structure of the organization involved. We propose that organizations work to confine systems which are already complex and uncertain by relying on various means to create “islands of rationality”, so as to furnish project managers with the capacity to make decisions and act. The aim of this study is to investigate the effectiveness of the different means used by organizations to reduce the perception of uncertainty and complexity which confronts innovation project managers.

The successful design and development of innovation is strategically important to many organizations. Product innovation is a primary means by which these organizations are able to adapt to market shifts, take advantage of new opportunities and technology, respond to competitive changes, or regenerate themselves. A recent survey of over 700 senior managers worldwide found that improving new product development was a predominant managerial priority (Arthur D. Little, 1991). Nethertheless, established firms still experience difficulties in the effective development of new products, and improving product innovation remains a crucial research concern.

Many factors key to successful innovation are well known. The commercial success of a new product has been shown to be dependent upon how well the perceived market opportunity has been identified, analyzed and incorporated into its design (Cooper, 1983; Dougherty, 1990; Lilien and Yoon, 1988; Rothwell, 1977). Commercial performance has also been associated with a strong R&D orientation and the appropriate use of advanced technologies (Cooper, 1984; Kanter, 1988). Cooper (1979) finds that among 18 factors which characterize successful new industrial products, one of the most important is the firm's technological and production proficiency. Studies on competitive strategies have emphasized also the influence of competition on the commercial performance of a new product (Porter, 1980; 1985); for example, Robertson and Gatignon (1986) argue that competitive factors have a vital role in the diffusion of a technological innovation.

To date, literature on new product development has emphasized the importance of these individual factors in achieving commercial success. The innovation process has thus been shown to be fraught with three corresponding categories of uncertainty: uncertainty about users' needs, uncertainty about the technology to use, and uncertainty about competitors' moves (see, for example, Souder and Monaert, 1992). What is now crucial for managers is not so much determining whether the firm should pay attention to these issues, but considering how the organization is to be able to deal with the uncertainty and complexity which arises from all three related areas: the customer, technology and competition.

In our study, we have used Milliken's definition of uncertainty as "an individual's perceived inability to predict something accurately because of a lack of information or an inability to discriminate between relevant and irrelevant data" (1987: 136). "Complexity" refers to the degree of difficulty involved in attempting to resolve a given system, and is directly linked to the amount of information needed to fully understand a given environment.

To deal with uncertainty and complexity, firms rely upon their organizational resources (Cooper and Kleinschmidt, 1986; Rubenstein et al., 1978; Souder, 1987; Souder and Monaert, 1992). However, the need for these organizational resources to be appropriately allocated and managed introduces a fourth source of uncertainty and complexity: the organization itself.

Innovations also vary with the degree of product novelty. Products may be more or less different from competitors'products. Although the development of a new product may occasion a clear departure from existing practices, an innovation which is incremental in nature, resulting from minor improvements or simple adjustments to an existing products, may not require any change in the way it is produced, marketed or used (Duschesneau et al., 1979; Ettlie, 1983; Munson and Pelz, 1979). Freeman (1974) states that "radicality" is strongly linked to uncertainty. The outcome of a radical product is more uncertain than the outcome of an incremental innovation. Similarly, a product may more or less complex to develop, depending whether it is to be targeted at specific customers needs or aimed at a broader range of users. Therefore, the product itself introduces a fifth source of uncertainty and complexity.

Several authors have suggested that the success of a new product is directly linked to the ability of the organization to reduce the uncertainty and complexity connected with innovation in general (Fidler and Johnson, 1984; Fischer, 1980; Souder and Monaert, 1992; Van de Ven, 1986). However very few empirical studies have investigated how this reduction is to be achieved. Our study is based on the preliminary assumption that organizations develop means to create what we will refer to as “islands of rationality”, which serve to circumscribe a too complex and uncertain situation. We have speculated that these means enable managers to act in a “rational” and orderly manner, and consequently improve their effectiveness in managing the innovation project. We will attempt to determine in which ways different approaches to uncertainty and complexity reduction influence the outcome of innovative projects.

In this research, we mainly follow a classical hypothetico-deductive approach. However field data were also used in order to reinforce our understanding of the studied phenomenom, generate hypothesis and provide a more in-depth analysis of the statistics performed on the 213 questionnaires which were collected during this research. The qualitative methodoly we followed is briefly explained in appendix I.

CONCEPTUAL BACKGROUND

Managing an innovation project is one of the most unsettling and destabilizing of endeavours. It is a situation in which organizational actors try to find solutions to problems which are loosely defined, and where limits are not drawn. However, project managers continue to make decisions and take actions under these conditions, with consequences which are impossible to accurately predict.

Some companies have solved the paradox of taking action in unpredictable situations by accepting uncertainty as a priori. Wide latitude may be given to organizational actors in which to explore new ground, within a framework of shared values and a common understanding of the ultimate goals of the organization. For example, work by Burgelman (1983) and Bygrave (1989) on entrepreneurship is illustrative of the determination of certain organizations to provide optimum conditions for experimentation with different types of innovations. In giving the organizational actors enough freedom and sufficient resources to explore -- without constraint -- new areas of growth and new ways of doing things, the organization creates a catalogue of responses ready for different and as yet unknown demands from the competitive environment. A catalogue from which elements may be selected, or recognized “serendipitously”, as the environment unfolds. Nystrom, Hedberg and Starbuck (1976) stress the exigency for an organization to develop such a repertory of alternative and novel responses to possible future situations; arguing that, when confronted with a new and therefore uncertain environment, it may be forced to move from its traditional positions. March (1981) and Weick (1977) suggest that activities which are not directly connected with the organization's traditional interests are often an appropriate means of improving its capacity of response to complexity and changing conditions.

However, experimentation, incoherence, and diverse activities -- especially those which diverge from the organization's usual area of interest -- are such sources of unstability that the resultant innovations may not necessarily be consistent with the organization's planned objectives. As roots of internal disorder, they may engender major strategic change and re-orientation. Some degree of stability and order is also needed to be able to achieve the organization's objectives. If the innovation process was a matter of experimentation and disorder alone it would be a maelstrom of perpetual change and revolution; as Daft and Weick submit, managers would be forced to "wade into the ocean of events that surround the organization and actively try to make sense of them" (1984: 286). According to Daft and Lengel (1984: 192) , "in response to the confusion arising from both the environment and internal differences, organizations must create an acceptable level of order and certainty".

Order is necessary, also, to furnish the facilitating conditions for decision making, and contributes to the closure of a too complex system for a cognitively limited mind. Order helps in "creating" certainty: and with certainty, traditional rational management schemes can be applied to their full extent. In addition, the discomfort which arises when managers are confronted with a problem which they intuitively know impossible to solve or master can be reduced.

This reason, which stresses the apparently non-utilitarian functions of formal approaches, has a psychologically-based origin which the cognitive dissonance theory of Festinger (1957) can help to explain. To fight against feelings of powerlessness, that they are in a situation of high complexity and uncertainty which is in total contradiction with their mission and "raison d'être", managers rely on formal tools to create an illusion: the illusion of managing. As an example, Feldman and March (1981: 177) state that the gathering of information provides "a ritualistic assurance that appropriate attitudes about decision making exist" and that " displaying the symbol reaffirms the importance of (the) social value and signals personal and organizational competence" (Ibid.: 182). Managers in this way avoid a reality which seems in complete contradiction with what they are being paid to do. Their purpose in invoking formal management tools is less to improve their performance than to give the illusion and assurance of doing so; it is more the sense of doing and mastering that these tools provide which matters than their practical uses. Managers can thus reduce the dissonance their feelings of powerlessness engender when confronted with a reality which seems too complex and unpredictable to be effectively managed.

If innovation requires some degree of instability and disorder to unfold, innovation project managers need closure of a too complex and uncertain system to be able to understand it. Means to manage innovation and to deal with its surrounding uncertainty and complexity are numerous, and some are more appropriate than others, depending on the degree of uncertainty and complexity faced. We believe that innovation performance depends on the appropriateness of these means. We will turn now to the hypothesized relationships between the level of uncertainty and complexity faced by an organization, and the effectiveness of the means it uses to reduce these, in relation to new product performance.

HYPOTHESES

To close the organization and make it more predictable, managers attempt to control their external environment (Pfeffer and Salancik, 1978) “to translate uncertainty to certainty in order to achieve internal efficiency and stability” (Skivington, 1982, as quoted by Daft and Lengel, 1984: 228). For instance, interlocking directorates and strategic alliances and cooperations with customers and competitors might prevent a situation described by (Astley and Fombrun, 1984: 286): where "organizations act independently in many directions, producing unanticipated and dissonant consequences in the overall environment they share”. Spender (1993), also, suggests that in a situation of unpredictable external associations, managers can rely on networking and cooperation to develop mutual beneficial relationships. In the same vein, he proposes that in a context characterized by "incompleteness", managers look for more information.

High uncertainty may lead managers to imitate or copy strategies used by others (Milliken, 1987). Managers often assume that their competitors have successfully found the most appropriate response, and tend to emulate their behavior (DiMaggio and Powell, 1983). However, organizations may also actively seek to create uncertainty (Jauch and Kraft, 1986). For example, pharmaceutical firms have been shown to patent their mistakes and failed products to encourage uncertainty about the direction of their product development (Business Week, 1984); in order to reduce uncertainty, managers from other firms may be imitating their competitors on the basis of misleading information (Porter, 1980).

Xuereb (1993) suggests that in high-technology sectors, where firms generally lack reliable data about users' needs (Lilien et al., 1990; Von Hippel, 1986), managers turn their attention to competitors’ projects, through information scanning and networking. To prevent other organizations from developing a competitive advantage, companies tend to include in their

own project their competitors' product characteristics. Consequently, in this type of highly uncertain and complex environment, a “virtual market” is created, on the basis of which the new product development takes place; a market defined without any reference to potential users. Conversely, when confronted with more predictable and less complex environments, innovation projects which rely on networking and external information on their competitors should not be adversely affected; in fact a more precise view of what the competition is doing (assuming that market signals are readable) should improve the innovation performance.
According to a project leader:

> *"The development of artificial intelligence is a good example of what we called here the endocrination effect.*
> *The first works concentrating on the importance of artificial intelligence began in the early 1950's in the United States. Artificial intelligence was destined to replace "man" in the activities surrounding thought and the creation of knowledge. It was to be equipped with software capable of analyzing and resolving problems without the help of any human intervention.The applications were numerous, with such programs being used in a number of different situations. From 1950 to 1981, artificial intelligence was common practice in both university and public research laboratories, however, this new concept had yet to capture the attention of firms operating in the computer industry. This situation changed drastically in 1981.*
> *In the beginning of 1981, representatives from a number of firms in the computer industry participated at the presentation of the Fifth Japanese Generation project. Managers attending this convention then realized that artificial intelligence was at the heart of the Japanese project. Their response was to immediately transmit this information back to both the research centers and head offices of their respective firms. With large amounts of national and international publicity devoted to the Fifth Generation project, a combined effort had begun not to let "japanese competitors" advance too quickly with this technology. As a result, large companies in the computer industry experienced a state of hope, worriedness and opportunism which ultimately lead to the creation of teams of researchers devoted to artificial intelligence.*
> *From 1981 to 1983, specialized journals frequently used the term "artificial intelligence" and presented various projects developed in firms operating in the computer industry. Market studies compiled by both companies and consulting firms specializing in the domain predicted an exponential growth in the marketplace that would reach more than $800 billion by 1990. Artificial intelligence was to intervene in all industrial sectors either directly in the form of software programs or indirectly in the form of written systems experts through the use of artificial intelligence languages.*
> *At the end of 1983, the European Economic Community introduced the ESPRIT program in response to both the Japanese's Fifth Generation project and an upsurge of American engineers. This program notably encouraged the development of artificial intelligence amongst european engineers. The direct and indirect effects of ESPRIT in the computer sector were numerous. The european program lead to the credibility of artificial intelligence, supported by*

financing and authorized the creation of ambitious research programs that incited the amalgamation of many engineers.

Programs developed by firms were becoming more and more ambitious: "each research team keeps a constant eye out on the competition and works to be more complete, faster and stronger".

In 1986, the first commercialized products were developed with producers unfortunately realizing that the innovations were evolving in a stagnant market of artificial intelligence languages when all projections predicted a fairly rapid growth. The artificial intelligence market was developing however, with sales only being realized by those actually developing the applications. Finally, the market was stagnated due to a lack of product know-how amongst end users and a failure in understanding the software based on artificial intelligence.:

This technology has provoked a crisis that we did not know how to master. The end users have not evolved. We expected to attack an enormous market when in reality we were only attacking a market niche. We followed our american and japanese competitors. We were not equipped with the marketing abilities to help us readily identify the client's expectations. Hence we used our judgement, our technical experience and our competitive project analyses to separate that which was indispensable from that which was useless".

The second generation of artificial intelligence languages is in a technological regression in comparison to the first products introduced to the market. For example, the first generation software were able to treat whole, real, rational and booleens.The second generation limits itself to processing the whole. This reduction of possibilities is justified by the fact that processing the whole allows for writing applications in production management and in planning which ultimately responds to potential clients.

Today, artificial intelligence is integrated within written software programs in more classical languages. It is more than a "plus" instead of being the basics of "intelligent" programs which were so highly praised in the beginning of the 1980's. The artificial intelligence market was now more than $20 billion in 1991".

The development of artificial intelligence shows how reliance on competitors can lead to the development of commercially unsucessful new product in an uncertain and complex environment. However, Gatignon and Xuereb (1997) demonstrates that a competitor orientation leads to superior innovation performance when the innovation's environment is predictible. When the environment uncertainty and complexity are low, all the competitors will have access to the same informations. Therefore, the key success factors of an innovation must be found relative to competitor's products and projects (Gatignon and Xuereb, 1997).

This leads to our first hypothese.

Hypothesis 1: Depending on the degree of uncertainty and complexity associated with an innovation project, innovation performance is influenced by information on competitors:

a) negatively when uncertainty and complexity are high.

b) positively when uncertainty and complexity are low.

In the same vein, according to one manager:

"As an international company, we have dozens of alliances with partners all over the world. Last year, I was asked by our CEO to study the results of these alliances. I discovered that when a user is a member of the alliance, the resulting product is usually a commercial success. When we are only between us (ie competitors or competitors &suppliers), we usually end up with a technological wonder with no direct commercial application. (How do you explain this result?). Well , usually, we create an alliance with competitors to share the risks and the investments in uncertain and complex projects . iI it's simple and predictible, we do not need anybody help. we can do everything by ourselves and keep the profit.... but bringing together two, or more, one-eyed firms doesn't mean that you'll get a perfect view of what you have to do in an uncertain and complex environment. In fact you'll end up being totally blinded as you'll have to make everybody happy by adding their own technical solutions or functionalities in the new product development. Usually, the partners disagreed on what the customers needs are, so we only discuss about technology..."

Even if it now well known that an alliance between competitors can help to reduce the uncertainty and the complexity associated with new product development by, for example, creating a critical mass around the technological solutions created, we believe that reliance on this mean to reduce uncertainty and complexity will not be powerfull enough to have a positive influence on innovation performance

Hypothesis 2: Depending on the level of uncertainty and complexity associated with an innovation project, innovation performance is influenced by networking with competitors:

a) negatively when uncertainty and complexity are high.

b) positively when uncertainty and complexity are low.

The development of a new product in a highly complex and uncertain environment creates the need for more market scanning and networking with users to identify customer needs. In contrast, market scanning and networking are not as effective in simpler and more certain environments, since products are targeted to a more familiar market, and innovation projects do not need to rely on extra information and specific coordinating devices. Gatignon and Xuereb (1996) demonstrates that in markets which are highly uncertain, a consumer orientation has a positive influence on the commercial performance of the innovation. However, as uncertainty decreases, a very high level of consumer orientation actually detracts from performance. In a low uncertainty and complexity environment, all the competitors will have access to the same information regardless of their level of consumer orientation. Therefore, a firm with a strong consumer orientation will not derive any specific benefit that the competitors will not have as well. However, the firm will incur all the costs associated with these marketing activities (Gatignon and Xuereb, 1996).

This leads to the following hypothese:

Hypothesis 3: Depending on the level of uncertainty and complexity associated with an innovation project, innovation performance is influenced by information on users:

a) positively when uncertainty and complexity are high.

b) positively, although to a lesser degree, when uncertainty and complexity are low.

According to von Hippel (1986):

"Market study results are rarely reliable with respect to fundamentally new products or when these products are implemented in industrial sectors which are characterized by frequent technological changes, as in high-technology". As well, Lilien et al. (1990), establish that the marketing services of companies belonging to high-tech sectors which can be characterised by on-going innovations, rapid technology obsolesence, weak entry barriers,.., dispose of less reliable information on both their markets and consumers than companies evolving in low technology industries. Hence, high technology industries where major product innovations are frequent, constitutes a "shadowy" zone for marketing.Marketing studies can only measure intentions and reactions of potential clients with respect to a new product in that they can only really cast a judgement only after its delivery and use. As a result and according to one of the managers we met:

"Market studies are generic and crude and can't be used as the basis of new product development."

Therefore, in situations of high complexity and uncertainty, innovation managers will have to find new ways to better incorporate users' needs in the new product design and development.

One of the Manager we met suggested a possible solution:

> *" At the beginning we didn't have a clear idea of the new product we wanted to develop, the technology was up to date and the potential applications were numerous and "new to the world". Therefore, we decided to incorporate potential users in the development team. These users were working with us so after a short period they had almost the same technical knowledge as ours. It allowed them to react permanently and we incorporated a lot of their reactions in the new product development. They really helped us in selecting the innovation's targets and in designing the new product. Usually, you have this kind of reactions only after the new product launch but as users were working with us we had them during all the innovation development. (Why did they cooperate). Well, we offered them access to new technological development, a discount on the new product and a short exclusivity period. I guess it's a win-win collaboration as the new product was a commercial success mainly because of their involvement.*

Hypothesis 4: Depending on the level of uncertainty and complexity associated with an innovation project, innovation performance is influenced by networking with users:

a) positively when uncertainty and complexity are high.

b) positively, although to a lesser degree, when uncertainty and complexity are low.

In order to cope with the uncertainty and complexity of their venture, innovation managers also rely on organizational procedures. For instance, Dougherty (1992) shows that each function of a firm develops a different vision of the prevailing environment, and that the success of an innovation is directly linked to the merging of these different visions. This is especially relevant in a highly complex and uncertain environment, where functions need to be differentiated and specialized, and where organizations tend to rely on group decision-making to confront issues related to marketing, R&D, production, finance and engineering. Coordination between functions is also facilitated by intense and frequent face-to-face interactions (Miller, 1987). Project management contributes to a better coordination and monitoring of the diverse tasks the organization has to undertake to develop a new product. As means of coordination, project management is helpful in tackling the cognitive limitations of the organizational actors. But again, in situations where the degrees of uncertainty and complexity are lower, multi-functional team and inter-functional coordination are less essential.

Hypothesis 5: Depending on the level of uncertainty and complexity associated with an innovation project, innovation performance is influenced by the use of project management:

a) positively when uncertainty and complexity are high.

b) positively, although to a lesser degree, when uncertainty and complexity are low.

Nelson and Winter (1982) suggest that firms have “routines” for coping with new situations, and that new routines develop slowly and incrementally. Routines allow managers to reduce their perceived uncertainty and complexity, but can hinder adaptation to new environmental demands. A routine readily becomes an end in itself, and an end which needs to be achieved whatever the characteristics of the environmental context. Managers thus frequently find themselves unable to react or adapt to the complexity and uncertainty of their environment. However, in situations which are relatively simple and stable, uncertainty and complexity can be efficiently dealt with using formal rules and procedures (Miller, 1987).

In the same vein, planning is frequently presented as an effective means that firms use to achieve their mission. Sinha (1990) shows that formal planning systems are a useful aid when confronted with decisions perceived as both important and risky. Planning is presented as a means to manage uncertainty. By formalizing the decision-making process, managers sequester zones of certainty and simplicity, within which they can proceed in a rational manner. Furthermore, planning, by providing an information network and encouraging communication (Quinn, 1980), is a means to deal with important decisions; important decisions which are generally characterized by numerous ramifications and complexity. Thanks to the decomposition of a broad mission into elementary tasks, the readability of the organization and its numerous links with its environment are improved. Planning helps in creating enclosures within a system which is too complex to be dealt with in a global manner.

However, the persistent search for order through excessive rationalism can be disruptive; formal approaches, although helpful in closing the organizational system and making it more predictable, increase its resistance to change. According to Quinn (1985: 77): " Managers in big companies often seek orderly advance through early market research studies or Pert planning. Rather than managing the inevitable chaos of innovation productively, these managers soon drive out the very things that lead to innovation in order to prove their announced plans." In his seminal study on the Apollo 3 mission, Weick (1977) has also demonstrated how the order that formal tools provide can be unsettling. Similarly, Miller and Friesen establish that momentum (the continuity and stability of patterns of change in strategy and structure) derived from past experiences, political coalitions or the existence of formal programs, can be costly when it “protracts an orientation that has proved to be dysfunctional” (1980: 611). In a situation of high uncertainty and complexity, order can sabotage performance.

According to one of the managers we met:

> *" In (our company), we are still using an old fashioned model to manage our innovation processes. The new product is supposed to "travel" in the different functions of the product line, research, engineering, production, marketing and so on. Therefore, nobody has a global control on the new product development and the different function are not taking care of the problems which do not relate directly to their own expertise area.. We rely on internal rules and routines (The new product life cycle guide) to insure the cooperation between the different functions. It (The new product life cycle guide) describes all the activities we have to perform and who is supposed to be responsible for them. But it just doesn't work because it's almost impossible to react if anything happens or you have to return to the beginning and start a new whole process. It can be useful for a simple project in a stable environment as in such a case we are able to predict almost everything since the beginning of the project but otherwise it just leads to failure either because the new product is just impossible to develop or because we launch our innovation months after our competitors.*

Hypothesis 6: Depending on the level of uncertainty and complexity associated with an innovation project, innovation performance will be influenced by internal routines, rules and procedures:

a) negatively when uncertainty and complexity are high.

b) positively when uncertainty and complexity are low.

The fragmentary nature of understanding requires that managers create meaning through organizational culture to create a new focus for their attention (Spender, 1993). As has been said, some firms, in uncertain and complex environments, leave a large latitude for organizational actors to work within a framework of shared values and goals. Burgelman (1983) and Bygrave (1989) show how organizations create the facilitating conditions to innovation through culture specially when environment is difficult to predict. By giving the organizational actors enough freedom to explore new areas within the limits of shared values, and reinforcing their behavior with the right incentives, the organization finds responses to different and as yet unknown demands from the competitive environment.

> *At (the company I was working for before), all the executives were former innovators and we all knew that to receive a promotion we needed to be creative and take risks. Here, we are a risk avoidance company. Any action we start has to be played by the rules and we need aproval by almost all the company top executives before starting anything new... It was working , ten years ago, when the company was still in a "proprietary culture" and a stable environment, but now with all the standards and open systems culture, it just doesn't work anymore.*

Hypothesis 7: Depending on the level of uncertainty and complexity associated with an innovation project, innovation performance is influenced by an innovation organizational culture:

a) positively when uncertainty and complexity are high.

b) positively, although to a lesser degree, when uncertainty and complexity are low.

In theory, firm strategy should guide decisions made and actions taken during an innovation project. But new product development may depart from strategic guidelines, to experiment with alternative ideas, new directions and unfamiliar markets (Burgelman, 1983) -- all of which arguably keep strategy viable and regenerated (Jelinek and Schoonhoven, 1990). While some authors suggest that innovation should be kept separate from mainstream strategy, Day (1990) argues that such separation might result in ad hoc products, as it does not facilitate the development of products which reinforce the strategic focus. Furthermore, strategy is frequently encoded in the organizational structure and decision-making process, and tends to prevail despite external changes (Miller and Friesen, 1984). Such deeply rooted strategic orientations can constrain new product development by systematically forcing new ideas into old patterns (Hall, 1984; Johnson, 1988). When the environment is familiar and reasonably elementary, following an habitual strategic orientation should facilitate management of an innovation project. However, in a highly uncertain and complex situation, following an established strategy might eviscerate such a project.

> *Here, we know that a (new product) project will end up as disaster once it is designed as a "strategic" one. (Why) In our industry, an innovation process duration is approximately two or three years, once a project is considered as strategic, you can't change anything about it or you have to change the whole firm strategy, but in the project environment a lot of factors can vary and at the end the innovation is no more related to its environment. There is also one other problem, once a project is considered as strategic, it is legitimated by the firm's strategy and the people in charge of its development do not feel the need to constantly validate theirs actions in reference with external dimensions like competitors or customers.*

Hypothesis 8 Depending on the level of uncertainty and complexity associated with an innovation product, innovation performance is influenced by strategy:

a) negatively when uncertainty and complexity are high.
b) positively when uncertainty and complexity are low.

Table 1 below summarizes our eight hypotheses, and gives the predicted signs based on the preceding discussion of relevant writings and interviews.

(INSERT TABLE 1 HERE)

METHODOLOGY

Sample

We collected our data through a large scale mail survey. 1800 questionnaires were sent to R&D and marketing executive drawn randomly from a commercially available list of French companies with sales of more than $50 millions in seven industrial sectors: durable and non-durable consumer goods, industrial equipment, chemical product, medical and pharmaceutical products, electronic products and computer based technological products. 193 questionnaires were not delivered and 213 were returned completely filled.

For our unit of analysis we asked each firm to select a single past innovation project. The questionnaire was filled out by R&D and marketing executives who have shown in past research to be knowledgeable key informants about the information concerning new product development (Xuereb, 1993). We compiled information on the uncertainty and complexity related to the innovation project, the means that had been used to cope with uncertainty and complexity, and the resultant product “performance”. We included data on several other factors which can influence a new product’s “performance”, to serve as control variables.

In order to verify that the questionnaire was reasonable in length and that the respondents did not have any difficulty with any of the questions, a pre-test of the questionnaire was performed on a few R&D and marketing executives. Based on their responses, some questions were re-worked and the final questionnaire was sent to the sample. The total of 213 returned questionnaires gives a 13,3 % response rate after deducting the questionnaires which did not reach the addressees. This rate is in line with rates reported in similar survey. An analysis of the characteristics of firms indicates no significant differences between respondants and non respondants. Neither were any statistical difference found between early and late responses. Consequently, there is no indication of response bias in our sample (Armstrong and Overton, 1977). Appendix II presents the distribution of the observations by classes of industry, and shows the variety of this sample which contributes to the generalizability of our results.

Variables

Multiple item scales were developed. All items were measured on a six point Likert type scale ranging from total disagreement to complete agreement. No objective measurements were sought, and the questions were purposely designed to facilitate subjective (perceptual) responses; primarily because of the difficulty faced by the respondent in retrieving the necessary data, but also because we believe that perception plays an integral role in inducing the organizational actor to select an appropriate mean to cope with uncertainty and complexity . Finally, although more objective measures do exist, they are generally only available at the aggregate (firm or industry) level.

On the return of the questionnaires, factorial analyse was performed on each set of items : context, means and performance. We operationalized the variables from the factorial analyse. The first factorial analysis was performed on items measuring complexity and uncertainty. Ten factors, with an eigen value greater than one, were retained. They all represented a given dimension of complexity-uncertainty: complexity and uncertainty associated with the organization, with the competition, the technology, the users and the product. The second factorial analysis was done on the items representing the means used to cope with uncetainty and complexity. Eight factors with an eigen value greater than one were retained. These factors cover different aspects of what we have referred to as “islands of rationality”: organization (routines, rules and procedures, organization values and culture), management (project management), strategy (strategy, partnerships with competitors, and customers), cognition (information on the market and competition). A final factorial analysis was run on items of innovation performance, together with items from which our control variables were established. Four factors with an eigen value greater than one were retained. These factors cover such variables as: performance; the market induced transformation following the innovation introduction; the degree of autonomy of the unit in charge of the project ; and the relative size of the organization. All the variables are unidimensional, as items load on a single factor. Twenty two variables were constructed from eighty items and items for each factor were pooled to create the variables used in the research. Appendix III gives the variables constructs and their associated reliability coefficients.

. *Dependent Variable*

The dependent variable, innovation performance, is based on five items which evaluate: 1/ the innovation market growth relative to that of competing products, 2/ the innovation return on investment relative to the company’s other products, 3/ the fulfillment of the innovation project objectives, 4/ the commercial success of the innovation, 5/ the innovation effect on the overall market share. Although self assessment measure of performance are prone to potential bias, they are the most commonly used form of performance assesment in strategy marketing research (Saunders, Brown and Loverick, 1992). In fact, they may be less problematic than more "objective" financial measures which can also be biased because of " the ulterior motives for which they are produced" (Saunders, Brown and Loverick, 1992: 184). Finally, a number of studies have demonstrated the convergent validity of such scales (Dess and Robinson, 1984; Doyle, Saunders and Wright, 1989; Venkatraman and Ramanujam, 1986).

. *Independent Variables*

Eight independent variables were used to measure the different means to cope with uncertainty and complexity associated with an innovation project. They were built from item based additive scales. All items for each variable load on a single factor. These means cover four broad categories.

The first category consists of "organizational" means to cope with uncertainty and complexity while managing the innovation project. They are measured by two variables: rules-procedures and plans (RPP) and culture (CULT). The second category consists of "cognitive" means. They are measured by two variables: competitor information (ICON) and customer information (ICL). The third category consists of "strategic" means. They are measured by three variables: strategy (STR), customer network (RCL) and competitor network (RCO). The fourth category consists of "managerial" means. It is measured by one variable: project management (IMA).

. Control Variables

We isolated three other factors which can influence the innovation “performance” and collected information on these to act as control variables. These three variables are the following: the market induced transformation following the innovation introduction (IRA), size of the organizational unit relative to the competition (TAC) and the degree of autonomy of the unit in charge of the project (AUT).

. Contextual variables

As discussed previously, means used to cope with uncertainty and complexity may vary depending on the degree of uncertainty-complexity associated with the innovation project. Ten variables dealing with different aspects of uncertainty and complexity were used. They were built from item based additive scales. All items for each variable load on a single factor. These variables are the following: organizational uncertainty (ORU), organizational complexity (ORC), competition uncertainty (COU), competition complexity (COC), technological uncertainty (TEU), technological complexity (TEC), customer uncertainty (MOU), customer complexity (MAC), product uncertainty (PRU) and product complexity (PRC).

Sample clustering

A stratification of the sample along variables of uncertainty and complexity was performed. The “furthest-neighbour” or “complete linkage” method was adopted for the clustering). Two other methods ("average linkage between groups" and "median clustering") were also used to test the stability of the clustering. Similar results were found.

Although four homogeneous groups (in terms of uncertainty and complexity) were obtained, two were found unsuitable for the study. One did not provide a sufficient sample size. The other could not be interpreted easily. Of the two remaining groups, the first was composed of 77 innovation projects of relatively high uncertainty and complexity. The second group was made of 39 projects of lower uncertainty and complexity. T-tests were performed to identify the characteristics of each group (see Table 2). A discrimant analysis was performed on these two groups. 98% of innovation project were correctly classified according to uncertainty and complexity dimensions.

(INSERT TABLE 2 ABOUT HERE)

Testing Procedures

To test the impact on the innovation project performance of the various means used to cope with uncertainty and complexity, we used partial log linear regression models. Partial models were adopted because of the relatively small size of the samples (77 and 39 respectively) and the significant number of independent and control variables (11). Furthermore, as some of the independent variables were highly correlated(see Table 3a for the group of high uncertainty-complexity and Table 3b for the group of low uncertainty-complexity), a full model estimation would have run into the problem of co-linearity. In addition, we were only interested in the statistical significance and the sign of the equation coefficients for both clusters of innovation projects; we did not intend to predict a performance but to test the influence of the different independent variables on the performance of the innovation. Partial equation models were thus adequate for our purposes. Within each cluster - innovation projects characterized by high uncertainty and complexity, and innovation projects characterized by lower uncertainty and complexity - partial equations were estimated. Each partial equation was composed of variables representing the broad categories of means used to ccope with uncertainty and complexity: organizational, cognitive, strategic and managerial. Standardized Beta-Tests were computed to enable inter-cluster comparisons.

(INSERT TABLE 3 ABOUT HERE)

RESULTS

Descriptive statistics are given in Table 4. From these statistics, a first observation can be made. The different means used to cope with uncertainty and complexity are similar in the two groups of innovation projects. Only two of the variables related to means used - RPP (rules and procedures) and ICON (information on competition) - show any statistical difference between the groups. Consequently, it does not seem that managers and organizations adapt their means to the perceived level of uncertainty-complexity (high or low) surrounding the innovation projects. From this observation, we can speculate that the choice of means is dependent on other considerations. These may be cognitive - to reduce a dissonance created by the task of managing a project which by nature is uncertain and complex, or psychological - to give the symbols and apply the rites of good management.

(INSERT TABLE 4 ABOUT HERE)

The hypotheses which we formulated above predicted that some means would prove more effective than others in achieving innovation performance. We have measured effectiveness by evaluating the degree of association between the means used to cope with uncertainty-complexity and the performance of the new product. Four sets of partial regressions were run. The results are presented below.

The first set of partial regressions deals with the association between product performance, organizational and managerial means to cope with uncertainty and complexity. Table 5 gives the six regressions -- three per group of homogeneous innovation projects in term of uncertainty and complexity -- run with performance as a dependent variable, and culture (CULT), rules and procedures (RPP) and project management (IMA), as independent variables.

(INSERT TABLE 5 ABOUT HERE)

Even though rules and procedures are used more intensively when uncertainty and complexity are high (see Table 4), our results indicate that they are not associated with greater success (ß= -0.04, p>0,1). The sign, which is not statistically significant, is negative. This suggests that strict reliance on rules and procedures might even have detrimental effects on project outcome. However, in the case of less uncertain and complex innovation projects, reliance on rules and procedures seems to have a positive and significant impact on the results (ß=0.24, p<0,1). Hypothesis 6 is thus, to some extent at least, supported by our findings.

An innovation "culture" and "values", reinforced by incentives, is shown to lead to successful new product performance. In this we found no significant difference between the two groups (ß=0.28, p<0.05 in the high uncertainty and high complexity group; ß=0.29, p<0.05 in the low uncertainty and low complexity group). Therefore results support Hypothesis 7a and Hypothesis 7b has to be rejected. Using innovation culture to manage new product development seems to be a reliable means to innovation performance whatever the degree of the surrounding uncertainty and complexity.

Furthermore, as we hypothesized (Hypothesis 5), a positive association was found between performance and project management in highly uncertain and complex situations (ß=0.40, p<0.01). As expected, a weaker, but positive, association was found in the case of lower uncertainty-complexity (ß=0.25, p<0.1) . Hypothesis 5 is thus supported by these findings. It is likely that project management enhances the capacity of managers to deal with an uncertain and complex environment through information exchange, dialectical confrontations of opinions and autonomy.

The second set of partial regressions deals with the relationship between innovation performance and the use of cognitive means of product management --information on users

(ICL) and on competitors' projects and strategy (ICON) -- to cope with uncertainty and complexity. Table 6 gives the results.

(INSERT TABLE 6 ABOUT HERE)

As predicted in Hypothesis 1, information on competitors is associated negatively with performance when projects are highly uncertain and complex (ß=-0.19, $p<0.1$) , and positively with performance in the case of less uncertain and complex projects (ß=0.09, $p>0.1$) . The first part (a) of Hypothesis 1 can't be rejected. This reinforces Xuereb's conjecture (1993) that a "virtual" market is created by firms competing in an uncertain and complex environment, and that new products meet the requirements of an imaginary demand. However, although the association was found to be marginally positive when uncertainty-complexity are low, this was not statistically significant.

Turning to the association between information on users and performance, we observe that in both cases the impact is positive (ß=0.44, $p<0.01$ in the high uncertainty and high complexity group; ß=0.23, $p<0.1$ in the low uncertainty and low complexity group). The impact of information on users is more pronounced when uncertainty and complexity are high; and our findings support Hypothesis 3. Innovation projects which are developed with a clear notion of users' needs have always more chance to succeed. This is even more so when uncertainty and complexity are high.

The fourth set of partial equations deals with the relationships between performance and the use of strategic means -- strategy (STR), networking with users (RCL), networking with competitors (RCO) -- to "fight" against perceived uncertainty and complexity (see Table 7).

(INSERT TABLE 7 ABOUT HERE)

As was predicted in Hypothesis 8b, a positive association is found between strategy and performance in the case of less uncertain and complex environments (ß=0.31, $p<0.05$). However, there is no statistically significant association between the two variables in situations of high uncertainty and complexity (ß=0.12, $p>0.1$) -- whereas we had hypothesized that the impact would have been negative. Hypothesis 8a must be rejected. This indicates that in a predictable and simple situation, relying on planned strategies leads to satisfactory results, but it seems that little is to be achieved from this when the innovation environment is too complex and uncertain.

The results, also only partially support Hypothesis 4. Consistent with 4a, we found a positive association between the reliance on networks with users and innovation performance when uncertainty and complexity are high ($ß=0.31$, $p<0.01$). In a situation of low uncertainty and complexity, the association was also positive, but not significant ($ß=0.19$, $p>0.1$). This reveals again the importance of a close association with users, especially when innovation projects are managed in highly uncertain and complex contexts. Relying on users probably avoids the innovation being developed for non-existent needs, and consequently enhances its chance of success.

Finally, as was hypothesized (Hypothesis 2), networking with competition has a detrimental effect on performance in environments of high uncertainty and complexity, which supports Hypothesis 2a ($ß=-0.26$, $p<0.05$). However, the speculated positive association in the case of lower uncertainty and complexity was not observed ($ß=-0.07$, $p>0.1$), and Hypothesis 2b must be rejected. This again reinforces Xuereb's "virtual market" hypothesis, according to which interactions and information exchange between competitors, in highly uncertain and complex environments, lead to innovation projects with little connection to the real market.

CONCLUSION

This study was premised on the assumption that innovation project managers rely on different means to fight against uncertainty and complexity surrounding the innovation project to facilitate their actions when managing innovation. We speculated that these means help to close a system which would be too complex and uncertain to be managed otherwise. That they confine the system within an insular field, which we have called an "island of rationality", in which managerial action may be undertaken. We also suggested that these "islands of rationality" enable managers to act with greater effectiveness, and that a variety of means are used to establish them: organizational (rules, procedures, plans, organization culture, values, incentives); cognitive (information on users and competitors); strategic (strategic intent and content, networking and partnerships with competitors and users); and managerial (project management). A twofold approach was adopted. Firstly, we formulated a set of ten hypotheses, based on existing literature, on the expected relationships between means for coping with uncertainty and complexity and the innovation performance. These hypotheses were then tested against empirical data collected on 116 innovation projects.

Empirical observations revealed that, as a general rule, there is no statistical difference between the diverse means used for managing highly uncertain and complex innovation projects, and those characterized by lesser uncertainty and complexity. The only remarkable exceptions were the higher reliance on rules and procedures when projects were highly uncertain and complex, and the more intensive use of information on competition when there was less uncertainty and complexity surrounding the innovation project. The implication of the first observation is surprising. Innovation managers, whatever the surrounding uncertainty and complexity, seem to rely on similar means. This suggests that managerial “recipes” are relied upon when managing an innovation project; without necessarily taking into account the context of the particular project. However, as we can see below, a differentiated use of these means makes a difference in terms of innovation performance. We also found a tendency to rely more heavily on rules and procedures in a situation of high uncertainty and complexity, even though such increased reliance does not lead to innovation performance.

We will turn now to the main results of the study. In a situation where surrounding uncertainty and complexity is high, we found that a supportive innovation culture; the reliance on project management; an adequate amount of information on users’ needs; and close relationships with prospective users through networks and partnerships are associated with a successful innovation outcome. These associations were also observed in situations of lower uncertainty and complexity, but to a lesser extent. However, it was only when uncertainty and complexity were less pronounced that reliance on more structured and formalized means such as rules, procedures, plans and strategy was positively associated with performance.

These results highlight the fact that when uncertainty and complexity are pronounced, less formal methods like innovation culture or project management are more effective in managing new product development than they are under conditions of lower uncertainty and complexity. They also suggest that, although in simpler and more certain situations managers can rely on the more formal means to direct their project, the fact that no association is found between rules and procedures and innovation performance when uncertainty and complexity are higher might reinforce the ritualization hypothesis in the use of organizational means. This is consistent with writings on strategic management which stress that formal tools do not allow managers to react rapidly enough to unplanned events. It is likely that in a highly uncertain and complex situation managers tend to rely on all means at their disposal to reinforce their feelings of certitude and good management, which could explain why rules and procedures are more extensively used in these situations.

The “virtual market” trap hypothesis, in which highly uncertain and complex projects might fall when they rely on information or networks with competitors is also illustrated by our findings. As, in situations of high uncertainty and complexity, firms have difficulty in deciphering what users’ needs are and what the real market is, they tend to rely on competitors’ projects to influence their decisions about the direction of their innovation projects. In doing so, they are attempting to prevent competition from developing an hypothesized competitive edge if their project were to fit market requirements. Consequently, firms end up including in their innovation project their competitors' product functionalities -- leading to results abstracted from reality. Our findings show that, in this situation, relying on information on competitors and networks is negatively associated with innovation success. Even in simpler and more certain cases, networking and competition information do not seem to have any effect on innovation performance.

We believe we have shown that means to cope with uncertainty and complexity are, to some extent, functional in the management of innovation projects. By creating a greater sense of certainty and simplicity, they probably aid managers to determine meaning and continuity in their day-to-day actions. They may also facilitate communication and coordination between organizational actors by giving them a better understanding of the tasks to be accomplished. However, not all these means are equally effective in leading to innovation performance. More tacit means seem to be better adapted to highly uncertain and complex projects, while more formal means are better fitted to the management of innovation when uncertainty and complexity are less pronounced.

Further research needs to be done, and it is not our belief that our findings are without flaws. The major limit of the present research is that we use a cross-sectionnal sample to measure effects that are inherently time sensitive. Technological uncertainty, for example, declines as a technology moves toward maturity (Anderson and Tushman, 1991). In the same vein, a specific mean might be efficient to cope with uncertainty and complexity at the begining of an innovation process and less efficient at the end of the same process. Furthermore, the performance evaluation is assessed by the same respondent who rates the uncertainty and complexity levels as well as the extent to which each means was used during the innovation process. Finally, we are using only perceptual measures. More objective measures exist but they are rarely available for the new product but only at the aggregate (firm or industry) level.

We do feel, however, we have provided some empirical evidence to reinforce certain accepted findings on innovation management; which stress the importance of considering the nature of the innovation context, and which open new doors in our understanding of the means used to cope with uncertainty and complexity while managing innovation.

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APPENDIX I
QUALITATIVE METHODOLOGY

The organization studied

Albeit the qualitative study is restricted to solely one company, this firm was selected in the high-tech sector where the frequency of innovations are high and consequently puts at the researchers disposal, an important internal field of study.

The organization selected in the scope of this study, United, is a European firm who's combined activities are completed in the high-tech sectors. United has more than 20,000 employees and has annual revenues surpassing 40 billion French Francs. Due to its large size, United is an international player, however, is of medium scope when compared to its principal competitors, where it represents approximately one third to one half of their competitors annual sales. Nevertheless, United is the European leader in its principal businesses.

As with all companies in the industrial sector, United invests approximately one-tenth of its sales figures in Research and Development. Contrarily to it's main competitors, United does not have a highly advanced nor large research center at its disposition. United is organized in world product lines. Each product line is considered autonomous and has at its disposal all the resources and competencies required to accomplish the activities at hand.

The innovation processes studied

This research is based on an analysis of fifteen product innovation processes completed by United between 1980 and 1990. At the beginning of the research, four innovation processes were identified by managers as being representative of the company's situation. The eleven others were freely selected by the authorS after an apprehension period surrounding the specifics of the company.

Data collection and validation

The data collection is based on one hundred and thirty in-depth interviews with United Managers and on an analysis of internal documents linked to innovation processes studied.

The interviews conducted are separated into two categories:

- 100 interviews were conducted with managers directly implicated in the management and development of one of the fifteen innovation processes studied. After a brief presentation of the research objectives being sought after, the interviews were based on a semi-directive process whereby the author interrogated the mangaers in question, by utilizing an interview guide based on the innovation process background, the actors involved, the decisions taken, the achievement context, the major events, the activities accomplished, the actions and reactions of the competition and the relationships with the consumers.
- 30 interviews were conducted with managers originating from the service areas of the firm (marketing, commercial, financial and strategic). These interviews allowed for the identification of the internal organizational context, the principal procedures of the firm, its strategy and the importance of innovation.

The separation of interviews into two categories of actors, allowed us to create an exhaustive data on the development of innovation processes by those individuals having a direct impact. As well, it permitted us to clearly understand and learn the specificities surrounding the internal organizational context achieved by managers not heavily implicated in the daily management of the innovation processes studied.

The average time for an interview was approximately three hours during which notes were taken. The notes were then subsequently detailed at the end of the interview and classified with regards to the innovation process to which it was associated. In addition, there existed in the company studied, a formal decision making process related to an innovation which required the completion of a certain number of documents (product definition, market analysis, competitive analysis, launching plan, maintenance plan, etc.) and summaries of meetings which we could consult.

We proceeded by combining the collected data which was then systematically applied to the innovation processes, between the different interviews completed and the internal documents studied. Each innovation process involved a number of contacts at various levels, such as operational - directors or managers involved in the management of innovation processes-, as well as functional - services marketing, commercial, financial and strategic. In conjunction, all the internal documents directly linked to the innovation processes studied were analyzed. The utilization of these three sources of information permits the comparison and subsequent verification of the information obtained. Yin (1984) shows this mixing of data to be necessary when the methodology concentrates on case studies.

Both the interviews and the internal documents studied allowed for the composition of 15 innovation "cases". Once each case was written, it was submitted to the managers implicated in the achievement of the innovation process described in the case. The text was accompanied with a questionnaire which was developed to allow the managers to make judgement on the following:
- the realism of the items reported;
- the realism of the chain of events reported;
- the presence of any omissions;
- the importance of omissions;
- the explicit character of reasons revolving around the success or failure of a project;
- the technical success of the project;
- the commercial success of the project;
- the financial success of the project;

This questionnaire was comprised of closed ended questions where managers responded on a Likert scale as well as open ended questions where they brought in additional elements or were more specific on other points. A systematic follow-up by telephone after a two week delay, resulted in a 100% response rate.

In general, each case was evaluated twice by innovation process managers identified in the case. Moreover, a simplified version of the questionnaire only containing questions relative to the success or failure of the innovation process was also mailed to managers partaking in the functional aspects of the company, more precisely, Strategy and Finance. These managers, albeit not readily involved in the daily management of the innovation process, brought to the study a more neutral opinion on the financial, technical and commercial aspects of the project.

The analysis of the responses completed allowed for the validation of the commercial failure or success of each process studied. The omissions brought to our attention through the responses provided through the open ended questions were only integrated in the innovation cases if they were signaled in each of the two or three answers by the managers of these processes. This procedure assures the realism of the innovation cases.

Once the cases were validated, a comparative developmental analysis of the innovation processes studied allowed us to determine the regularity of the behaviour for both actors and firms as well as the analysis of both the internal and external developmental environments of an innovation process (Burgelman and Sayles, 1987; Dougherty, 1990; Van de Ven and Poole, 1990). The comparative data analysis also allowed the study of all links and interactions that existed between the external environment of the firm and the success of the innovation process (Burgelman, 1983). Strauss (1977) recommends the following method; immersing oneself into the collected data by an attentive reading of the interview minutes and the collected and validated documents; a continuous search during the reading of the relations between both the internal and external environment of the enterprise and the development of the innovation process; the identification and analysis of regularities found across the different innovation cases. This question related to the existing links between the uncertainty and complexity of the innovation process and the means used by united's actors to reduce it was our "core problem", as defined by Bailyn (1977). The comparative analysis is completed with regards to a double grid linked to the uncertainty and complexity of the innovation process (High Uncertainty and Complexity versus Low Uncertainty and Complexity) and to its failure or success factor. The usage of such a procedure allows one to determine the common characteristics of the innovation processes with regards to their type and result. As well, this type of procedure allows for the analysis of the differences discovered in the development of the four classes of innovation processes.

APPENDIX II
Distribution of Industries Represented in Sample

Industries	Percentage of sample
Consumer durable goods	5,7
Consumer non durable goods	15,1
Consumer services	1,4
Medicals & Pharmaceuticals	4,2
Industrial equipment	34
Electronic products	4,7
Chemical Products	3,8
Computer based products	11,8
Industrial services	1,9
Miscellaneous	17,4

APPENDIX III

Measures of Major Constructs and Their Reliability

DEPENDENT VARIABLE
Innovation success (or performance) (PERF) : the innovation market growth relative to that of competing products, the innovation return on investment relative to the company's other products, the fulfillment of the innovation project objectives, the commercial success of the innovation, the innovation effect on the overall market share. Reliability coefficient of .9043.

CONTROL VARIABLES
Market induced transformations following the innovation introduction(IRA): modification of competitive rules, modification of the market. Reliability coefficient of .8131.
Size of the organizational unit relative to the competition (TAC) : Relative size, relative market share, relative ressources, relative number of employes. Reliability coefficient of .9015.
Degree of autonomy of the unit in charge of the project (AUT): overall autonomy, autonomy in strategy formulation, autonomy in ressources, autonomy in technological strategy formulation. Reliability coefficient of .7965.

CLUSTERING VARIABLES
Organizational uncertainty (ORU): incapacity to develop and implement an agreed upon strategy, political decision making process, numerous internal conflicts, no long term commitment to innovation projects, no long term resources commitment. Reliability coefficient of .8239.
Organizational complexity (ORC) : difficulty to know who is doing what in the organization, existence of numerous groups of diverse culture, large number of hierarchical levels, divergence between goals. Reliability coefficient of .7647.
Competition uncertainty (COU): frequent modification of competitor strategies, difficulty to predict competitor actions. Reliability coefficient of .6148.
Competition complexity (COC): very diverse competitor strategies, great competitor diversity, difficulty to understand competitor actions, difficulty to understand competitor strategic moves, variety of competitor strategic advantages. Reliability coefficient of .7041.
Technological uncertainty (TEU): duration of technology's life cycle, frequency of technological revolution, frequency of manufacturing processes changes. Reliability coefficient of .7184.
Technological complexity (TEC): innovation project complexity, innovation based on very diverse scientific fields, large number of different technologies used in the innovation project, complexity of technologies used in the innovation project. Reliability coefficient of .6943.
Customer uncertainty (MOU): difficulty to predict customer needs evolution.
Customer complexity (MAC): difficulty to understand customer needs and expectations, customer heterogeneity, diversity of market segments needs and expectations. Reliability coefficient of .7374.

Product uncertainty (PRU): large dissimilarity between the innovation and other competitor products, high final users perceived difference between the innovation project and other competitor products. Reliability coefficient of .6835.
Product complexity (PRC): innovation project based on very diverse customer expectations, diversity of the innovation uses. Reliability coefficient of .7258.

INDEPENDENT VARIABLES
Rules-procedures and plans (RPP): project and product definition, constant project evaluation, existence of standardized rules and procedures to manage innovation process, presence of a carefully planned project management. Reliability coefficient of .8301.
Culture (CULT) It is based on eight items related to: innovation based incentives, innovation risk taking behavior, innovation orientation, innovation organizational culture and values. Reliability coefficient of .8916.
Competitor information (ICON) : information on competitors R&D programs, analysis of the competition, simulation of competitors reaction to the innovation, innovation project based on competitors own project, innovation project based on competitors R&D programs. Reliability coefficient of .7816.
Customer information (ICL) : innovation project decision based on customers needs, innovation development based on users advice and recommendations, innovation development based on working group with users. Reliability coefficient of .7119.
S**trategy** (STR) : innovation based on the firm's competitive advantage, innovation derived from the strategy, innovation based on internal resources, project definition based on the firm's strategy. Reliability coefficient of .7168.
Customer network (RCL) : partnerships with users to develop new products, participation of users in the definition of new products, information network with users to identify future needs. Reliability coefficient of .7788.
Competitor network (RCO) : information network with competitors on the industrial sector evolution, partnership with competitors to develop new products. Reliability coefficient of .8193).
Project management (IMA): innovation headed by a project manager, multidisplinary team, interdepartmental co-ordination, team autonomy, project management. Reliability coefficient of .7889).

TABLE 1
Impact of the Different Means to Cope with Uncertainty and Complexity on Innovation "Performance"
Hypothesized Signs

Means used for "reducing" uncertainty and complexity	Impact on Performance in "High" uncertainty and "high" complexity environment Hypothesized Sign	Impact on Performance in "Low" uncertainty and "low" complexity environment Hypothesized Sign
Information on Competitors Hypothesis 1	-	+
Network with Competitors Hypothesis 2	-	+
Information on Users Hypothesis 3	++	+
Network with Users Hypothesis 4	++	+
Project Management Hypothesis 5	++	+
Rules and Procedures Hypothesis 6	-	+
Culture Hypothesis 7	++	+
Strategy Hypothesis 8	-	+

TABLE 2
Test of Inter-Groups Means Differences

Uncertainty and complexity variables	"High" uncertainty and "high" complexity max: 6 min: 1 n=77 Means	"Low" uncertainty and "low" complexity max: 6 min:1 n=39 Means	Statistical significance of the means differences * 0,1 ** 0,05 *** 0,025 **** 0,01
ORC (organizational complexity)	3,03	2,93	n.s.
COC (competitive complexity)	3,41	3,10	**
TEC (technological complexity)	3,87	3,10	**
MAC (market complexity)	4,06	2,98	****
PRC (product complexity)	5,17	1,93	****
ORU (organizational uncertainty)	2,75	2,86	n.s.
COU (competitive uncertainty)	3,21	2,75	***
TEU (technological uncertainty)	3,51	3,25	*
MAU (market uncertainty)	4,08	2,18	****

PRU (product uncertainty)	4,88	3,96	****

TABLE 3
Correlation Matrix between Independent Variables

a. High uncertainty-complexity group

	CULT	RPP	ICL	ICON	STR	RCO	RCL	IMA	IRA	TAC	AUT
CULT	1	.327 **	.2770 *	-0.032	.3106 **	.018	.4069 **	.3935 **	.2519 *	.3791 **	.0587
RPP		1	.222	.5024 **	.376 **	.0846	.2163	.3375 **	.2583 *	.4147 **	.0864
ICL			1	.1149	.1487	.0414	.8294 **	.5505 **	.0923	-.0148	.1977
ICON				1	.1281	.1567	.1806	.1524	.063	.0526	-.1492
STR					1	.0407	.1816	.2921 **	.1434	.3834 **	.1335
RCO						1	.1413	.0497	.1412	.0173	.238 *
RCL							1	.6046 **	.1144	.021	.2443 *
IMA								1	.0941	.0247	.391 **
IRA									1	.196	.0803
TAC										1	.0053
AUT											1

b. Low uncertainty-complexity group

	CULT	RPP	ICL	ICON	STR	RCO	RCL	IMA	IRA	TAC	AUT
CULT	1	.7118 **	.5837 **	.3476 *	.572 **	-.3099	.5893 **	.7065 **	.3803 *	2768	.3894 *
RPP		1	.4709 **	.4028 *	.5127 **	-.1861	.5166 **	.5861 **	.343 *	.3852 *	.177
ICL			1	.0559	.4005 *	.0076	.813 **	.496 **	.2375	.2043	.3652 *
ICON				1	.4248 **	.0479	.2048	.138	.2492	.4694 **	.0984
STR					1	.0039	.4056 **	.3933 *	.1496	.4996 **	.0516
RCO						1	-.1325	-.3723 *	-.1817	.3483 *	-.1807
RCL							1	.6096 **	.3082	.26	.3912 *
IMA								1	.5239 **	.1796	.4648 **
IRA									1	.2018	.3983 *
TAC										1	.3616 *
AUT											1

* $p < .05$ ** $p < .01$

CULT: Innovation "culture" STR: Strategy AUT: Organizational unit autonomy
RPP: Rules, plans, procedures RCL: Network with users TAC: Relative size
ICL: Information on users RCO: Network with competitors IRA: Innovation induced market

ICON: Information on competitors IMA: Project Management transformation

TABLE 4

Means for "Creating" Certainty and Simplicity

Descriptive Statistics and Means Differences

Means used for creating certainty and simplicity Islands of Rationality	"High" uncertainty and "high" complexity max: 6 min:1 n=77 Means and (S.D.)	"Low" uncertainty and "low" complexity max:6 min:1 n=39 Means and (S.D.)	Statistical significance of the means differences * p<0,1
CULT (Culture)	4,0133 (1,1055)	3,7853 (1,1933)	n.s
RPP (Rules and Procedures)	4,0673 (1,2185)	3,6125 (1,3563)	*
ICL (Information on Customers)	4,3632 (1,1207)	4,2583 (1,0608)	n.s.
ICON (Information on Competition)	2,7513 (1,0735)	3,1179 (1,0279)	*
STR (Strategy)	4,4071 (1,043)	4,1188 (1,0175)	n.s.
RCO (Network with Competitors)	2,4038 (1,2768)	2,3 (1,28)	n.s.
RCL (Network with Customers)	4,2179 (1,1138)	4,0917 (1,1742)	n.s.
IMA (Project Management)	4,5647 (1,142)	4,4075 (1,1536)	n.s.

TABLE 5

Success as a Function of Culture, Rules and Procedures and Project Management

	High uncertainty and complexity n=77	Low uncertainty and complexity n=39	High uncertainty and complexity n=77	Low uncertainty and complexity n=39	High uncertainty and complexity n=77	Low uncertainty and complexity n=39
	ß	ß	ß	ß	ß	ß
RPP	-0,0491	0,2418*				
CULT			0,2831**	0,2955**		
STR						
RCL						
RCO						
ICON						
ICL						
IMA					0,4008***	0,2524*
AUT	0,1911*	0,2024	0,1737*	0,1217	0,0265	0,1314
TAC	0,0173	-0,1086	-0,1015	-0,066	0,0124	-0,0375
IRA	0,2575**	0,5179***	0,2035*	0,5155***	0,2426**	0,5028***
R^2	0,108	0,54***	0,16***	0,55***	0,23***	0,53***

* $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$

RPP: Rules, plans, procedures
CULT: Innovation "culture"
IMA: Project Management

AUT: Organizational unit autonomy
TAC: Relative size
IRA: Innovation induced market transformation

TABLE 6

Success as a Function of Information on Users and Competitors

	High uncertainty and complexity n=77	Low uncertainty and complexity n=39	High uncertainty and complexity n=77	Low uncertainty and complexity n=39	High uncertainty and complexity n=77	Low uncertainty and complexity n=39
	ß	ß	ß	ß	ß	ß
RPP						
CULT						
STR						
RCL						
RCO						
ICON	-0,2771***	0,0781	-0,1859*	0,0911		
ICL	0,4932**	0,2228*			0,4405***	0,2272*
IMA						
AUT	0,0647	0,158	0,1685	0,2315*	0,1027	0,1482
TAC	0,0384	-0,0872	0,0034	-0,0977	0,0308	-0,0565
IRA	0,2523**	0,5716***	0,2654**	0,5948***	0,231**	0,5825***
R^2	0,36***	0,54***	0,13**	0,50***	0,28***	0,54***

* p < 0.1   ** p < 0.05   *** p < 0.01

ICON: Information on competitors
ICL: Information on users

AUT: Organizational unit autonomy
TAC: Relative size
IRA: Innovation induced market transformation

TABLE 7
Success as a Function of Strategy and Networks with Users and Competitors

	High uncertainty and complexity n=77	Low uncertainty and complexity n=39	High uncertainty and complexity n=77	Low uncertainty and complexity n=39	High uncertainty and complexity n=77	Low uncertainty and complexity n=39	High uncertainty and complexity n=77	Low uncertainty and complexity n=39
	ß	ß	ß	ß	ß	ß	ß	ß
RPP								
CULT								
STR	0,0341	0,273**	0,1157	0,3094**				
RCL	0,3497***	0,0572			0,3111***	0,194		
RCO	-0,2936***	-0,0059					-0,2661**	-0,0696
ICON								
ICL								
IMA								
AUT	0,1515	0,2258	0,1743	0,2607*	0,0994	0,1603	0,2473**	0,207
TAC	0,0028	-0,1908	-0,0421	0,2131	0,0026	-0,0653	0,01	-0,0299
IRA	0,2504**	0,5884***	0,2469**	0,6128***	0,238**	0,5678***	0,2634**	0,5961***
R^2	0,29***	0,57***	0,11*	0,57***	0,21***	0,52***	0,16***	0,50***

* $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$

STR: Strategy
RCL: Network with users
RCO: Network with competitors

AUT: Organizational unit autonomy
TAC: Relative size
IRA: Innovation induced market transformation