Decision-making in disruptive technological innovation projects : a value approach based on technical and strategic aspects

François Petetin

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François Petetin

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M. Vincent BOLY, Institut National Polytechnique de Lorraine	**Rapporteur**
M. Emmanuel CAILLAUD, Université de Strasbourg	**Rapporteur**
Mme Lucienne BLESSING, Université du Luxembourg	**Examinateur**
M. Jean-Claude BOCQUET, Ecole Centrale Paris	**Directeur de thèse**
Mme Gwenola BERTOLUCI, Ecole Centrale Paris	**Co-encadrant de thèse**
M. Jean-Michel KIAT, Ecole Centrale Paris	**Co-encadrant de thèse**
M. Jean-Marie BOCQUART, Directeur Technique de L'HOTELLIER	**Membre invité**
M. Nicolas PAILLONCY, Ancien directeur général de L'HOTELLIER	**Membre invité**

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« Il faut bien comprendre le système des valeurs, après, ça va tout seul… »

Alexandre Astier, *Perceval et le Contre-sirop*, Kaamelott livre II

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Introduction:

Innovation, however key for the development of companies, can be a real adventure. The uncertainty related to the value it can create is often an important dissuasive factor. For small companies dealing with disruptive technological innovation it represents an important and specific challenge. In this thesis we tackle this particular issue. In a research action conducted in the SME “L’Hotellier”, we devised a method that aims to help managers to pilot disruptive technological innovation projects in SMEs through the control of the critical decisions of the project. This approach is based on the study of the values created by the innovation and of the risks threatening this value creation. This thesis is divided in five main parts. We begin by studying the context of our research. Then we identify and analyze our problematic. Based on the results of this analysis, we propose a model for the management of these critical decisions. This model is then experimented twice in an innovation project in L’Hotellier. The results of these experimentations are analyzed in order to assess the validity and value of our model. Finally, a conclusion summarizes our contribution to the scientific field of design sciences and discusses the limits and perspectives of our work.

In our first chapter, we develop the context of this study. We present the enterprise in which we conduct our research action, its products, development processes and its relations to the innovation in general. We then present the innovation project that is the heart of our experimentation. The next step of this chapter is a generalization of this industrial context. We study the key characteristics of our environment in order to identify a general extended context of application of our model. For each key characteristic, a short bibliography presents the main features of our general context.

This general context is characterized by three different aspects: the industrial sector, the size of the enterprise and the type of innovation. In our case, we focus on the aeronautic sector. We analyze some of its characteristics and show that although it favors high technologies, innovating in this sector presents some difficulties. The high expectancies in terms of reliability that characterize it act as a brake for disruptive innovation. The second key characteristic is the size of the firm developing the innovation, in our case, we chose to consider small structures like SMEs. Indeed, through a bibliographic analysis, we point out some of the qualities and downsides of such structures. We underline the fact that they often have scarce human and financial resources which can handicap them in accessing to specific knowledge. This weakness could be key for some steps of the innovation development because these structures usually only scarcely formalize processes and knowledge. Finally, the last element of the context considered is the type of innovation developed. A bibliographic review of the different innovation typologies shows that innovation can take various forms. In our case, we choose to focus on disruptive technological innovations, a category that we define as innovations that present a high technological uncertainty and involve a market discontinuity. Based on an analysis of this type of innovation, we show that such innovations are characterized by a lack of knowledge regarding the technology and the market. This context analysis led to establish that one of the most important challenges in technological disruptive innovation projects in SMEs is the identification and the access to critical knowledge.

This question of the identification and access to knowledge led us to investigate some of the main innovation process models that can be found in the literature, both from innovation management and design engineering fields. We list and identify their strengths and weaknesses and point out that these models mainly describe the innovation process as a more or less complex succession of activities and decisions involving retro-actions loops. We emphasize that due to the uncertainty involved in technological disruptive innovations, decision-making phases present an important challenge, not well covered in today’s literature, especially in small industrial structures with scarce resources.

In our second chapter, we present our problematic that result from these conclusions: *Given the fact that SMEs are not able to follow classical innovations processes models, what are the main aspects that should be the focus of disruptive technological innovation projects?* We begin this chapter with a deeper study of this problematic. We focus first on the performance of innovation for enterprises. Through a bibliographic analysis, we show that the purpose of innovation is the creation of value. This concept of value creation is relatively complex and can include different types of values, from economical to ethical and environmental. This value is not only created for the enterprise but for all the various stakeholders of the innovation project. We identify several existing typologies of these stakeholders and value creations.

However, due to the uncertainty related to the innovation context, this creation of value cannot be taken for granted. Risks are associated to these value creations and must be managed. In order to precise this concept of risk and its implications in our work, we conducted an analysis of different risk management models. We focused on risk related to innovation and showed that in a disruptive technological innovation context, these risks are mostly related to the market and technology of the innovation. Based on this preliminary analysis of our problematic, we concluded that value creations and risks represent key criteria that should be used in the critical decisions of innovation projects. Based on these premises, we show that piloting a project based a value and risk approach of decision-making requires a focus that includes both the product and the value chain of the innovation. In addition to that, we show that a model that aims to assist managers in the steering of a disruptive technological innovation project must be able to tackle operational, tactical and strategic issues. This led to the formulation of our research question: *How can a SME manage a technological disruptive innovation project while taking into account a complex value creation, a point of view enclosing the whole value chain and the product it supports, this with a scope ranging from operational to strategic management levels?*

The following of our problematic chapter deepens this research question. We present different methods and tools that aim to manage value creations. By analyzing their key features we show that none covers all the dimensions cited in our research question. Then, in order to assess the extent to which the control of decision-making could answer our problematic, we conducted a bibliographical analysis of the decision process. We chose to adopt Simon's bounded rationality theory and proposed the framework of a decision model adapted from different models found in the literature that would constitute a satisfactory answer to our research question.

In the next chapter, based on this problematic analysis, we develop the main stages of our model. This model starts with a preliminary step: the <u>recognition of a critical decision</u> and is followed by four steps. The first one is the <u>problem setting</u> step that consists in the definition of the goals and constraints related to the decision and in the translation these into value creations. After a second step of <u>alternatives identification</u>, a third step, <u>alternatives evaluation</u> is conducted, in which the value created and the risks associated for each alternative are assessed. Lastly, this information are represented and transmitted to decision-makers in order to ease decision-making in the <u>values and risks representation</u> step. We choose here not to implement a phase of criterion aggregation that would enable the identification of a hypothetic "best solution".

The next three chapters detail our experimentation. We begin by explaining the context of the experimentation and precise our protocol of experimentation, defining the two decision we focus on and the actors of the decision process. We then present the application of our model in these two decisions. The first decision is the selection of a manufacturing process for the innovation developed. Since this decision was taken relatively early in our thesis, we applied our model a posteriori. This enables us to compare the amount of information the decision is based on with and without our method. The second decision is the selection of the value chain for the innovation, including the selection of both the supply chain of the critical component of the innovation and the market offer.

The next chapter analyzes the results of our experimentation. The first section of this chapter assess how did our model answered to our research question. We structure this analysis by studying separately the four aspects of our research question: taking into account complex value creation, enclosing the whole value chain and the products it supports, having a scope ranging from operational to strategic management levels. For each of them, we demonstrate through examples extracted from our experimentation that our model is an adequate answer to this aspect of our research question.

In the second part of this analysis, we study the value that has been created by our model. We analyze how our model validates our hypothesis. We show that by increasing the quantity of relevant information available to decision-makers, we increase the quality of the decision process. In addition to this, we show that by formalizing and rationalizing this process, we enable decision-makers to efficiently steer the innovation project. Finally, we show that this project steering process is agile thanks to the wide variety of actors of the decision included in our model. By adopting a value and risk focus on the critical decision of a project, we have an iterative model that can help managers to pilot a disruptive technological innovation projects in SMEs in an agile manner.

We conclude this study by synthesizing our results. We present and analyze the contributions of our model. We underline what constitute its originality and what scientific value creation we can claim. We then discuss the limitations of our model. Finally, we propose several perspectives in which our model could be further developed.

I. Context

In this first chapter, we present the context of our research. We begin by presenting the enterprise in which our research action is conducted. We present the innovation that is the subject of our experimentation, its specificities and the actors of the project. This context is then generalized. We define the industrial context that our model is applied to and the type of innovation that we treat.

1 Research action

During our work, we focused on a specific type of industrial problem and studied a small aeronautic integrator name L'Hotellier as an example of this type of issue.

This work was conducted in research action inside the enterprise L'Hotellier. The PhD candidate was hired for two main missions. The first was pursuing an innovation development that had been started several years ago and put on hold during the last year. The second mission that led to this work was to carry out a research centered on innovation process in order to devise an innovation process model that would maximize the chances of success in the innovation project the PhD candidate was leading.

In this section, we are going to present our case study, the company L'Hotellier and the innovation project we experimented on.

1.1 Presentation of the company

L'Hotellier is the result of a merger between two France-located companies: Kidde Dexaero, a specialist in fire protection and detection and Louis L'Hotellier, a company specialized in aeronautic fire detection. L'Hotellier is part of Kidde Aerospace and Defense, the world's leading supplier of fire protection and safety systems products for civilian and military aircraft. Kidde Aerospace and Defense is a business unit of Hamilton Sunstrand, a company that supplies technologically advanced products to aerospace and industrial companies. Hamilton Sunstrand is part of United Technologies Corporation (see Figure 1).

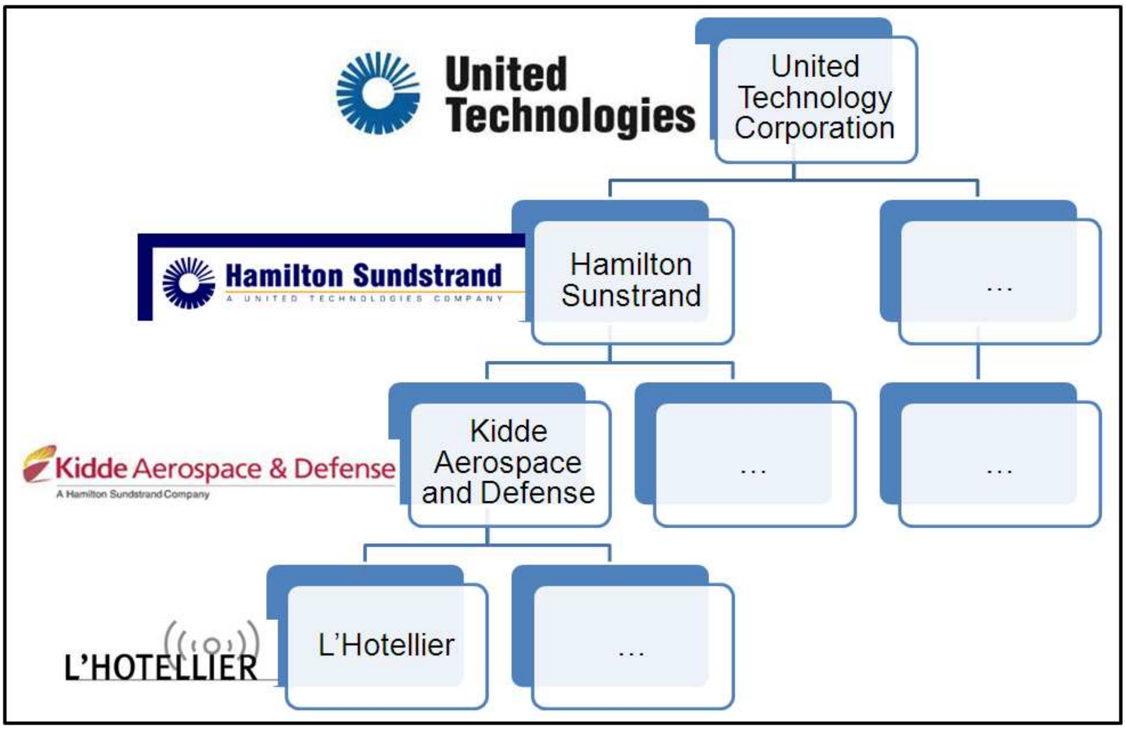

Figure 1. L'Hotellier position in United Technology Corporation

L'Hotellier's main activity is the design and manufacturing of systems enabling fire detection and suppression in airplanes, helicopters and armored vehicles. These systems are usually composed of several products: spots and linear fire detectors located in the engine or cargo areas, smoke detectors for cargo or cabin area, fire control panels and warning units for the management of the detection/extinction functions, fire extinguishers for engines and cargo bay and finally portables extinguisher for manned areas.

With a hundred employees, L'Hotellier is very small compared with other companies of the group (Kidde Aerospace, the biggest organization in the Kidde Aerospace and Defense business unit has around a thousand employees). However, L'Hotellier enables Kidde Aerospace and Defense to access the far from negligible French aeronautic market.

1.2 Product specificities

The products developed and manufactured by L'Hotellier are categorized in three main families: mechanical, electr-mechanical and electronical. The mechanical products are constituted of all the extinguishers, where electronicals regroup the other products: detectors, control panels, cartridges... The main functions that need to be accomplished by these products are relatively basic (see Figure 2). And, since reliability is a key issue, simple, robust and proven solutions are privileged.

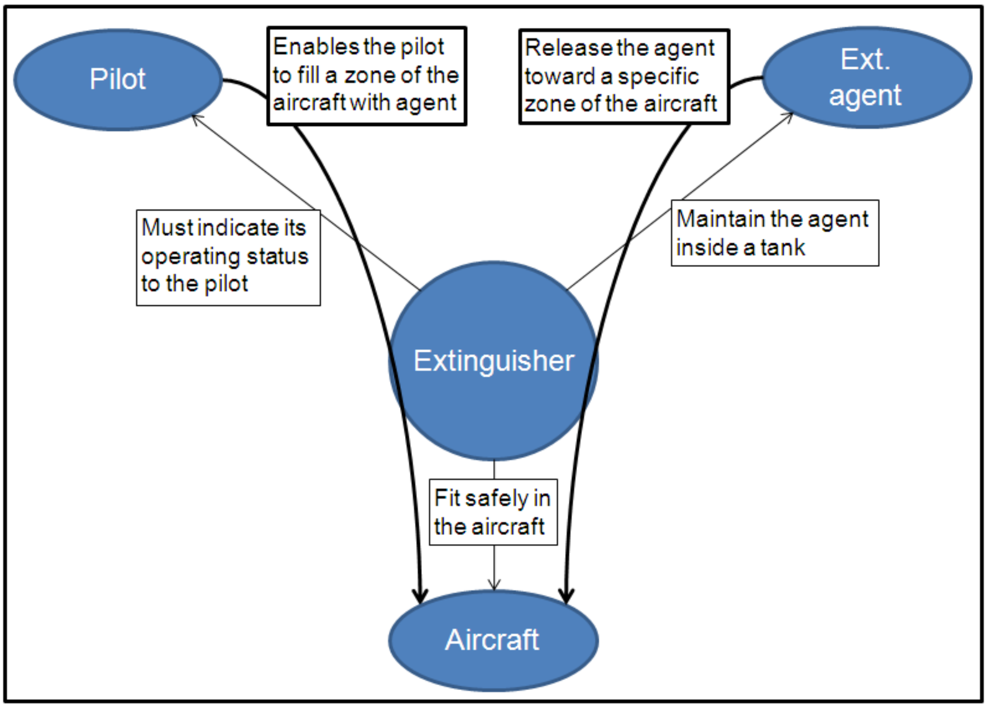

Figure 2. Functional analysis of an extinguisher during its operational phase

In the following section, we present the process followed for the development of these products.

1.3 Company development processes

Product development in aeronautics is mostly driven by the realization of the documents required by the customer, which makes every project different from the others. However, these differences are often not so big and formalizing a standardize development process is often possible. This process can be followed with a few adjustments in order to adapt to specific customers requirements.

In our case study, products are developed following a standardized process. Each category of product (fire extinguisher, control panel, cartridge, smoke detectors) has dedicated processes map describing the different steps of the product development. Depending on the importance of the project, the process maps used have different level of detail. Projects with a budget superior to fifteen thousand euros are conducted following the "standard work" process maps and smaller projects use a simplified version.

Each development process is split in four stages: "business proposal", "preliminary design", "detailed design" and "verification and validation". To each of these stages a process map is associated. On these maps are represented the different activities that form the development process. They are situated in a dozen "swim lanes" that represent the different profession of the development process. The flow of information between them is represented by arrows going from one activity to another. These maps only formalize the process related to the design activities; however, each map is associated to another representing the links between design and other activities (finance, marketing, production, etc.)

The process maps dedicated to smaller project are a simplified version of the "standard work" maps (see Figure 3). Only seven swim lanes were kept: "project management", "design analysis", "design", "drafting", "materials and processes", "verification and validation" and "reliability, maintainability and safety". These maps focus only on the design activities without making links with other functions.

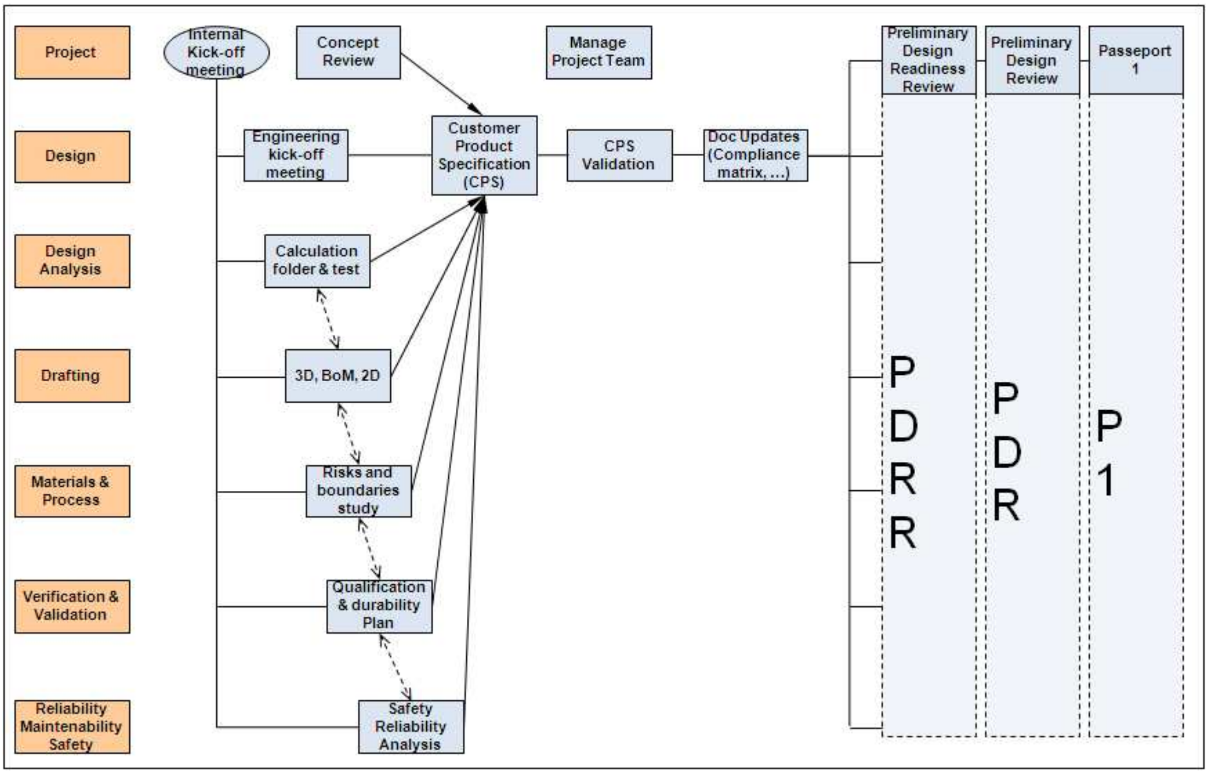

Figure 3. Preliminary design process map

As we can see, L'Hotellier has a well standardized design process, adapted to the different products it develops. However, these products always rely on proven mature technologies. These maps only concern the product development and do not tackle nor are adapted to the issue of disruptive innovations. At best, it is used to treat the very few incremental innovations. Two innovation oriented processes exist in the American main office. One describes the process of selection of new technologies to be developed. This process is not used in L'Hotellier that does face this kind of problematic since its activity is more oriented toward product development than technological research. The second one describes a technology development process based on the Technology Readiness Levels (Mankins 1995), detailing the process advocated to move from one level to another. However, this process is very simple and not prescriptive enough to identify the knowledge required for the development of the technology. Furthermore, the customer and product dimensions of the technology are almost not taken into account. This question of the characteristics of L'Hotellier regarding innovation is further described in the following section.

1.4 The innovation, the company and its environment

In order to get a better understanding of the relation the firm has with innovation, we used an analysis method that we co developed (Cuisinier, Vallet et al. 2011).The purpose of this method is the characterization of innovative organizations. To accomplish this purpose, it offers a set of eight "explicative variables" (position on the value chain, power on the value chain, influence of market pull or technology push, history, market constraints, turnover and product lifecycles, nature of innovation and competition) characterizing the enterprise and its industrial context. Another set of five "explicated variables" (strategy definition and resource allocation, open innovation percentage, innovation culture, operational management and innovation process) represent characteristics of innovative organization. By assessing the influence of the explicative variables on the explicated ones, one can have a good analysis of the level of innovation in the enterprise and the factors that are responsible for this state. We present the results of this analysis in the following sections (see Table 1).

1.4.1 Strategy definition and resource allocation

This variable characterizes the level of maturity of a firm in the definition of its strategy and in the allocation of its resources. It focuses on the way these elements favor innovation in the firm. In this regard, L'Hotellier is characterized by a strategy that does not make of innovation a priority. Innovation budgets are the first to be cut down in time of crisis. This is due to two main causes. Firstly, innovation are almost always developed on the company's own founds. Since the expectations in term of reliability of the customers are very high, a product is only acceptable if it has been proven and certified. A new system has to be developed and tested on company founds first, before its adaptation for a specific program is acceptable by a customer. Secondly, the strategy is mainly defined by the group, of which L'Hotellier represents only a small part. The definition of the level of admissible company founded projects is based on macroscopic criterion that only slightly takes into account the specificities of L'Hotellier.

1.4.2 Open innovation percentage

Open innovation is very scarce at L'Hotellier's. This can be traced down to two different reasons. First, since the innovations developed are mainly incremental, the use of extern resources is not very useful. The second reason is the feeble cost of L'Hotellier's products compared to other aircraft systems. For a one-hour flight costing several thousands of Euros, the cost of the anti-fire system only amounts to a few Euros. Thus, customers only have moderate interest in collaborating with L'Hotellier for the development of innovations.

1.4.3 Innovation culture

Innovation culture is not very developed in L'Hotellier. Several reasons explain this phenomenon. From a market point of view, as we have already said, the high expectations in reliability does not encourage the implementation of new solutions whose certification takes a lot of time and that always seem risky compared to proven ones. This does not only apply to L'Hotellier but also to their competitors that, facing the same challenge, are not aggressive on this topic.

The second reason explaining the low innovation culture is related to L'Hotellier's products. The functions that the extinguishers, detectors and other electronical devices are required to perform have not changed for decades. Simple and effective solutions have been found and perfected through the years to perform these functions. Process innovation diminishing costs and changes are required by customers regarding the level of aggressiveness the product is confronted to in the aircraft environment (temperature, corrosion, etc.) are the only causes behind modifications. As a result, the innovations are mostly incremental (process change, change of materials). Furthermore, due to the relatively small importance in terms of cost and weight (two major drivers for innovation in aeronautics) of L'Hotellier's products compared to the other main systems of the aircrafts (motors, structure, etc.), L'Hotellier is not much pressed by its customer to engage in disruptive innovations.

1.4.4 Operational management

The variable operational management characterizes the quality of the tools and methods used to manage R&D projects. R&D processes in the aeronautic industry are very formalized and characterized by a heavy number of documents defined by the customer and whose realization drives the development process. As an aeronautic subcontractor, L'Hotellier is confronted to this way of working. However this level of definition in the development of products does not extent to the development of innovative systems that are added on the products. As such L'Hotellier does not have a dedicated innovation process.

1.4.5 Innovation process

This variable characterizes the course of an innovation from the idea to the market. As we have said, innovation is scarce in L'Hotellier. As a result, and due to the low innovation culture, the innovations being developed follow a "hero innovation pipe" pattern. Innovations are carried outside the enterprise development process by a few individuals deeply implicated. The innovation projects that succeed and make it through to the market are the result of the efforts of these individuals.

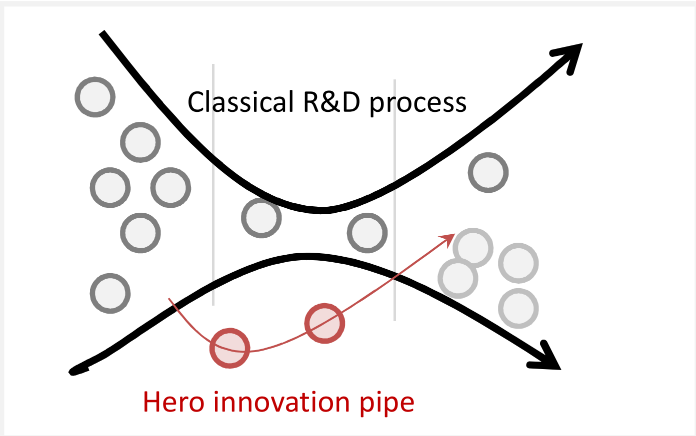

Figure 4. "Hero innovation pipe" (Cuisinier, Vallet et al. 2011)

1.4.6 Conclusion

After this analysis, we can conclude on the fact that, due to external (market requirement, top-down strategy from the main office, importance on the value chain) and internal (type of products) requirements, L'Hotellier are not prone to disruptive innovation. However, despite this grim picture, L'Hotellier is currently developing an innovative system to be implemented on most of their extinguishers, based on new technology: the ceramic disk. In the next paragraph, we precise the main characteristics of the innovation developed.

	Position on the value chain	Power on the value chain	Market Pull / Technology Push	History	Market constraints	Turnover and products lifecycle	Nature of the innovation	Competition
Strategy definition and resources allocation	No	No	No	Yes	Yes	Yes	Yes	Yes
				Strategy mainly decided by the American main office	High expectations in terms of proof of reliability favors quality rather than innovation	Very long product lifecycles (30 years) Very low frequency of new products launched	Mainly incremental innovation	Not very aggressive on the topic of innovation
Open innovation percentage	No	Yes	No	No	No	No	Yes	No
		System supplied for the customer too small to push them to invest resources in its development					Mainly incremental innovation that doesn't require external resource	
Innovation culture	No	No	Yes	No	Yes	No	Yes	Yes
			Feeble demand for new technology from the market		High expectations in terms of proof of reliability discourage innovation		Mainly incremental innovation	Not very agressive on the topic of innovation
Operational management	No	No	No	No	Yes	No	Yes	No
					Aeronautical sector impose strict process. The realization of the significant amounts of documentation required drives the project.		Mainly incremental innovation	
Innovation pipe	No	No	No	No	Yes	Yes	No	No
					High expectations in terms of proof of reliability and documentation	Very long product lifecycles (30 years) Very low frequency of new products launched		

Table 1. Our analysis of the characteristics of L'Hotellier as an innovative industrial organization adapted from (Cuisinier, Vallet et al. 2011)

1.5 Innovation developed

As stated before, innovations in L'Hotellier can usually be traced to a small group of individuals (development with the "hero innovation pipe"). In the case of the ceramic disk, it was an idea from L'Hotellier's chief technical officer that launched the project. After a first feasibility study and a pause in the project, it was revived at the instigation of the chief executive officer. The aim of this project is to develop a new system for the opening of the extinguisher tanks.

1.5.1 Actual system

Aeronautic extinguishers are composed of a tank that contains a pressurized extinguishing agent. These tanks are located close to the aircraft motors. They include one or several heads, closed by small metallic membranes that need to be opened by the pilot. Currently this opening is triggered by the explosion of a pyrotechnical cartridge positioned in front of the membrane (see Figure 5).

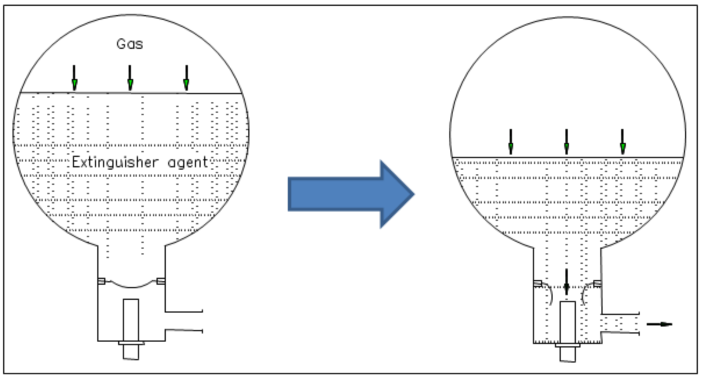

Figure 5. Opening of an extinguisher triggered by a pyrotechnical cartridge

This system, very reliable, known and used since decades presents a few downsides. Due its pyrotechnical nature, it is dangerous to handle and technicians that manipulate it must go through specific formations. Furthermore, the storage and transportation of pyrotechnical devices must comply with heavy regulations(Radio Technical Commission for Aeronautics and European Organization for Civil Aviation Equipment 2000). In order to limit these regulations to the cartridge and not the whole ensemble, extinguishers and cartridges are sold and maintained separately. This induces a significant amount of costly mounting and demounting operations, as well as logistic complications, since both systems needs to be revised periodically. In additions to these aspects, these devices also have a significant impact on the environment. The explosion of a pyrotechnical device releases lead azide, a polluting compound. Finally, since these products are relatively well known, they are relatively easy to copy and it is estimated that almost forty percent of the after-market cartridge business is lost due to unagreed competitors.

1.5.2 Ceramic disk

The ceramic disk would be a solution to these problems. The principle of this innovation is to replace the metallic diaphragm that close the extinguisher tanks by an active membrane in ceramic. An electrical current in this ceramic disk would cause a localized heating, the dilatation and finally the rupture of the disk (see Figure 6). Since it does not involve any pyrotechnical device, it would not fall under the explosive-related regulations with the resulting economies and logistic simplifications that implies. Furthermore, the disk being sold as part of the extinguisher and being more difficult to copy, no after-market would be lost.

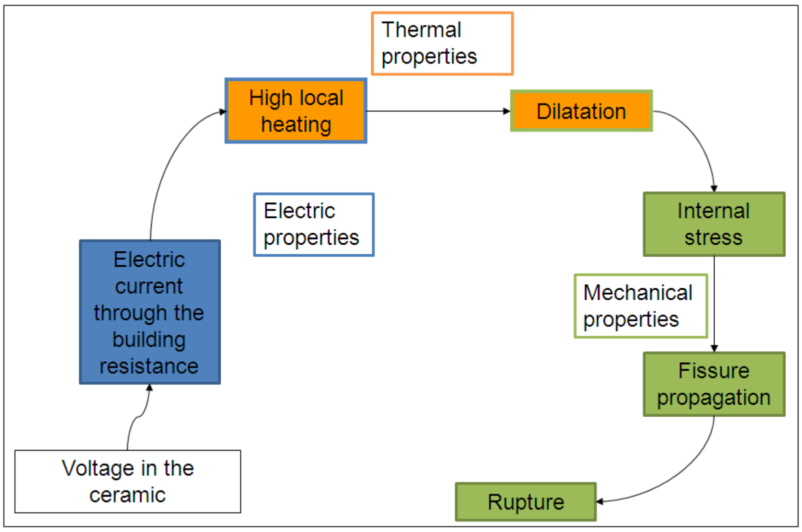

Figure 6. Ceramic disk mechanism

However, developing this innovation presents a significant challenge. The ceramic material is very uncommon. It is only used in the industry casted in thin layers on other materials. No mature technology exists to manufacture it in the required shape and its mechanical and electrical properties are not well known. In addition to this technological issue, this innovation presents another one, market related. The pyrotechnical cartridges represent L'Hotellier's cash cow product. Replacing it by a new one is particularly risky.

1.6 Conclusion

We have given the main characteristics of L'Hotellier, the company in which our research action is conducted and now we have a good picture of our specific industrial context. Design processes in this firm are standardized but mostly adapted to incremental innovation. The products are based on old technologies that enable the main, relatively simple, functions to be performed simply and with a high reliability. This reliability is one of the main expectations of the customers. The innovation developed, totally new for the firm is based on a non mature technology but represent a good opportunity.

In the following parts we generalized this picture to the industrial context we focus on. The first step is a focus on the aeronautic sector. Then we describe the specificities of small and medium enterprises. Finally, we specify the type of innovation we are interested on.

2 Generalized industrial Context

2.1 Aeronautic industrial sector

This study focuses on the aeronautic and defense sector. In terms of product and processes, this sector is characterized by extremely high expectations regarding reliability and quality. The design and development of new products and systems must accommodate with a heavy regulation and documentary constraints that can represent a barrier to creativity. Certification of disruptive innovation may prove difficult because of lack of appropriate regulation. These regulations are specific to existing solutions. They can be inadapted to new ways of performing the same function. Furthermore, the adoption of innovations based on new technologies is impeded by the lack of experiences and the absence of data establishing the robustness of the process. *"until new ideas are well-proven, most customers prefer low-risk incremental improvements"*(Kroo 2004).

On a market point of view, this sector is characterized by Business to Business commercial relations with a very small number of industrial customers and competitors. Product are developed and sold for particular programs or platforms. Being selected on a program ensures a continuous stream of income for the whole lifespan of the program. The competitive advantage given by the innovation in the selection process is thus extremely valuable. However the modern aeronautic context is characterized by a diminution of the number of new programs (Murman and Walton 2000). In order to increase the volume of distribution of their innovations, firms may have to develop them with the additional constraint that they should be compatible with former products. In this way, they would be able to distribute them through retrofits on older programs.

Different types of enterprises cohabit in the aeronautic sector. The final assemblers of course are very often big companies that dispose of the required resources. However, smaller companies can play a significant role acting as second or first rank suppliers. It is the characteristics of these smaller enterprises that we focus on in the next paragraph.

2.2 Size of the firm developing the innovation

After having defined the industrial sector, we want to focus on the size of the organization we want to study. We focus on Small and Medium Enterprises. SMEs are defined as enterprises with less than 250 headcount and either a turnover inferior to €50 million or a balance sheet total inferior to €43 millions. The literature provides some insights about the main characteristics of SMEs. First, due to their small size, they seldom have a position of leader on their market (European Environment Agency 1998). This can diminish their bargaining power in business negotiations. They often have scarce human and financial resources which can handicap them in accessing specific knowledge that could be key for the development of innovation (Tukker, Ellen et al. 2000; Lindemann, Hessling et al. 2001). They also are characterized by very flexible organizations where work relations are informal and management processes barely defined (Dandridge 1979; Gondran 2001; Le Pochat 2005). This informal process of communication allows a good sharing of tacit knowledge (Koskinen and Vanharanta 2002) in return this knowledge is rarely formalized (Wong and Aspinwall 2005; Abeti, Ciancarini et al. 2008).

Because of the constraints associated to the aeronautic sector, its SMEs suppliers don't practice frequently disruptive innovation. The new product development process is principally devoted to dimensioning the product for a specific aircraft model. A real competitiveness exists on the market but the importance of the risks taking associated with disruptive innovation and a lack of technical skills latent to SMEs involve that disruptive innovation is rare in these companies. Consequently they have a design process dedicated to the dimensioning of new products. Formalized innovation processes do not exist and could not be supported by their organization.

2.3 Key features of the targeted type of innovation

There are several manners to make a difference between innovations. Numerous typologies exist that classify innovations in different categories based on several criterions. Distinctions are very often based on the size of the innovation developed, on the maturity of the technologies used, on the novelty of the system for different stakeholders or on the level of discontinuity it presents regarding the current environment. These typologies overlap on several aspects. The works of Garcia and Calantone (Garcia and Calantone 2002) and Amara et al.(Amara, Landry et al. 2008) synthesize and describe these different propositions. Here, we focus on two types of distinctions, the novelty of an innovation regarding its environment and its technological uncertainty.

2.3.1 Novelty of an innovation in its environment

Novelty is an obvious characteristic of any innovation. This novelty can apply to many aspects of the innovation. Here we study the degree of novelty of an innovation in its environment using the approach of Garcia and Calantone that consists in assessing the level of marketing discontinuity, a criterion widely accepted in the literature. A marketing discontinuity means that the product innovation may require new marketplaces to evolve or new marketing skills for the firm. This discontinuity can apply on a micro level or a macro level. A discontinuity on a micro level impacts only the firm developing the innovation and its customers where a macro level discontinuity impacts at least the whole industry sector involved.

2.3.2 Innovation technological uncertainty

Product and process innovation can incorporate new technologies. The characteristics of these technologies can also be considered as significant criterions in innovation typologies. Instead of continuing with Garcia and Calantone approach that assesses the macro or micro level of discontinuity in the technology used in the innovation, we adopt here the views of Shenhar and Al (Shenhar, Dvir et al. 1995) that discriminate innovations based on the uncertainty of the technology. They describe four levels of innovation:

- Low technological uncertainty innovations that are based on existing and well documented base technologies, where there is no technological uncertainty.
- Medium technological uncertainty innovations, resting on base technologies but incorporating some new technology or feature. The technological level of uncertainty in this innovation is fairly low. In this category, we can find most of the incremental innovations.
- High technological uncertainty innovations that rely on existent but new technologies. The first-time integration of these technologies leads to a serious level of technological uncertainty.
- Super-high level of uncertainty innovations that are based on totally new technologies. For this innovation time must be spent during the development process to test and further develop the technologies.

2.3.3 Synthesis

At the end of this analysis, we restrain the field of innovation and consider a particular category composed by the intersection of the innovation with micro marketing discontinuities and with a very high level of technological uncertainty, as these are the one that have the most interesting potential. We refer to this category of innovation throughout our work as “disruptive technological innovation”. This restriction allows us to have enough precisions on the kind of innovations we want to study, while still being soft enough to allow a significant number of innovations to stay in the scope of our study. This particular category of innovation is especially interesting. It is characterized by an uncertainty that highly limits the use of tools and rationalized decision-making methods usually used, in design engineering (functional analysis, value analysis, QFD, …) as in management sciences (Porter’s fives strength, SWOT, …) and thus leaves a gap in the available supports methods.

3 Innovation processes models

In order to help firms achieve innovation, numerous studies have been developed describing innovation processes aiming to help firms to adopt an organization fit to the development of innovation. However, with the rich variety of innovations existing in multiple and various context, one can ask whether these models can achieve enough flexibility to be applicable in particular cases without losing their prescriptivity. Especially in the case of disruptive innovation projects in enterprises that are not structured for this purpose, nor experienced. In the next paragraph we focus on some of the main innovation process models described in the literature and used in the industry. We discuss their merits and drawbacks.

3.1 Innovation processes and enterprise management

3.1.1 Black box models

Early theories about innovation concentrate on the inputs and outputs of innovation. For Schumpeter (Schumpeter 1939), science and technical progress drive the innovation process, described as a creation – destruction process. The emergence of new technologies leads to new products, manufacturing processes and know-how. This creation causes necessarily the abandonment of previous technological fields, products or organizations. New technologies result in inventions that are industrialized by R&D services and sold to customer, thus becoming innovations.

In reaction to this technology push approach, Schmookler (Schmookler 1953) proved by analyzing patent statistics that the pull of demand could also be a significant cause of innovation (Scherer 1982; Kleinknecht and Verspagen 1989).

3.1.2 Chain-linked model

Kline and Rosenberg (Kline and Rosenberg 1986) later developed a non linear model that aims to join three different components. The first one is the development process with its classic phases (perception of a potential market, invention or analytic design, detail design and test, redesign and production, distribution and marketing). The second and third ones are the research activity and the knowledge produced. The chain-linked model proposes several paths to innovation connecting these three spaces and introduces feed backs from one activity to another (see Figure 7).

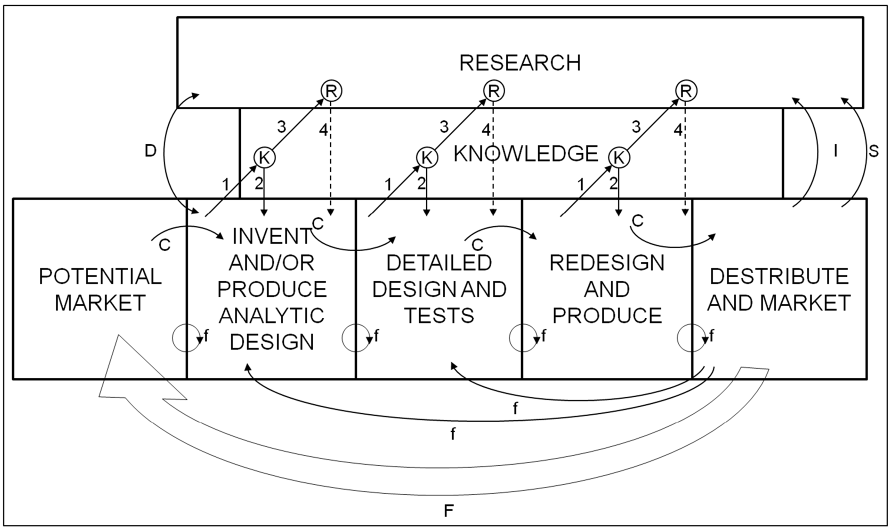

Figure 7. Chain-linked model (Kline and Rosenberg 1986).

Symbols on arrows: C: Central chain of innovation; f: Feedback loops; F: Particularly important feedback; K-R: Links through knowledge to research and return paths. If problem solved at node K, link 3 to R not activated, return from research (link 4) is problematic-therefore dashed line; D: Direct link to and from research from problems in invention and design; I Support of scientific research by instruments, machines, tools and procedures of technology; S: Support of research in sciences underlying product area to gain information directly and by monitoring outside work. The information obtained may apply anywhere along the chain.

3.1.3 Stage-Gate model

In between the management and engineering approaches are the works of Cooper. The stage-gate system he developed proposes a methodology to ensure a better management of the innovation process. This method is often used in the enterprise world. According to its developer, the stage-gate systems *"simply apply process management methodologies to this innovation process"*(Cooper 1990). The innovation process is divided into a number of separate stages. Each of these stages contains a group of predetermined activities. The entry to each stage is a "gate" that controls that the deliverables elaborated in the previous stage reach a level of quality sufficient for the project to go on smoothly. According to the result, a Go/Kill/Hold/Recycle decision is taken. The use of this model can require changes in the organization of the firm or in its development processes (see Figure 8).

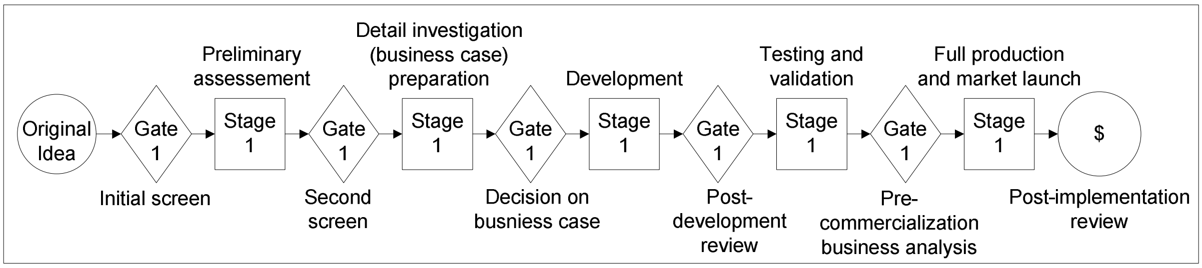

Figure 8. Stage-gate model (Cooper 1990)

The objective of these theories is not to explain the process of innovation. Even if they try to analyze the link between the input and outputs of innovation, their main purpose is to offer a framework that enable the structuration of the reflection on innovation. They achieve the performance of taking a very large environment into account (the whole enterprise, its suppliers and customers). The stage-gate and the chain-link model propose rough paths to innovation detailing different phases. However they do not prescribe the detailed activities that need to be performed to move from one stag to the other.

3.2 Design process engineering

The second group of model comes under of the design engineering area. The Pahl and Beitz model (Pahl and Beitz 1996) is one of the most predominant approach in this regard. It proposes a rationalization of the different steps of a new product development process. To achieve this goal, it offers a functional interpretation of each of these steps. The whole process is separated in several batches in order to enable each of them to be tackled by specialized designers (see Figure 9).

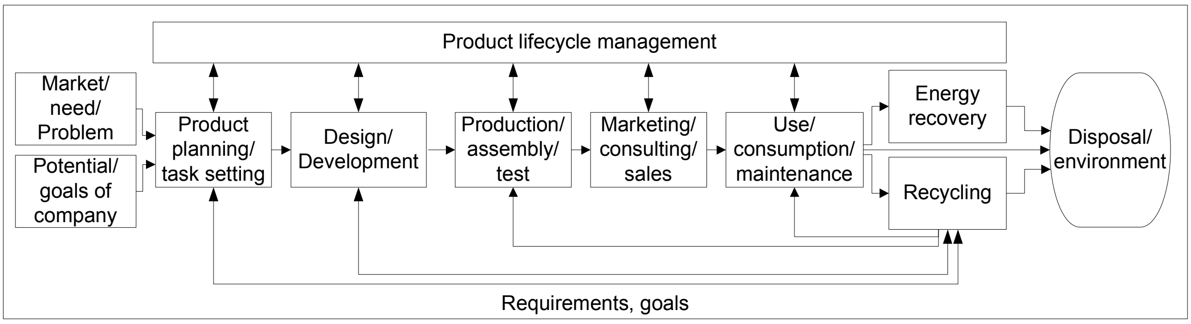

Figure 9. Pahl and Beitz model (Pahl and Beitz 1996)

It is closely related to the Value Analysis and Design to Cost approaches. In its successive evolutions, it has incorporated the Design to X methods inducing a very analytic approach of the design. As a consequence, this method is very useful and adapted to the re-design of complex systems but characterized by a low level of innovation. It is also useful for the integration of on the shelf innovation in a project; a current practice in the automotive industry. However for disruptive innovations, this model presents a few issues. It does not explain the processes, skills, conditions, etc. that are required to express the initial information on the different stakeholders involved in the innovation. Furthermore, even if the model is prescriptive about the nature of the different steps of the innovation process, it lacks information on tools and guidelines needed to perform these steps.

3.3 Emerging theories

3.3.1 CK theory model

The C-K theory (Hatchuel and Weil 2002; Le Masson, Weil et al. 2006) is a design theory that describes the design process as a combination of operations and spaces of concepts and knowledge. Based on an existing knowledge, an initial concept is formalized (disjunction K-C). Using the available knowledge, a partition of the space of concepts is created that offers several alternatives and more detailed concepts (expansion C-C).

Validating the feasibility of these concepts (Validation C-K) this can induce the creation of new knowledge (expansion K-K). The process stops once a concept has reached a sufficient level of definition through successive expansions of the C space and is validated. This model is especially efficient for firms that want to innovate on a regular base and who have a knowledge management system that enables to capitalize the knowledge developed in an innovation to reuse it on another. However, its high level of conceptualization and its requirement in terms of human and financial resources makes it difficult to implement in SMEs.

3.3.2 Radical Innovation Design

Radical Innovation Design is an approach that advises to consider the design process as an investigation process (Yannou, Jankovic et al. 2011). Depending on the project it is applied on, it can include specific steps and tools. Its main objectives are the constitution of multi-disciplinary teams. The management of these teams is based on the creation of concept proofs and value proofs. This methodology is without doubts very close to the questions we raise in our work, for example regarding the means that can be used to create relevant information for decision-making. However, it does not tackle the aspect of strategic decision-making during the whole innovation process.

3.4 Synthesis

The models presented in this chapter have significant differences. They do not have the same purpose or the perimeter of action (see Table 2). Despite these differences, they all underline the importance of identifying the customer needs in steps prior to the development process, even if these are not translated into technical terms or requirements.

Regarding their usage in our case study, we consider that these models usually assume that the company disposes of the organization and resources required to accomplish the complete product definition, manufacturing and commercial distribution. This assumption can be an important limitation in some cases, due to the nature and design practices of some types companies in a particular industry or to the nature and novelty of an innovation for example.

Furthermore, they all fail to tackle a key issue: the enterprise choices about the principal characteristics of the product or service innovations and about the value chain offering the possibility of its industrialization. In a complex environment constituted of numerous stakeholders with contradictory expectations, the definition of these characteristics is very complex to establish and key for the success of a project.

As a conclusion, we can say that these aspects make that these models are not sufficient to tackle disruptive technological innovations projects in a SME which is not structured for the management of these types of innovation projects. In a context were the key issue is to ensure the access to the right market-related or technology-related knowledge, none of the models explicitly propose solution to fulfill this goal.

Type of Model	Purpose	Prelim requirements	Limitations
Black-box	Describes the relationships between inputs and outputs	Information on the innovation	Analysis of past events
Stage-Gate	Validate the quality of the output of the activity constituting an innovation process	Definition of the activities of the innovation process Definition of success criteria for each activities	Works for an existing innovation process
Pahl and Beitz	Describes the different steps of a rationalized innovation process	Knowledge and know-how	Lacks information on how to complete the different steps described,
Chain-linked	Describes the exchanges between development process, knowledge and research activities during the innovation process	Knowledge and know-how	Mostly descriptive No details on the different steps of the development process
CK	Conceptual model represents generic innovation processes. Can help optimize an organization for innovation	Trained resources, Knowledge Management support system, Knowledge and know-how	Not adapted to small structures because of the amount of resources used

Table 2. Our analysis of the different types of innovation process model considered

However, as we have said, the existing models present numerous aspects that enable a better comprehension of the relations between several activities related to innovation (chain-linked model) or the importance of decision-making in several stage of the innovation process (stage-gate model). Our model is partly built on these aspects.

4 Conclusion

This analysis of the industrial and bibliographic context brings several points to light. In the analyses of the industrial context, we found that the main problematic for disruptive innovation project management is to ensure an access to key knowledge in the context of the SMEs. The nature of this knowledge is multiple. It can be related to the market or the stakeholders of the innovation, it can also be related to one or several non-mature technologies used in the innovation.

On the other hand, in all the models we presented, the specific situation of disruptive technological innovation is at best only partly treated. With the issue of knowledge access we identified, the question of strategic decision-making is essential and however not much treated. In cases such as go or no-go of the project, selection of a technical solution or choice of a business model, a model could be very helpful for SMEs. The interdependency that exists between the technical, economical and strategic implications of these decisions is neither highlighted nor treated. Criteria that should be taken into account in a good strategic decision-making are multiple. With the uncertainty characterizing a disruptive innovation project, the robustness of their evaluation is questionable, and so would be a mathematical aggregation designed to facilitate the selection of the best alternative.

As a consequence, instead of focusing on the organization of the innovation process itself that can be managed as a general project we choose to focus on the issue of the robustness of the process that leads to critical decisions. Identifying and presenting to decision-makers the right knowledge is indeed necessary in order to ensure a good decision-making process. This is especially relevant in the specific context of SMEs, characterized by a relative restriction in term of human and financial resources. For a specific industrial environment (SMEs developing disruptive technological innovations), we have identified a lack in today's literature that we ambition to cover with our work.

The analysis of the industrial context also led to the identification of the fact that the main decisions of a disruptive technological innovation project present the most critical steps of these projects. This led to the following conclusion: c*ontrolling the critical decisions of a disruptive technological innovation project is a sensible way for a SME to manage the innovation development process.*

In the next chapter, we further develop our problematic. We define our research question and formulate hypotheses.

II. Problematic & proposition

1 Problematic

As we have seen in the previous part, a SME developing a disruptive technological innovation does not have at its disposal an operational standard innovation process to follow. Furthermore, it does not have the necessary knowledge (product and market) and sometimes resources that would enable it to operate the classical design models offered in the literature. Based on these premises, we formulate the following research question:

Formulation of the problematic: *Given the fact that SMEs are not able to follow classical innovations processes models, what are the main aspects that should be the focus of disruptive technological innovation projects.*

In this chapter, we present the construction of our problematic. Our course of action is double. Our first purpose is to investigate deeper this problematic thanks to a literature analysis. Based on this investigation, we formulate our research question. Once this task is completed, our second purpose is an investigation of possible solutions. This leads us to the identification of the hypotheses on which our model is built. These hypotheses propose a possible solution for our research question (Blessing and Chakrabarti 2009).

In the first step of our approach (see Figure 10), we begin with the investigation of what constitute the performance of innovation. We establish that the purpose of innovation is value creation. This value creation can take multiple forms and serve interest of multiple stakeholders. We then focus on the factor that makes this value creation uncertain: the risks present in the innovation project. We identify several types of risks and tools that allow the managing of these risks. Based on this twofold analysis, we reach a reformulation of our research question.

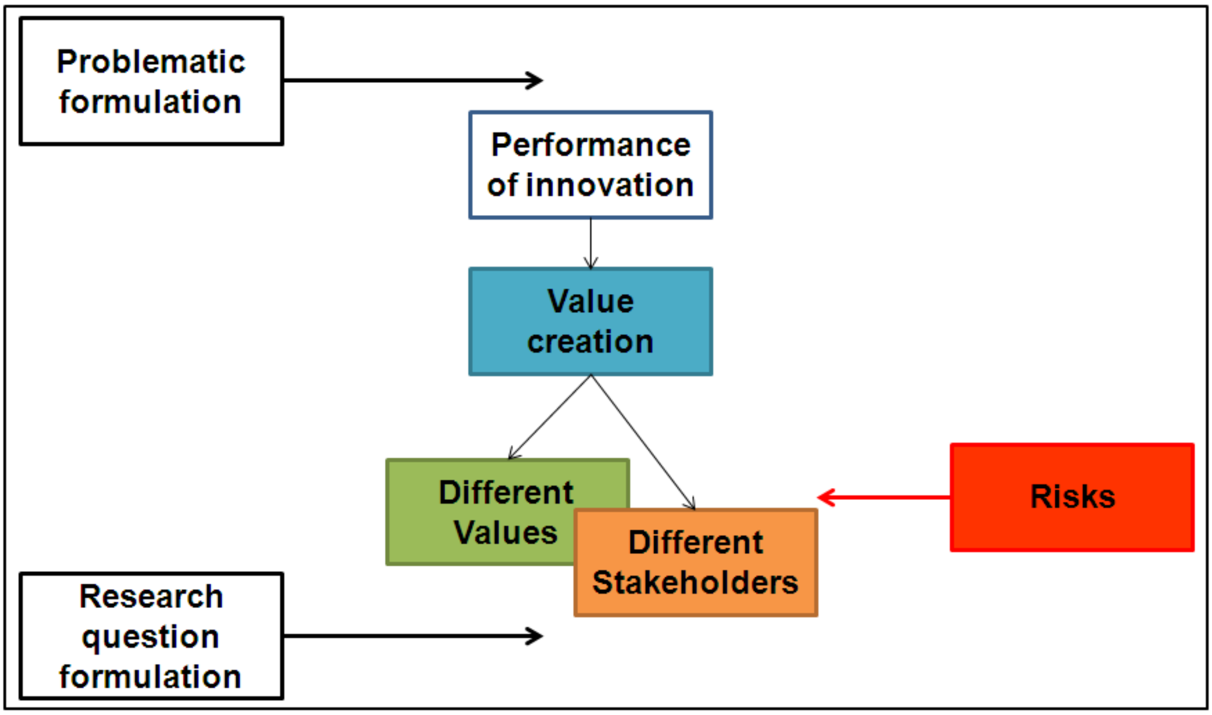

Figure 10. Problematic construction: first step

In a second step, we study several methods and tools widely used in the industry to manage value creation. We show their limitations for our problematic. We then drive a deeper focus on the decision-making process identified as key in disruptive technological innovation projects. We identify several theories in this field and select an approach. Finally, we select a decision-making model that could, once adapted to our situation, help us to provide a model for the control of critical decisions in disruptive technological innovation projects. We conclude by the reformulation our second hypotheses (see Figure 11).

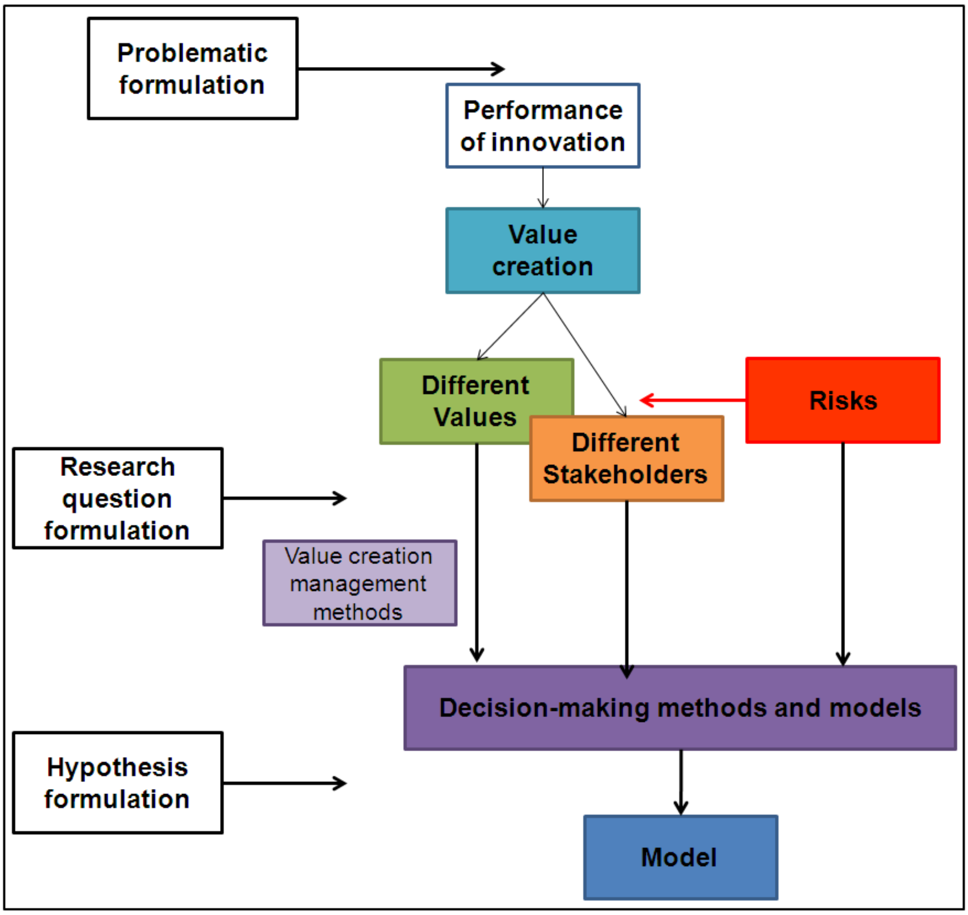

Figure 11. Problematic construction

2 Performance of innovation for enterprises

A good management of any structure consists in piloting this structure in order to reach a maximum level of quality and quantity in its outcome. The performance of a project is a measure of how a project accomplishes its goals. So, in order to assess the performance of an innovation project, one must analysis the purpose of this innovation. In the next part, we focus on this aspect and study the purpose of innovation from a general point of view.

2.1 Value creation

According to Van Horne (Van Horne, Frayret et al. 2006), the purpose of innovation is value creation. He defines innovation as "*the use of innovative knowledge so as to create effective value for the stakeholders of the industry*". This notion of value creation is inseparable from innovation.

2.1.1 Value creation for the firm developing the innovation

The most obvious beneficiary of this value creation is the firm developing the innovation. Schumpeter presents it as one of the main causes of economic activity and growth (Schumpeter 1939). In his work about the stage-gate system, Cooper (Cooper 1990) describes innovation as "*the strategic weapon*" for a company to win the "*product war*" and shows that the innovativeness of a company is "*the single strongest predictor of investment value*". Hitt (Hitt, Ireland et al. 2000) in his work on technological knowledge management emphasizes that innovations produce core competencies and sustained competitive advantage for a firm. For authors in the field of resource-based view, the innovative capability is a key to its competitiveness since it enables it to offer valuable, rare, inimitable and differentiated products to the market (Conner 1991).

2.1.2 Sharing the value creation

Innovation can be decisive for companies. However, limiting the benefits of the innovation to the creation of value in the enterprise that launch it is very restrictive. In addition to this gain for the company, other stakeholders can benefit from innovation. The value created can be important enough to be shared between several actors. Jacobides (Jacobides, Knudsen et al. 2006) even suggest that creating value through innovation should be seen as the prime objective, the way this value is shared (protection of the innovation, cession of licenses, etc.) comes in second. Studying the benefits of innovation also include studying all its different beneficiaries.

2.2 Multiple value creations

Obviously, creation of economic value is key in an innovation development: for Garcia and Calantone (Garcia and Calantone 2002), "*an innovation differs from an invention in that it provides economic value*". However, the value created can take multiple other forms: services, social, environmental… In the next paragraph, we define precisely what kinds of value we are discussing.

2.2.1 Different types of values

Companies have for a long time adopted a Taylorian view on value. In a context where demand was greater than supply, their only focus was the economic value created by their products and costs and profits the only measured indicators. Then, with the increase of supply in the seventies, firms make more efforts to diversify from competitors. Products are no longer evaluated solely on their prices. The significance of the term value broadens and begin to include product quality and on time delivery (Lebas 1995).

The meaning of value evolves then with the economy. It is no longer linked only to the product but to the whole organization. The earlier definitions shift to include the factors increasing the capacity of organizations to create value. With the introduction of the concept of knowledge economy, knowledge, know-how and innovation are also considered as value (Le Masson, Weil et al. 2006).

Furthermore, since the arrival of outsourcing, Supply Chains are getting more and more complex. As a consequence, the quality of communication between actors begins to be also taken into account as a potential value for companies (Eckert and Clarkson 2004).

Finally, the increasing focus put on the notion of sustainable development since the 1990s made firms understand the capacity they have to create or destroy societal and environmental values. Image given by the enterprise to the market becomes another type of value for organizations. Nowadays, no company can pass on notions such as social, environmental and ethical performances and employee satisfaction because of the impact it could have on their image among customers (Déjean and Gond 2003).

The focus adopted to identify the values that an organization can create has evolved from a mono-criterion view to a multi-criteria view (see Figure 12). From a monolithic financial view, it diversified into various viewpoints including quality, ethics, etc.(Schindler 2009).

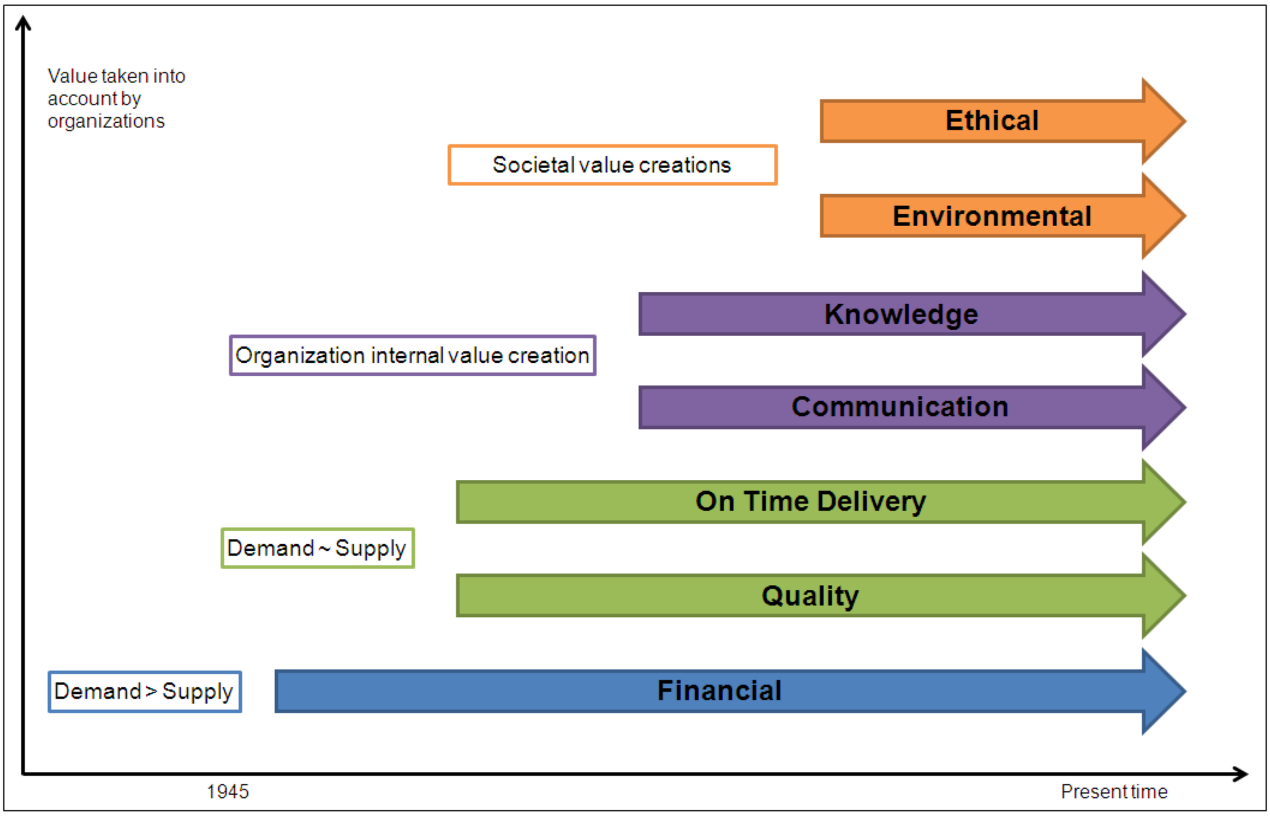

Figure 12. Our representation of thedifferent types of value creations taken into account through time

2.2.2 Value creation in innovation

As we can see, value creation can take multiple forms. And innovation has the potential to create all these kinds of values for various stakeholders. According to Boly (Boly 2008) the value of an innovation is the result of eight different aspects:

- Economic: margins generated,
- Strategic: competitive advantage earned,
- Intellectual: new knowledge and know-how developed,
- Commercial: market share gained,
- Functional: better performance achieved,
- Degree of novelty: innovativeness of a product increased for the customer,
- Reputation: image of the firm strengthened,
- Hedonistic: pleasure and welfare of the main actors of the innovation development increased.

It is to be noted that the enterprise is not the only beneficiary of these value creations; it beneficiates to numerous stakeholders too. In a project management context, it is essential to take into account these key stakeholders in order to ensure its success (Wateridge 1998; Fowler and Walsh 1999; Achterkamp and Vos 2008). The following parts focus on the definition of these stakeholders.

2.3 Multiple stakeholders

2.3.1 Stakeholder theory

The notion of stakeholder is close to notion of value and the concept of multiple value creations. The name "stakeholder" is an adaptation of the term shareholder. It extends the perimeter of the parties concerned in organization. The financial value is not anymore the only one taken into account and as a consequence the focus is not put only on people having financial interest in an organization. In this regard it can be said that the stakeholder theory has been developed in reaction to the conventional input-view of organizations

(Donaldson and Preston 1995) (see Figure 13). It includes other groups that may have interest in the firm such as political groups and associations. Furthermore, enterprises begin to understand that relations are bi-lateral and that having the support of stakeholder requires a balanced relation.

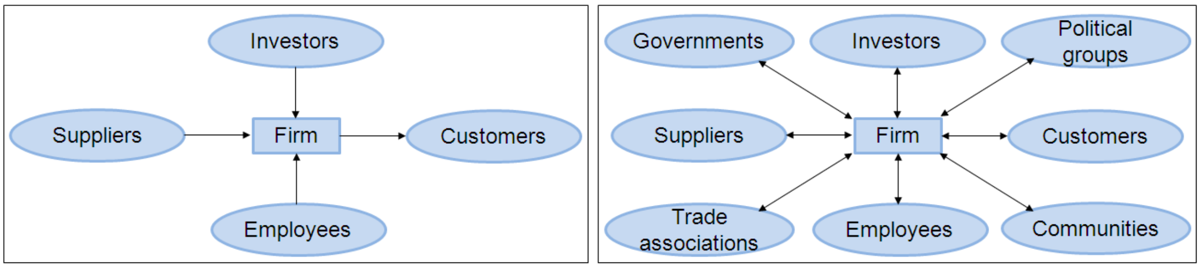

Figure 13. Input-output and stakeholders models

More precisely, all groups that can influence the enterprise (meaning they have the power and the opportunity to do so) or can be influenced by it should be taken into account in the development of a new offer. For Freeman, *“. . .a stakeholder in an organisation is any group or individual who can affect or is affected by the achievement of the organisation’s objectives.”(Freeman 1984)* Stakeholders can thus represent a potential help or danger for the firm. It thus very important to be sure to include one’s study all the relevant stakeholders.

2.3.2 Stakeholders typologies

Several classifications of the stakeholders of an organization exist. These classifications have several purposes. They can be used for the determination of the stakeholder of a project; using typologies increases the chances of being exhaustive since all categories are looked into. Furthermore, these typologies enable a better understanding of the relations between each stakeholder.

The first very classic decomposition is the one proposed by Carol and Näsi that differentiates internal and external stakeholders (Carroll and Näsi 1997). Another distinction can be made between primary stakeholders, linked to the organization through a contract like employees, suppliers, and customers and secondary stakeholders like competitors, local authorities and lobbying groups (Carroll and Buchholtz 2000). This approach is further developed by Lepineux (Lépineux 2003) who enumerates five categories of stakeholders: shareholders, internal stakeholders (employees and trade union), operational associates (customers, suppliers, subcontractors, banks, insurance companies) social community (authorities, associations, NGOs) and natural environment.

Another typology by Mitchell et Al. (Mitchell, Agle et al. 1997) classify the stakeholders based on the salience level, described as *“the degree to which managers give priority to competing stakeholder claims”*(Achterkamp and Vos 2008). Three criteria are used to define this level: the power, the legitimacy and the urgency. Based on these criteria a seven stage model is described (see Figure 14).

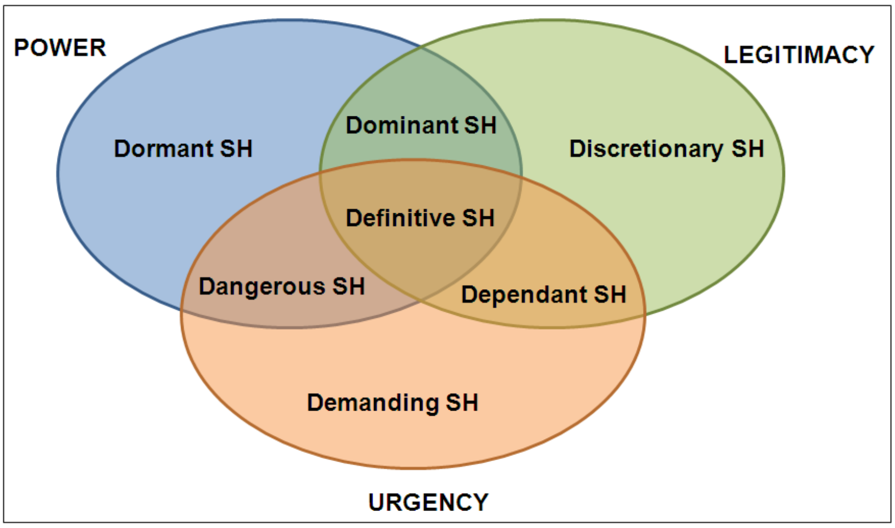

Figure 14. **Salience stakeholder model (Mitchell, Agle et al. 1997)**

Another study characterizes the relations between industrial partners and can be used in order to classify industrial stakeholders (Maranzana, Gartiser et al. 2011). The last typology we present here is the work of Schindler (Schindler 2009). This typology has deduced from an analysis of different management theories such as Dynamic Capabilities, Balanced ScoreCards, Value Analysis, Value Management and Total Quality Management. Several stakeholders are identified that give an exhaustive and systemic view of the stakeholder of an enterprise (see Figure 15).

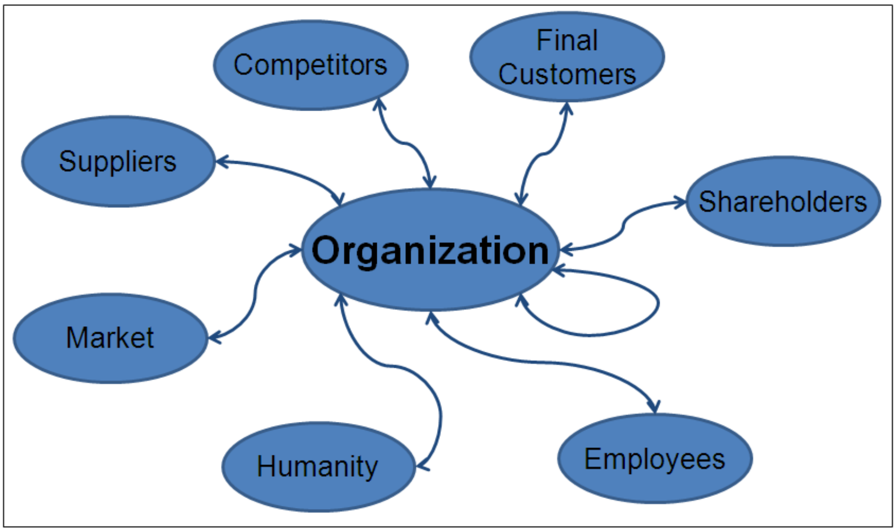

Figure 15. **Schindler's stakeholders of an organization (Schindler 2009)**

With these different and complementary classifications of stakeholders, we now have categories that can help us identify the stakeholders of any organization. They can also be used to categorize their relation with the organization. In our experimentations, we will use this last typology as a starting point in the identification of the stakeholders of the innovation. The previous one can be used as a help to operate a selection in the stakeholders in order to focus on the most important ones.

2.4 Conclusion

From this analysis, we can see that studying the performance of an innovation project comes to studying the value created by this project. Furthermore, since a wide variety of values can be created this value creation must also be adapted to the expectations of the stakeholders of the project. The creation of value is extremely complex and goes well beyond the sole creation of financial value for the company. These values are very different and, as a consequence, cannot be aggregated. Furthermore, the stakeholders that beneficiate from these value creations are also very complex. They are very different and they can have antagonistic goals. Devising the right cocktail of value creation to satisfy the most important stakeholders of the project is an important challenge in an innovation project.

However, this value created by innovation is submitted to risk and could result in some events in value destruction. Uncertainty is ubiquitous in innovation. In disruptive technological innovations, this uncertainty lies in two main aspects: technical performances of tools and methods on which the development of the innovation is based and market answer to the innovation (Assielou 2008). These subjects are developed in the next part.

3 Risk threatening value creation in innovation projects

The innovation process is full of uncertainty. Disruptive innovations as we have seen imply a discontinuity for the enterprise. A consequence of the novelty (market, technology) is the lack of information existent to treat the problems encountered and to predict with certitude the outcome of the project. The successful development of the innovative product is not certain and neither is the market response to the innovation. With this uncertainty come risks threatening the potential of value created by the innovation. These risks need to be taken into account in the innovation process, evaluated and managed. According to Van de ven (Van de Ven 1986), one of the key question in understanding the innovation process is *"What kinds of problems will most likely be encountered as the innovation process unfolds ad what responses are appropriate for managing these problems"*. Since risk management is an important part of innovation development, in this part, we draw a deeper focus on the notion of risk and the way it can impact innovations.

3.1 Overview of the concept of risk

3.1.1 Definition

According to the project management dictionary, project risks can be defined as: *"The possibility for a project not to unfold according to planned due dates, costs, and specifications; these deviation regarding the previsions being considered as non-acceptable. Risk is the outcome of a hazard, an uncertainty or an unpredicted event"*(AFITEP 1996). In this definition, we can see a distinction in the causes of risks. A further investigation in these causes shows us that:

- Hazards are defined as *"non standard events in the project development, causing missed deadlines, additional expenses or loss of earnings" (AFITEP 1996).*
- Uncertainty is *"a gap of information that can cause risks but also opportunities for the project" (AFITEP 1996).*
- *"Unpredicted events are events that had to been thought of"*(AFITEP 1996).

3.1.2 Standard risk model

From these definitions, we can establish that risks are characterized by two main pieces of information: their likelihood and impact. The standard risk model (Smith and Merritt 2002) is based on these premises. It proposes a representation where a <u>risk event</u>, characterized by a <u>probability</u> of occurrence, has a possible <u>impact</u> on the project, also characterized by a <u>probability</u> of occurrence. The result of this impact is a loss for the <u>project</u> (see Figure 16).

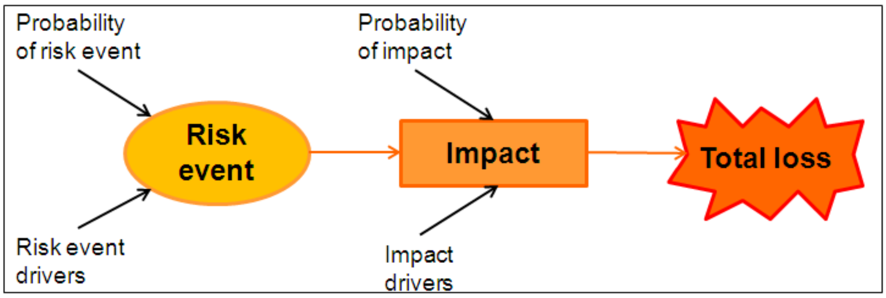

Figure 16. Standard risk model (Gericke, Klimentew et al. 2009)

Based on this model, it is possible to identify the most important risks through the calculation of the probability of occurrence of the risk (multiplication of the probability of the event and the impact) and its impact. The gravity of the risk can be attenuated by acting on the risk event and impact drivers.

These definitions underline the importance of performing a complete and thorough identification of all the events that could harm the project. Because of their possible multiple impacts (cost quality, on time delivery), a risk management policy must be implanted in projects.

3.2 Risk management models

In order to increase the performance of innovation projects, it is crucial to adopt an effective risk-management strategy since *"without proper risk assessment and risk management, projects can easily run out of control, consume significant additional resources, greatly inflate project costs and may lead to failure"*(Mu, Peng et al. 2009). Besides the obvious benefit of controlling the project risks, a risk management process is good for the project as it is a transversal activity that increase collaboration between the members of project team (Aubry 2005).

The risk management process in project is continuous and iterative (Nieto-Bru 2009); several risk management models exist that detail this process. According to risk management standards (Project Mangement Institute 2004), risk management consists in the treatment of the project uncertainties through a structured four steps generic approach: risk identification, analysis, treatment and control. Courtot (Courtot 1998) proposes a five-stage model: risk identification, risk evaluation, risk mastery, risk control and capitalization. In a review of the different models of risk management, Vargas-Hernández (Vargas-Hernández 2010) identifies the four phases found in all risk management systems: identifying, analyzing, solving and monitoring & learning. As we can see, there is a consensus on the main phases of risk management process in a project. The following develops the five phases of Courtot's model (see Figure 17), one of the most complete ones.

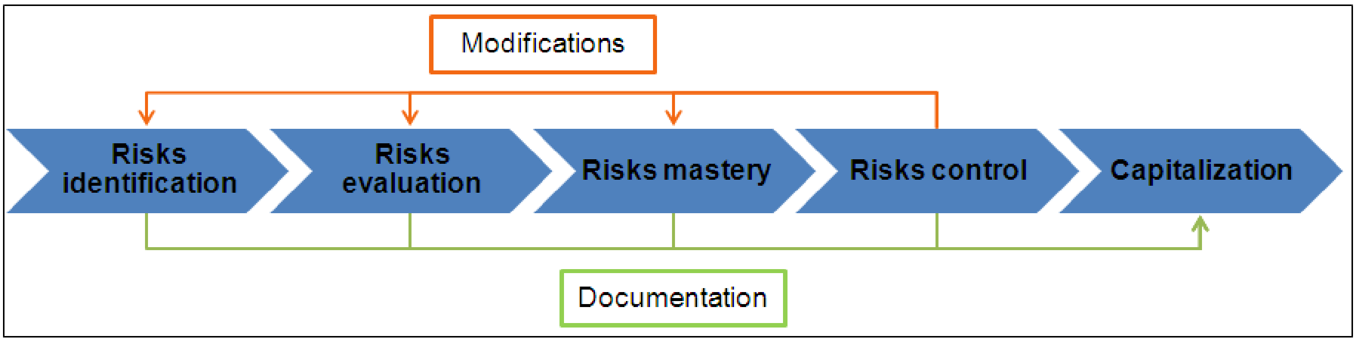

Figure 17. Main steps of the risk management process (Courtot 1998)

3.2.1 Risk identification

This first phase of the risk management process is very important. The objective of this phase is to identify all risks and to study their causes and potential consequences. This analysis is usually qualitative and needs to be performed thoroughly at the beginning of the project. Any risks that are not identified will not be managed and can thus have significant impact on the project. However, once this identification has been performed, it is still necessary to adapt it in an iterative way throughout the project. Changes in the environment can induce new risks or modify those that had already been identified. A regular update can help solve this problem.

3.2.2 Risks evaluation

Once the risks have been identified, the next phase consist precising the characteristics of these risks. In this phase, a more quantitative approach is adopted. If possible, the probability of apparition is assessed for each risk. Sometimes, however, due to lack of information such quantification is not possible. In such cases, scales can be used to quantify this probability.

The probability of apparition of the risks being known, the second step in this evaluation phase is the assessment of their gravity and their classification on an adapted scale. This leads to the calculation of the criticity of each risk by multiplying their probability of apparition and their gravity. Based on this criterion a classification of the risks can be obtained. It enables risk managers to make a distinction between acceptable and non-acceptable risks and to focus on preventive actions for the most important risks. The probability of not detecting the risk can also be used as a criterion for risk classification.

3.2.3 Risk mastery

Based on the classification obtained in the previous phase, a strategy is implemented in order to master these risks. Risk managers can engage in actions aiming to diminish the probabilities of occurrence or the impacts of the most significant risks. Four main strategies exist in this regard:

- Avoidance: project characteristics are modified in order to decrease the probability of occurrence and impact of the identified risk or to avoid it altogether.
- Transfer: the potential impact of the risks is decreased by externalizing it toward other stakeholders (customer, supplier, insurance company).
- Reduction: actions are taken to control the evolution of the risk. A response strategy is prepared should the risk occur.
- Acceptance: the risk is known and no actions are taken to counteract it.

The selection of a strategy for a given risks depends highly on the criticity of the risk, but also on the culture of the enterprise, the importance of the project, etc. Because of the relative scarcity of dedicated decision-making tools, the selection of an adapted strategy for each risk is usually left to the risk manager's expertise (Gericke, Klimentew et al. 2009).

3.2.4 Risk control

At this stage, risk manager have implemented a strategy that enabled the risks to be mastered. However, as we have said, the environment of the project is prone to change and can rend the measures taken obsolete. It is thus necessary to follow the evolutions of the risks during the project. New risks can appear or change. Their criticity then may need to be re-assessed. This in turn also influences the preventive actions that had been taken for the risk mastery and that need to be updated.

3.2.5 Capitalization

Information disposal is fundamental for a good risk management process. Knowledge about the risks encountered during the project can be very useful for the future. The documentation of the risk management process in a project enables the knowledge gained to be reused in other future projects if similar situations are encountered. This decreases the chance to forget some possible events in risk identification. It may reduce the uncertainty related to the risk identified and thus enable a more precise assessment of their criticity. It can help risk managers chose a more adapted risk mastery strategy that can yield better results. Finally, it can increase the efficiency of the response to hazards encountered during the project.

3.3 Risk in innovation projects

The uncertainty associated with the novelties present in innovation projects make them especially vulnerable to risks. According to Ferney-Walch and Romon (Ferney-Walch and Romon 2006), the more radical is the innovation, the higher is the incertitude regarding technical and economic feasibility. The lack of experience can be the cause of major lapses in the risks identification phase that can have dramatic impact. The risks evaluation phase can also suffer; the lack of information related to the risks identified can cause errors or significant imprecision in the assessment of the probability and the impact of risks. The risks mastery phase may also be less efficient. With no applicable lessons learns from similar projects, risks mastery solutions may be harder to devise and their outcome less sure. These problems specifically due to innovation are summed-up in Table 3.

Risk management phases	**Types of intelligence deficit**	**Impact**
Risks identification	Deficit of experience	Significant risks non-identified
Risks evaluation	Deficit of knowledge	Misevaluation of risks probability and impact
Risks mastery	Deficit of experience Deficit of knowledge	Less efficient response in the devising of risks mastery solutions

Table 3. Specific problems of risks management in innovation projects identified in this analysis

These risks are the inevitable counterparts of the possible value creation expected from innovations. Kastensson notes that for innovation managers "*…risk taking is a success factor to achieve innovation…*" (Kastensson, Larsson et al. 2010). As a consequence researchers have focused on specific risks that can be encountered in innovation projects. According to several authors(Cooper and Kleinschmidt 1995; Keizer, Halman et al. 2002; Mu, Peng et al. 2009; Wang, Lin et al. 2010), the two most important domains in which risks appear for innovation projects are: technology and market. In the following part, we focus on the study of technological and marketing risks. We develop the specificities of these risks for the first three steps of the risk management model, the last to steps being less impacted by the innovative characteristics of projects.

3.4 Marketing risks

3.4.1 Source of marketing risks

A major source of risk in innovation development is related to the uncertainty in the market. This uncertainty can be the cause to a poor adequation between the innovation and its market environment, which can have a dire impact on the success of the innovation. In a context of technological innovation, this uncertainty is described by Moriarty as "*the ambiguity about the type and extent of customer needs that can be satisfied by the technology*". This uncertainty can be sourced to several factors (Mu, Peng et al. 2009) summed-up in Figure 18:

- Customer perceived risk: customers can have fear regarding the reliability of a new product and doubts toward its performance and ability to satisfy their needs.
- Customers needs misevaluation: discrepancy to customers' needs has been spotted as one the main cause of innovation failure (Redmond 1995). This can be caused by bad evaluation of the customer expectation or by the evolution of his needs, that can change quickly and in unexpected fashion during the innovation development.
- Inaccurate prediction of economic parameters: according to Ogawa and Piller (Ogawa and Piller 2006), forecasting potential sales volume of new products is becoming more difficult than ever. Furthermore, accurately assessing the cost of production and the prices of radically new products can prove to be also very difficult. Significant errors on those parameters can prove to be very risky for the profitability of the business model.

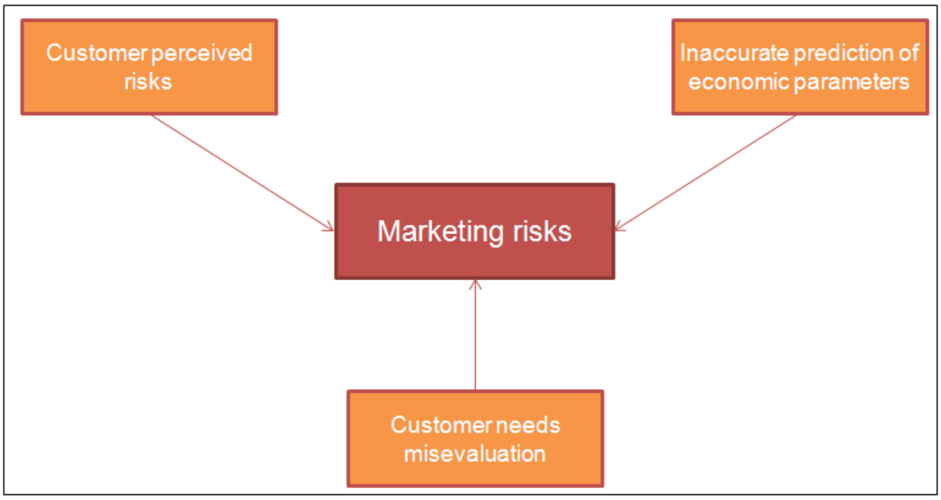

Figure 18. Marketing risks origin (Mu, Peng et al. 2009)

3.4.2 Marketing risks treatment

Determinist approaches cannot be used to identify marketing risk. Firms usually rely on brainstorming, experts analysis or on the use of check-list and risk typologies (Verdoux 2006). Specific approaches however exist to treat the different kinds of marketing risks we presented. Ogawa and Piller (Ogawa and Piller 2006)propose to strengthen the trust relation in making commitments to customers in order to decrease the risks perceived. This in return makes the customer commit to the firm and reduce the risk of rejection.

Regarding risks of customers' needs misevaluation, the only to handle this risk is to engage actions that increase knowledge of the customer. Having "*reliable knowledge about customer preferences is among the most important areas of information necessary for product development*"(Holt 1988). This can be done in involving the customer into the innovation design process (Ogawa and Piller 2006) or through inquiries or interviews.

Lastly, in order to moderate the impact of errors in the prediction regarding the product performance or the market response, scenario planning can be used in order to better assess the impact of uncertain phenomenon (O'Connor and Veryzer 2001; Miller and Waller 2003; Driouchi, Leseure et al. 2009).

3.5 Technological risks

3.5.1 Source of technological risks

Technological risks include all risks related to uncertainties caused by the technologies key for the innovation. This covers technologies needed to manufacture the innovation or key to ensure that the innovative product has real functional capacity. Technological risks arise from two major sources (see Figure 19): lack of predictability or of capability (Du, Love et al. 2007).

- Predictability is the capacity that a firm has to assess correctly the performances of a technology key for an innovation. These performances are both absolute and relative. The technology must enable the innovation to perform its functions correctly (absolute point of view). In addition, the technology must be competitive enough so that the innovation will not become rapidly obsolete due to other technologies (relative point of view).
- Capability is the ability for a firm to have a sufficient mastery of a technology to ensure quality throughout all the phases of an innovation's life (design, manufacturing, marketing, use, after sales).

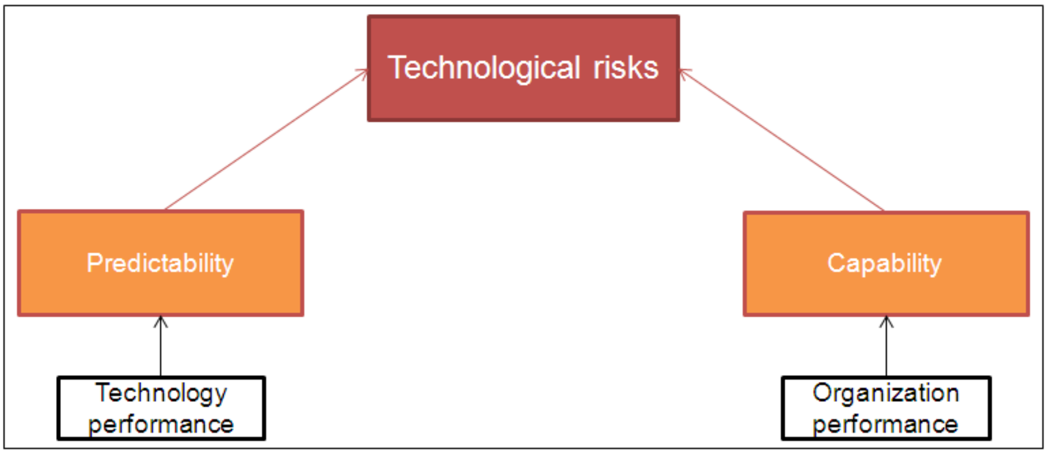

Figure 19. **Technological risks origin (Du, Love et al. 2007)**

3.5.2 Technological risks treatment

The classical methods used for technological risk identification and analysis in the aeronautics and defense sector are mainly deterministic. They aim to identify and evaluate of all hazards and failure scenarios. This can be done through the combined use of Functional Analysis with Failure Modes Effects and Criticality Analysis (FMECA) and Fault Trees or Reliability Block Diagrams for quantification purposes(Gonzalez 2000; Epstein 2002).

Another standard approach in this sector is the use of Technology Readiness Levels (TRL)(Mankins 1995), a concept introduced by the NASA to evaluate the maturity of the technologies used on their programs. Technologies with a low readiness level are those that present the most uncertainties. By crossing this TRL analysis, with an evaluation of the consequences of a system failure (see Table 4), a basic risk matrix can be obtain (Young 2007). This approach however has its faults one being that it encourages the use of mature technologies that could quickly be rendered obsolete by new ones.

TRL (Level of maturity)	Probability of failure	Consequence of failure (Impact)		
		Negligible (Low)	Significant (Medium)	Catastrophic (High)
1-3	High	Significant risks	Top risks	Top risks
4-6	Medium	Underlying risks	Significant risks	Top risks
7-9	Low	Underlying risks	Underlying risks	Significant risks

Table 4. **TRL use in risk evaluation (Young 2007)**

The general approach to technological risks treatment consists in engaging in actions to decrease the uncertainty of the technologies involved (Browning, Deyst et al. 2002). This can be done in setting up test plans in order to gain knowledge and experience on the technology or in setting up development plans to increase the technology TRL(Young 2007). Another possibility is to externally acquire technological knowledge that can be a valuable mean to reduce technological risk (Mu, Peng et al. 2009).

3.6 Conclusion

We have seen in the first part of this chapter that the purpose of innovation is value creation. However, disruptive innovations are characterized by novelty and a discontinuity regarding the enterprise's practices. Because of this, risks are ubiquitous in innovation projects. The creation of multiple values for several stakeholders is not certain but is threatened by the risks related to the innovation. These risks in the specific case of disruptive technological innovation are mostly related to the technology and the market.

The presence of risks should not turn companies from innovation as it is crucial for them. According to Midler, in product development, the biggest risk is to choose not to take any(Midler 1998). However, in order to ensure the success of the project, these risks need to be identified and managed. Risk management is crucial for the outcome of a project, especially in disruptive technological innovations where the marketing and technological risks are particularly important. Furthermore, the presence of some critical risks can endanger the project. As a consequence, we can see that in addition to the sole value creations, the risks associated to these value creations must also be taken into account in the management of the project.

4 Findings of the first step of the problematic

4.1 Requirements of methods aiming to manage value creation in disruptive technological innovation projects

In conclusion of this overview, we can say that value can take many different forms and concerns various stakeholders. If exploited correctly, this complexity is a richness that goes beyond simple economic value. With the acknowledgment of all these possible complex value creations, organizations must adapt in order to be able to benefits from this richness. These values concern various internal or external stakeholders. All this makes the evaluation, the co-construction and the choice of a relevant values created by an innovation for its stakeholders very difficult. Conceiving a value chain able to create the optimal value aggregate for its stakeholders requires ability to:

- Identify the nature and the importance of each dimension of the value created in order to ensure that the launching of the innovation sustains the strategy of the firm.
- Identify the activities and resources that can generate this value.
- Select the best combination of these resources and activities in order to maximize the value creation for the stakeholders and satisfy the objectives of the firm.

In addition to the inherent complexity of value creation, a focus must also be put on the risks associated to these value creations. Due to the novelty disruptive characteristic of the innovation, lacks of experience, knowledge and information make the creation of value subject to risks.

Based on this analysis, we can precise several requirements that a method aimed at managing value creation in a disruptive technological innovation project must respect:

Requirement1: A successful management model for disruptive technological innovation projects in SMEs should be able to identify the nature and the importance of each dimension of value creation.

Requirement2: This management model should be able to identify as well the activities and resources responsible for these value creations.

Requirement3: In addition to the identification of value creations, this management model should enable the identification of the risks associated to these value creations.

Requirement4: This management model should facilitate the selection of the best combination of these resources and activities in order to maximize the value creation for the stakeholders and satisfy the objectives of the firm while controlling the risks associated.

4.2 Dimensions of the innovation process impacted by these requirements

If we analyse these requirements, we can see that they cover a very large scope (see Table 5). Some of them are related to products: in our case the innovative product being developed. Others, however, point out at organizations: in our case the extended value chain of the innovation during all its lifecycle. This extended value chain is not limited to the enterprise; it includes here the organization developing the innovation (the design chain) and the organization that allows its commercialization (the supply chain) which can involve internal and external stakeholders.

Furthermore, these requirements imply a necessary focus on the different management levels:

- The strategic level where the main orientations of the enterprise are decided a level where few information and experience is available.
- The tactical level where actions are devise to sustain the strategy of the enterprise at a lower scale. Information and experience exist at this level but are not directly available.
- The operational level that includes all aspects of the day-to-day life of an organization, routine decisions where information and experience is at hand.

	Operational	**Tactical**	**Strategic**	**Innovative product**	**Organization**
Requirement1: identification of the nature and the importance of each dimension of value creation.			X	X	
Requirement2: identification of the activities and resources that can generate this value.	X	X			X
Requirement3: identification of the risks associated to these value creations.	X	X		X	X
Requirement4: selection of the best combination of these resources and activities in order to maximize the value creation for the stakeholders and satisfy the objectives of the firm while controlling the risks associated.			X		X

Table 5. Positioning of the requirements of our method

4.3 Research question formulation

The purpose of this first step of our problematic construction was to gain a better understanding of the main issues that our research question tackles. We have seen the importance of the questions of value creation and risk management in innovation. Based on this analysis, we can formulate our research question in a precise manner.

Research question: *How can a SME manage a technological disruptive innovation project while taking into account a complex value creation, a point of view enclosing the whole value chain and the product it supports, this with a scope ranging from operational to strategic management levels.*

As we can see, according to our analysis, beyond any methodology to manage a process of radical innovation, two dimensions must undoubtedly be treated: value creation and risks. In the second step of our problematic development, we focus on the potential solutions at hand to reach a successful management of innovation project. Our first step is the investigation of the tools and methods dedicated to value creation management existing in the enterprises and the literature.

Since the innovation process is a succession of decisions, in order to build the best alternative for the enterprise, managing a disruptive innovation process involves controlling decision-making throughout this process. These decisions are multiple: innovation or not, selection of the appropriate resources in terms of process/know-how and of their level of integration, etc. This control must be assured by the effective comparison of the value created by different technical, economical and administrative scenarios and the natures and importance of the risks taken by the enterprise in these different scenarios. In the next paragraph we treat about this question of the values created by the innovation, their nature, quantification and relative importance.

5 Managing value creation:

Achieving the identification of the good mix of value creation is a complex task. However, lots of tools and methods have been developed through the years whose functions are to help organizations to manage value creation. Each of these tools and methods has a specific domain of application and focus. There are two fields of application:

- product-centred methods that tackle the issue of the management of the value created by a product,
- organization-centred methods whose object is the management of the organization that creates the value.

One can also make a distinction between two main types of approaches: strategy-focused and tactic-focused methods. Strategy-focused methods concentrate upon long term value creation. They usually try to advise their users on which are the best organizations or products to propose in order to ensure the development of the firm. Tactic-focused methods on the other hand try to help an existing organization to increase their value creation on an existing product. In the next pages we are going to present an overview of the main methods used in industrial engineering.

5.1 Strategic-focused methods:

Business plan is a tool used before the creation of a new business (be it profitable or non-profitable). It is the formalization of the business goals (including expected sales volumes and ROI), the plan devised to reach them, the investments required and the resource that are going to be used in the plan. The creation of a business plan reduces the risk that the organization fails to reach its targets. (Pic, Richard et al. 2007)

The SWOT analysis is a method used to show the Strength, Weaknesses (both determined through an internal appraisal), Opportunities and Threat (both determined through an external appraisal) of an organization in its environment and according to its objectives. Identifying these factors enables the organization to determine a strategy exploiting the positive ones to counter negative ones. This can be done through TOWS matrices that stimulate the elaboration of strategy built on a pair of factor: one internal (strength and weakness), one external (opportunities and threats). (Dyson 2004)

Another method more centred on the analysis of the environment is the Porter five forces analysis (Porter 1979). This method underlines the existence of the five main forces that impact the performance of an industry: threat of new entrants, threat of substitute products, suppliers 'bargaining power, customers' bargaining power, competitive rivalry in the industry. Analysing these factors enable a company to adapt its strategy on its environment and thus to increase its chances of success.

Unlike the former one, the Resource Based View is an approach that focuses on an internal vision of an organization. It analyses the resources that present interesting value creation potentials. Barney (Barney 1991) gives four attributes that can help assessing this potential:

- Valuability (capacity a resource has to exploit a strength or neutralize a weakness)
- Rarity (characteristic necessary to procure a competitive advantage to the firm)
- Imperfect imitability (characteristic necessary to ensure the advantage is sustainable)
- Difficult substitutability (no equivalent resources can be found by competitors)
-

This approach has been extended afterwards to knowledge (Knowledge Based View) as being an immaterial resource with particular characteristics (transmission, stocking…)

The stakeholder theory can also be considered as a distinct value creation management approach, based also on an analysis of the environment of the organization. As we have seen, the objective is to take into account different kinds of values, especially non-economical and to study value creations for different kinds of stakeholders.

All these tools help organizations to conduct a reflection on their strategy and to adopt one that fits the specificities of the external or internal environment. But in order to implement this strategy throughout the organization, the results of this reflection must be traduced into inputs for tools having a more tactical focus. In the next paragraph we focus on more tactic-focused tools and methods.

5.2 Tactic-focused methods:

Total Quality Maintenance (TQM) is a method developed mostly by J.M. Juran, P.B. Crosby and W.E. Deming whose objective is to help a company to ensure customer satisfaction through a good process management that induces continuous improvement. The Deming management method issues guidelines consisting of "14 points" that has to be respected in order to escape 7 deadly "*diseases*" and several "*obstacles*"(Anderson, Rungtusanatham et al. 1994; Rungtusanatham, Forza et al. 2005)

The Statistical Process Control (SPC) method was developed by W. A. Shewhart in the 1920s but it's in the 1940s that it began to be more commonly used due to the influence of W.E. Deming. This method is used to control the variation of certain attributes of a product during the execution of a process.

6Sigma is another method that aims to improve the quality of a product. Schroeder (Schroeder, Linderman et al. 2008) define 6 sigma *"…an organized, parallel-meso structure to reduce variation in organizational processes by using improvement specialists, a structured method, and performance metrics with the aim of achieving strategic objectives*".

Lean Manufacturing is a method which aims to help a production system to decrease the level of input resources necessary to deliver a product of a given value to a customer. This is achieved through an optimisation of the flows of material and information and an elimination of waste in the process (Lewis 2000).

The Deming Wheel (PDCA) is a methodology that can be used to implement new processes or increase existing process. It is based on the repetition of four steps: process planning, process execution, theoretical and real results comparison and eventually analysis of the differences and process update to solve the problems picked out.

Balanced Score Cards(BSC) is another tool, relatively new compared to the previous ones since it appeared during the 1990s. Its purpose is to reconcile the strategic and the operational visions in the global measure of the performance of a firm. It concentrates on four perspectives (Michalska 2005):

- The financial perspective: vision the shareholders have of the company.
- The customer perspective: vision the customers have of the company.
- The perspective of internal processes: processes that need to be improved in order to be more competitive.
- The development and learning perspective.

For each perspective targets that need to be reached in order to fulfill the company's strategy are defined. The fulfillment of these targets, measured through indicators, represents the position of the firm in relation to its strategic targets.

Activity Based Costing (ABC) is a method primary used to assign overhead cost more precisely, depending on the use a product has of overhead functions. This theory (later extended to Activity Based Management and Activity Based Budgeting) has later been used to help understanding the cost of complexity and diversity of products. With such utilisations, this tool can be considered as strategic-focused. (Sandström and Toivanen 2002).

Value Analysis is a method that aims to optimize the value created by a product. To achieve this optimisation, Value Analysis recommends taking into account the value created by every function of the product during the design phase, these functions being determined through functional analysis. It is then possible to concentrate the effort of the design team on the function that creates value for the end-user.

Along with Porter's value chain (Porter 1986), value analysis is at the root of Value Management. This company management approach was developed during the 1990s. According to European and British standards*, "Value Management integrates the operational managers' efforts with those of higher management [. . .] by concentrating objectively on outcomes which are in line with overall corporate objectives, in preference to local or short-term priorities''*.(CEN 2000) This large approach conciliates several management tools such as TQM.

Value Analysis is also a support to Design to Cost a method that includes a target cost as a design parameter. Adding this approach to Value analysis enables a design team to better arbitrate between the cost of a function and the value it creates. (Burman 1998)

Finally, Concurrent engineering is a method whose focus is in-between strategic and tactic. It advocates cooperation between marketing, engineering, manufacturing in the design phase of a product in order to shorten development time and improve quality (Swink 1998).

All these tools are used by various categories of people: from executive committee to middle management and in different sectors such as financial or technical services. All aim to increase the value generated, which is very beneficial in the case of disruptive innovation. However, some are applied in an operational framework for the management of routine operations (Lean, BSC ...) and cannot be directly used in our context. Others are usable in a project framework and can contribute to the creation of key knowledge for innovation projects. But they only focus on value creation through the organization or the product without concretely relating both dimensions.

5.3 Conclusion

As we have seen there are numerous tools that exist and that can help a company to manage its value creation, be it from a tactic or a strategic point of view. However while facing the development of an innovation; it is necessary to keep both aspects into mind. It is widely accepted in today's literature that the success of an innovation relies partly on the compatibility of this innovation with the strategy of the firm that launch it (Hauser, Tellis et al. 2006; Garcia-Muiña and Navas-Lopez 2007; Boly 2008; Massa and Testa 2008).

However, in order to ensure the quality of the innovation and to shorten its development time it is also key to adopt a tactic-focused approach (Boly, Morel et al. 2000; Tatikonda and Montoya-Weiss 2001).

Another reading of this methods and tools classification is their object of focus. They can be centered on the innovative product or on the organization that develop and produce it (see Figure 20). A product-centered approach seems essential for us since we want to study the value created by the innovation. Yet such an approach is not sufficient; a company dealing with radical innovation may be confronted to important changes in its production system. It is thus essential to be able to study not only the value created by the product but also the organization that enables this value creation.

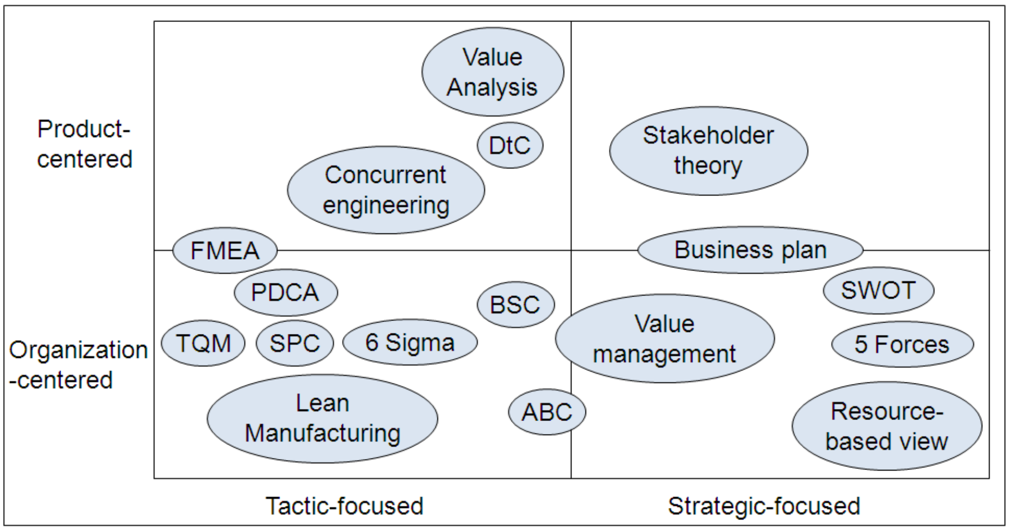

Figure 20. Tactic/strategic and product/organization positioning of value creation management tools

In conclusion, we can state that the tools we described are not sufficient to help us to resolve our problematic. All of them are useful in their own area. They enable the extraction and the synthesis of relevant information at different levels of the innovation project: operational/tactical/strategic and product/organization. They can also help to bring particular problematic to light and offer solutions. However, in an environment that requires access to information at all levels, the use of one of this method, however useful to create or formalize knowledge on one specific aspect (product, organization, tactic, strategic) is not sufficient. Furthermore, no methodology proposes a coherent roadmap of the usage of these method and tools in a way that would cover all levels. The positioning that needs to be adopted in order to satisfy the four requirements that emerged from the investigation of our problematic must include both the operational, tactical and strategic aspects as well as both the product and organizational aspects.

As a result, we must devised a method that does not replace other tools but can serve as a framework for the use of some of them while covering the areas required (operational, tactical, strategic, product and organization) and that aims to facilitate decision-making in the various phase of the innovation development. As we have seen in the first chapter of this work, this could be done through the control of the critical decisions phases. Depending on the type of choice faced, decisions can well have product or organization focuses and, even if critical decisions are of a strategic nature, they use inputs issued of operational and tactical focuses and their implications concern also these levels of management.

6 Decision-making in innovation projects

Design can be seen as an iterative decision-making process. (Wallace and Burgess 1995).This is also true for the innovation process that can be seen as a succession of decisions that need to be taken between several alternatives to fully complete the design of the innovation, its production and marketing. (Herrmann and Schmidt 2002; Eriksson, Johnsson et al. 2008).These decisions are multiple: project team set-up, choice of concepts and technologies, marketing strategy, etc. Thus, a good piloting of disruptive innovation projects comes to guaranteeing that these decisions accomplish the purpose of innovation: ensuring the right value creation for all the stakeholders of the project. In the following paragraphs, we take a look at the bases of the decision-making process. We define the notion of decision and present a first representation of the decision process. Then, we present the different approaches that can be adopted on decision sciences. Finally, we analysis several decision process models and select a model that we adopt in our research.

6.1 Decision overview

6.1.1 Definition

Decision theorists define decision making as the process of making choices among competing courses of actions (Raiffa 1968; von Winterfeldt and Edwards 1986). In an organization, this activity is closely linked with the notion of management. For Simon, Decision-making is synonymous with managing (Simon 1960), thus it cannot be reduced to a choice amongst alternatives. Decision-making consists in identifying and solving the problems encountered by any organization. The purpose of decision in organization can be the solving of a problem or the seizing of an opportunity. However, it is always closely linked with an analysis of an initial state and a final desirable state. For Mintzberg et Al., "*The need for a decision is identified as a difference between information on some actual situation and some expected standards*" (Mintzberg, Raisinghani et al. 1976).

6.1.2 Decision process

The decision process (see Figure 21) can be seen as divergence-convergence process (Gavriloff and Jarrosson 2001). It is initiated by a problem, characterized by a general context. During a first divergence step, information is gathered on the problem at hand and its context. A convergence phase follows that leads to the problem formulation. The next divergence step consists in the research of solutions. The convergence phase following is the selection of a solution amongst the ones that were proposed.

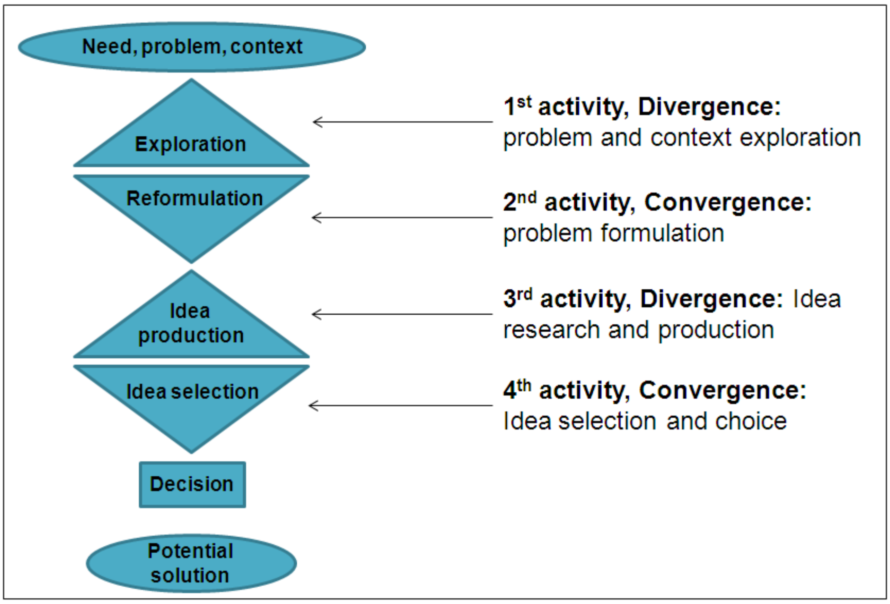

Figure 21. Decision process (Ghomari 2008)

6.1.3 Roles of decisions in organizations

This general process shows that usually, the purpose of a decision is to solve an initial problem. In organizations, however, decisions can have other roles. According to Brunsson (Brunsson 2007), decisions have four main roles in the organizations: choice, mobilization, responsibility allocation and legitimation.

- Choice is the main role of the decision process: the selection of one out of possible alternatives

- Mobilization can be another goal of decision-making. Decisions can also serve as a way to ensure the mobilization of an organization toward a common purpose. The decision process can be a way to ensure commitments from the actors of the organization.
- Decisions can also be used in order to allocate responsibilities. Defining who the decision-makers are is a way to attribute to them some responsibilities.
- Finally, decisions can serve as a way to legitimate an action. The selection of a solution is followed by the implementation of this solution. These actions are rendered legitimate by the decision process that took place.

These four roles of a decision impact the way the decision process is conducted in organizations (Eriksson and Brannemo 2011). Identifying the purpose of the decision is important. It ensures that it is carried out and reaches and outcome in accordance with this initial purpose.

6.2 Types of decisions and decision support

Decisions can be very different from one another and, depending on their characteristics, different types and levels of support can be required. Different factors can be used to classify decisions. According to various authors (Holsapple and B. 1996; Lebraty 2006; Ghomari 2008), classifications can be made based on the level of structuration of the problem addressed by the decision, the management level of the decision and the context of the decision.

6.2.1 Structuration level

Two main distinct levels of structuration can be defined(Simon 1960; Gorry and Morton 1971; Le moigne 1974; Ghomari 2008). The first level, structured decision or programmed decisions, regroups routine and repetitive decisions. They have clearly defined targets. Decision process or standard solution already exists to tackle these decisions.

At the opposite, unstructured decisions or non-programmed decisions do not have ready-made solutions. This can be due to several causes: the novelty of the problem, its complexity or its importance that make it deserve a tailored solution. A third level in between those two is sometimes also defined: semi-structured decisions that require a combination of standard and new approaches.

6.2.2 Management level

The second classification is based on the management level associated to the decision(Ghomari 2008). Three levels are identified in the literature. The first level, regulation or operational decisions regroups all decision that deals with the day-to-day life of the company. The second, tactical decisions regroups decisions linked to the adaptation of the enterprise to its environment. Classic process cannot be used; however, new ones can be devised based on the existing know-how. Finally, strategic decisions have the most impact on the enterprise. They require the creation of new knowledge and intelligence.

6.2.3 Decision support systems

As a conclusion, we can see through these typologies that all decisions are not equivalent. There is a consensus among main authors to underline the fact, where some decisions are relatively easy to make, other are much more difficult. The absence of experience regarding the decision, the stakes associated to its outcome make decision support systems essential in some cases.

The purpose of decision support systems is to assist decision-makers that face challenging decisions. It can be defined as *"…computer technology solutions that can be used to support complex decision making and problem solving."* (Shim, Warkentin et al. 2002) or simply as "*…any system that makes some contribution to* *decision making."*(Sprague 1980). They focus on less well structured, underspecified problems. Their expected to:

- help decision-makers to more efficiently solve their problems
- help rationalize decisions,
- help to make good use of decision-makers knowledge through interactive support (Carlsson and Turban 2002).

Besides these main characteristics there is a wide variety of decision support systems which focus on different aspects of the decision and which can be very different depending on their positioning regarding decision sciences. In the next paragraph, we describe the main research currents that study decisions.

6.3 Different decision theories

Decision sciences are a very rich interdisciplinary scientific field. Different approaches exist to treat this particular activity. Three main current are usually identified (Lebraty 2006). The first one, the operational research current or prescriptive approach, studies rational decision making. Its aim is to devise methods that would enable an ideal fully informed decider to identify the optimal selection. The second, the cognitive or comportementalist approach aims to describe the cognitive process in human-decision making, assuming that by nature the reasons behind decisions taken are not fully rational. The third approach, naturalistic decision-making or decision in natural settings underlines the importance of the decision context. It proposes to take into account the constraints of the environment and focuses on the recognition by the decision-maker of decision situation. Since the choice of a decision support approach deeply depends on the type of theory it follows, we further detail these three currents in the following section in order to have a complete understanding of the type of current that is the most adapted to our situation.

6.3.1 Operational research or prescriptive approach

The prescriptive approach is based on a two steps model. The first step consists in identifying all the possible solutions to a given problem. When this step has been completed, in the second step, all the alternatives are evaluated and the optimal solution according to a previously determined criterion is selected. The application of this approach has many limitations in real life, since uncertainty and subjectivity of decision-makers make the modeling and the calculation of an optimal solution very difficult. In order to better fit the expectations of the industry and the complexity of these challenges, this approach has been enhanced in two ways. First, the use of probabilities statistical analyses has been included. This enables a relative uncertainty regarding the data of the decision to be taken into account in the prescriptive approach. Secondly, the preferences of decision-makers can also be taken into account with the use of subjective utility function as a criterion.

6.3.2 Cognitive approaches

The second theory focuses on the way decisions are taken. The development of cognitive sciences and psychology caused the prescriptive approach to be challenged. The rationality of the decision-makers and the access he has to key information necessary to the decision is put at doubt in two different ways. First, he has a limited access to the relevant piece of information; secondly, his cognitive process is characterized by biases.

Cognitive biases are described as deviation from rational decision making. They represent *"a predictable propensity of human decision makers towards irrationality in some important circumstances"* (Arnott 1998). Numerous taxonomies of these biases exist. As many as thirty seven different biases have been identified. These biases can be classified in different categories (see Figure 22):

- Memory biases regroup all biases related to the storage and the recall of information. They constitute the lowest level of cognitive bias.
- Statistical biases are defined by the tendencies human have to process information without taking into account the principle of statistical and probability theories (for example ignoring the size of a sample or mistaking random events for characteristics of a process).
- Confidence biases represent all excessive confidence decision-makers can have, due to different reasons in the inputs on which the decision may be based.
- Adjustment biases are all the biases that are based on the importance for the decision-makers of the state of the situation before the decision as base of solution.
- Presentation biases represent all biases related to the perception of information in every phase of the decision process.
- Situation biases represent the impact of the some aspects (complexity, uncertainty, urgency, etc.) on the decision-maker.

Based on this typology, we have represented the areas of decision-making process that are impacted by these biases.

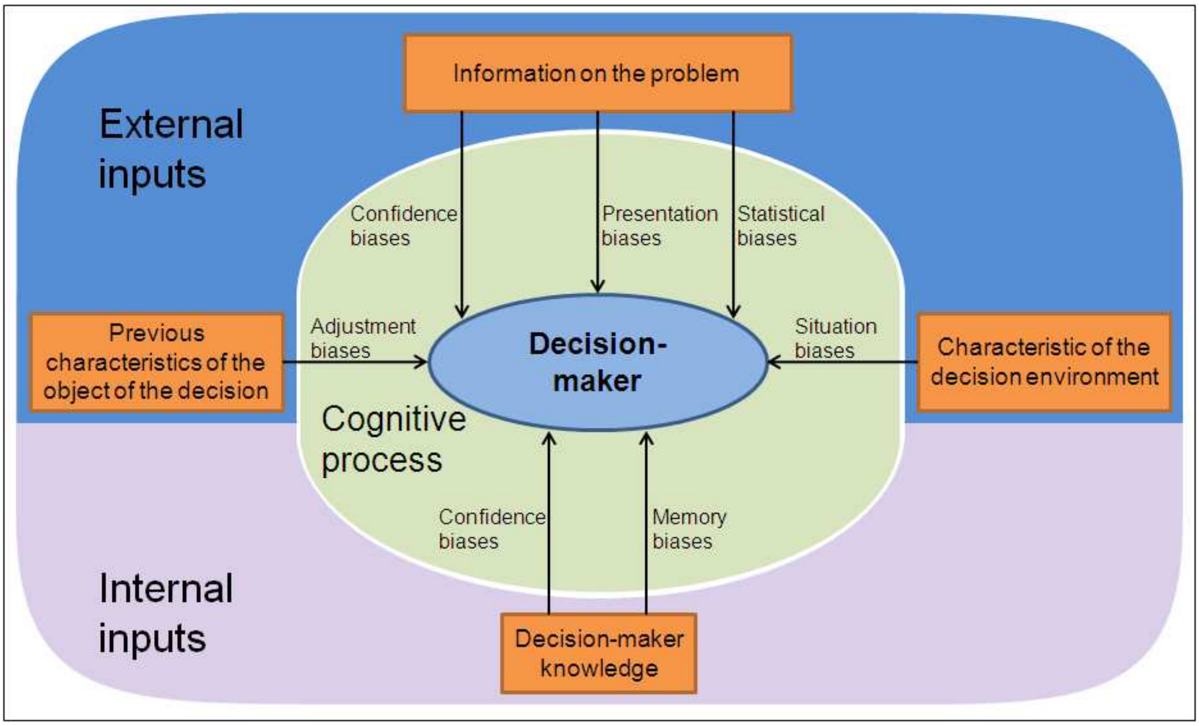

Figure 22. An analysis of Arnott decision biases (Arnott 1998) and their area of impact

The second characteristic of these approaches is the greater focus is put on the inner decision-making process. The notion of heuristic is introduced to explain this process. Heuristics enable decision-makers to tackle complex problems where a systematic study of every possible solution is not possible (Pomerol and Adam 2006). This approach cannot claim to systematically find “the optimal solution”. However, it is an efficient way to reach acceptable solutions.

6.3.3 Naturalistic decision making

The last approach is the naturalist decision-making. This current draws on the previous one but differentiates itself by a specific focus on the decision situation. This approach has a very specific frame. It treats only decisions characterized by (Klein and Klinger 1991):

- Decision-makers with a high level of expertise in the specific subject of the decision

- Dynamic and continually changing conditions
- Real-time reactions to these changes
- A very short amount of time allocated to the decision that force decision-makers to act fast
- Ill-defined tasks
- Significant personal consequences for mistakes

The purpose of this approach is more to understand the specific aspects that hinder decisions in these specific contexts than to prescribe a model to follow. Since this method postulates expert decision-makers, the focus of this approach is not the choice of an alternative (main concern of novice decision makers) but the situation assessment process.

	Purpose	**Environment**	**Type of problem**
Prescriptive approach	Find the optimal solution	Environment enabling an exact modeling	Structured
Cognitive approach	Find an acceptable solution	Complex environment	Unstructured
Naturalistic	Limit the impact of the situation stresses	Urgency and stress in the decision situation	Unstructured

Table 6. Specificities of the different decision theories

6.4 Selection of an approach

As we have seen, these three approaches have their differences (see Table 6), regarding their focus and the environment they study. They are adapted to specific types of problems. Lebraty (Lebraty 2006) proposes a matching between decision categories and decision theories based on three criteria:

- The type of decision: this includes the hierarchical level at which the decision is taken and the importance of its consequences.
- The decisional context: it can be static or in evolution, this factor takes into account the time pressure that can apply on decision-makers and the link between context and decision.
- The type of knowledge required for the decision: explicit or tacit.

Based on this decomposition, he analyses that operational decision and decision using explicit knowledge are more adapted to the operational approach, where strategic decisions and decisions using tacit knowledge are more adapted to the cognitive approach. As for the very specific field of naturalistic decision making, it is best adapted when the environment of the decision adds a significant amount of stress to decision-makers (see Figure 23).

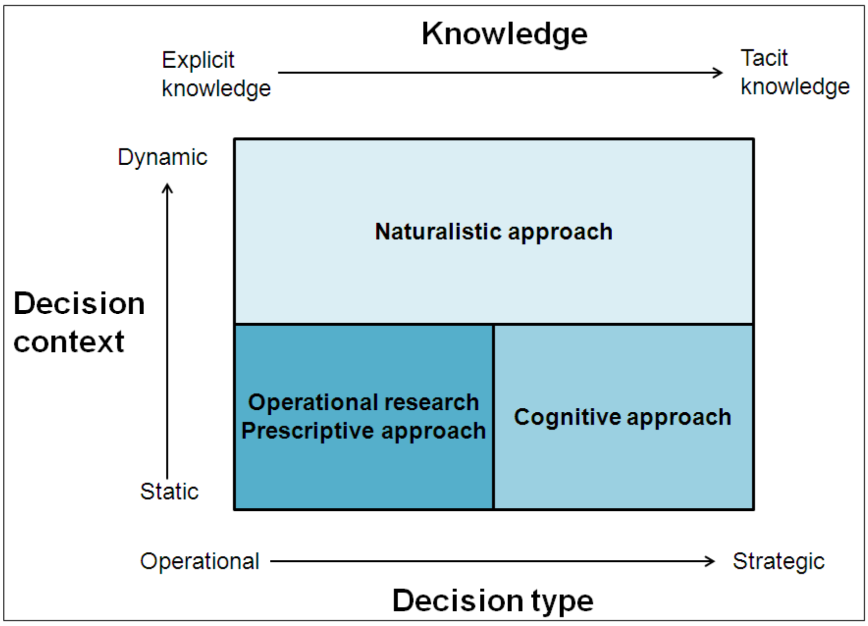

Figure 23. Link between decision type and decision theory after (Lebraty 2006)

Our specific context is limited to the main decisions in disruptive technological innovation projects. In these projects, decisions can be very difficult to make. However, we can postulate that these decisions are made at a high hierarchical level and have an important impact. The type of knowledge involved can be explicit but have a significant tacit component. The influence of the decision situation/moment is not very important in our case. There is no real time-stress or urgency associated. As a consequence of this analysis, we define that the cognitive decision making approach is the more appropriate approach for our scope of study.

6.5 Decision model and decision support tools

6.5.1 Bounded rationality decision models

As we have seen before, one of the most important challenges of decisions in disruptive technological innovations is the limited amount of information to which decision-makers have access. Because of this and of the cognitive limitations of decision-makers, prescriptive models of decision would be of very little help. The cognitive approach however takes into account this limited rationality of decision-makers, described as "bounded rationality" by Simon (Simon 1955; Simon 1956).

Simon (Simon 1960) proposes a three phases model: Intelligence, Design and Choice (IDC, see Figure 24). The Intelligence phase regroups the identification of the problem and the gathering and ordering of data. In the Design phase, solutions are devised based on the data gathered in the previous phase. In the Choice phase one of the solutions is selected. This selection is based on criteria that enable a comparison between the alternatives of each solution.

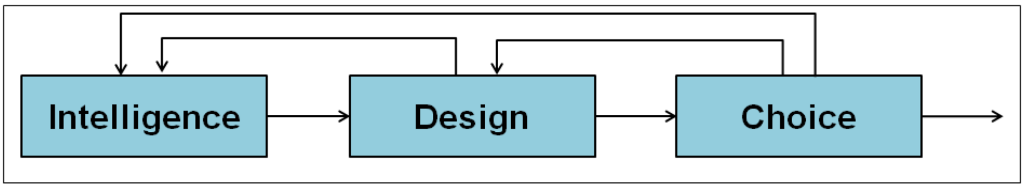

Figure 24. Simon's IDC model(Simon 1960)

This model has later be further detailed by Mintzberg et Al. (Mintzberg, Raisinghani et al. 1976), describing these phases in terms of seven central routines (see Table 7). The intelligence phase is divided in two routines. The first one, decision recognition regroups the activities required to highlight a problem or an opportunity from the large amount of data (vastly verbal) at which decision-makers are exposed. The second routine, diagnosis consists in the clarification of the problem. The decision is not formulated. Existing information channels must be investigated and new ones opened in order to clarify and define the issues.

Two other routines constitute the design phase (called development phase by Mintzberg et Al.), search and design. The search routine consists in looking for ready-made solutions inside or outside the organization. In the design routine, custom-made solution are developed or existing solutions are adapted to the problem at hand.

Finally, the selection step can be divided on three distinct routines: screening, evaluation-choice and authorization. The first one, screening is used when the alternatives created in the development phase are too numerous to be each evaluated. The appropriateness of all the alternatives is assessed in order to remove all the ones that would surely not fit the situation. The purpose of this routine is to reach a number of applicable solutions small enough to enable their evaluation. In the second routine, evaluation-choice, the remaining alternatives are evaluated and one is selected. Finally, an authorization routine can be found when the decision-maker does not have the authority to launch the actions that result from the decision.

Simon's phases	Mintzberg et Al. 's routines	Content of the routines
Investigation	Recognition	Decision identification
	Diagnosis	Decision clarification
Design	Search	Search for ready-made solution
	Design	Adaptation of existing solution or design of new ones
Choice	Screen	Elimination of inappropriate solutions
	Evaluation-choice	Evaluation of each alternative and selection of one of them
	Authorization	Activation of the solution by the hierarchy

Table 7. Simon(Simon 1960) and Mintzberg et Al. (Mintzberg, Raisinghani et al. 1976) bounded rationality decision models

6.5.2 Other decision models

- Other approaches exist to help rationalize decision-making but usually, they can all be fitted in the eight steps decision making process described by Baker and Al (Baker, Bridges et al. 2002).
- Step 1. Define the problem: the purpose of this step is to have a clear vision of the problem.
- Step 2. Determine requirements that any acceptable solution must meet.
- Step 3. Establish goals whose achievement through decision would be desirable. These goals can be contradictory.
- Step 4. Identify alternatives that could solve the initial problem.
- Step 5. Define criterions that are objective measures of every goals achievement.
- Step 6. Select a Decision-Making Tool that would enable an evaluation of the identified alternatives.
- Step 7. Evaluate alternatives against criterions using the selected decision-making tool.
- Step 8. Validate solutions against problem statement.

This deterministic approach postulates that decisions can be fully rationalized. The sixth and seventh steps offer tools whose purposes are to rank the different alternatives in order to identify the best one. These can be very simple when the alternatives are characterized by a unique quantitative criterion or much more complicated when multiple quantitative and qualitative criterions are involved.

Several methods exist that take multiple criterions into account. Some are very simple like the Pros and Cons Analysis other are more complex. We can cite for example Kepner-Tregoe Decision Analysis (K-T), Analytic Hierarchy Process (AHP), Multi-Attribute Utility Theory Analysis (MAUT), Cost Benefit Analysis (CBA), etc. All these techniques however aim to provide the deciders with a single piece of information: the unique best solution, defined through the evaluation of the different criterions, taking into account the fact that some are more important than others to the deciders.

6.5.3 Choice of a model

As we can see, there is a consensus in the literature on the main phases of a rationalized decision process, even when the boundaries of this rationality are taken into account. As a consequence, we chose to adopt Baker's model which is more precise and more adapted to the industrial context. Yet one aspect does not fit our context.

A specificity of this model is the use of decision making tools. In our case, we established that the selection between the alternatives must be based on the comparison of the multiple values created by the alternatives and on the risks threatening this creation of values. Decision-making tools exist to tackle multi-criterion problems such as those cited in the last paragraph. However, their purpose is a classification of solution that would enable the identification of the best one.

In the industrial context that we defined, on the contrary, we think this should not be done. Due to the number of criterions, the process used to weight each criterion is very opaque, could lead to errors and so would result in a final ranking of the alternatives for an innovation project that would seem artificial and hard to trust for the deciders. Furthermore, the implementation and use of most multi-criterions decision tools require important time and knowledgeable resources that small firms usually cannot have, especially in the first steps of the development of the innovation where few resources are available to assess the feasibility of the innovation.. However providing an evaluation of the alternatives according to several criterions is still useful as it would give deciders more information on the decision to make (Nutt 2007).

What we propose is a model composed of five steps (see Figure 25). The first step is the identification of a critical decision. It follows the Mintzberg's first routine, recognition. The second step, problem setting, regroups Baker's activities: "define the problem" and "determine the requirements". The third step is the alternatives identification. It is followed by the selection of the criterions (value creations) that would be relevant for the final decision. The fifth step "value creation and risks assessment" is the evaluation of the alternatives. Finally, in a last step called "value creations and risks representation", the key aspects of the decision are presented to decision-makers.

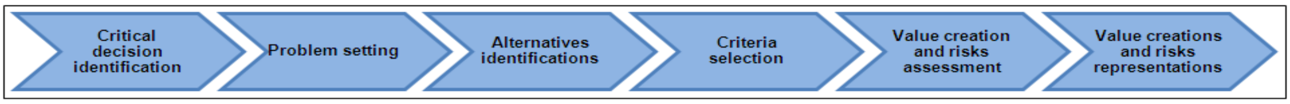

Figure 25. Model main phases

This approach we propose does not fully rationalize the decision process. The decider is left with several alternatives. However, he has access to the information we deemed the more useful in decision-making: the value and risks characterizing each and every alternatives. This enables him to maintain some autonomy in his decision, thus increasing his level of involvement in its implementation. This is corroborated by a study comparing the response of decision-makers to advices that shows that information on the alternatives is better appreciated than a prescriptive recommendation for a particular solution(Dalal and Bonaccio 2010).

In the case of critical decisions in an innovation project, there are usually multiple individuals implicated in the process. The member of the project team, the project steering committee, the decision-making process is a group process. The characteristics of such critical decisions are detailed in the next part.

6.6 Group decision-making

According to Kim et Al. *"The increasing complexity of the socio-economic environment makes it less and less possible for single decision maker to consider all relevant aspects of a problem"*(Kim, Choi et al. 1999).This socio-economic complexity can be found in all critical decisions of innovation projects. As a consequence, decision-making is becoming more and more a group process. This enable the decision-making process to beneficiate from the expertise of all its members (Bonner, Baumann et al. 2002).

6.6.1 Perimeter of action

There is a wide consensus in the literature pointing that using group for decisions usually lead to better results than individual decisions (Bonner, Baumann et al. 2002). The members of the group increase the available knowledge and know-how. These valuable resources can be inputted in all the aspects of the decisions. As shown by the definition of a decision-making group by DeSanctis et Al.: "*A decision-making group can be defined as two or more people who are jointly responsible for detecting a problem, generating possible solutions, evaluating potential solutions or formulating strategies for implementing solutions*" (DeSanctis and Gallupe 1987).

6.6.2 Different types of group decisions

If the group can act throughout the all decision-making process, its power is not always the same. Two main modes of group decision exist: unilateral decisions and negotiated or bargained decision. In unilateral decisions, the group is prized for its knowledge that ensures a better quality of the decision-making process (Herrera, Martinez et al. 2005). However, the final decision is the responsibility of a single individual.

At the opposite, in bargained decisions, the members of the group usually are at the same hierarchical level. A consensus needs to be reached in the decision which can make the decision process very complex when a large number of people are concerned. In this case, politics and power play a very important role (Ghomari 2008).

6.6.3 Group decision-making process

The group can act in two different manners (Ghomari 2008). The decision-making can be distributed or cooperative. In a distributed decision process, each members of the group have their own area of expertise. They all have a partial representation of the problem that need to be solved. The members of the groups are selected for their expertise in the domains concerned. In cooperative decisions, the expertise of the members are also sought, however, it is the creative capacity of the group that are prized. Usually, the distributed decision process is associated to a unilateral decision where the cooperative process is associated to bargained decisions, but this is not necessary.

6.7 Analysis

We make here the choice of focusing on the critical decision-making process of innovations projects to control its good development. Regarding the requirements we identified, we can see that such a choice is coherent (see Table 8). This is due to the fact that decisions are of different natures. Thus controlling the critical decision-making process enable to treat situations related to the innovative product as well as situation related to the organization. From the management level point of view, operational, tactical and strategic levels are all concerned by the critical decision-making process. The main problem treated is usually of tactic or strategic nature, however, the decision is based on data coming from all management levels and its outcome also affects all levels.

Requirements	Decision-making approach
Identification of the nature and the importance of each dimension of value creation.	Performed during the “problem setting” phase
Identification of the activities and resources that can generate this value	Performed during the “problem setting” phase
Identification of the risks associated to these value creations.	Performed during the “value creation and risks assessment” phase
Selection of the best combination of these resources and activities in order to maximize the value creation for the stakeholders and satisfy the objectives of the firm while controlling the risks associated.	Performed by decision-makers based on the information presented

Table 8. Requirements addressed by the decision-making approach

7 Conclusion

We begin this chapter with the formulation of a problematic. This problematic is deeper analyzed in a first step. It led to the formulation of several requirements regarding the importance of taking into account value creations and risks in a model of disruptive technological innovation project management. Our analysis shows that this model should tackle problems of operational, tactical and strategic nature. On the second hand, it should be able to treat problems related to the innovative product or the organization supporting its lifecycle. A study of methods and tools used for the management of value creation revealed that such tools do not have a wide enough perimeter to treat disruptive technological innovations. We then studied decision-making models that we suggested could serve as a framework for project management, also possibly enabling the integration of the value creation management methods and tools previously cited. This analysis shows the perimeter of these models fits the expectation required for a project management model. This leads us to formulate the following hypothesis:

Hypothesis: In a context of disruptive technological innovation projects in SMEs, presenting information about the diverse value creations (different types of value and different stakeholders) and the risks related to these value creations is benefic for the decision-making process. The decision-making process is improved due to the fact that:

- Brings people from different trades at the decision table.
- More relevant information is available for decision-makers.
- The decision-making process is formalized and at least partly rationalized.

Based on this hypothesis, we devised a model that we tested in two experimentations. The following chapter details the different aspects of this model.

III. Model presentation

Our model aims to pilot disruptive technological innovation projects through the control of their critical decisions. For each critical decision, we propose six phases. The first phase consists in identifying critical decision. The next ones are based on the first phases of the rationalized decision-making process as presented by Baker. We modified Baker's rationalized decision-making process in order to better fit our problematic. First, we grouped the first three steps (problem definition, requirement determination, goals establishment) in a problem setting phase that enables the identification of the possible value creations for the decision. The alternatives are identified in the next step. Finally, a selection is made in the possible value creations previously identified in order to reach a number of criteria small enough to be easily treated. These criteria (value creations) are assessed in the next step as well as the risks that are associated. Finally, this information is presented to the decision-makers to help them in the decision.

1 Different levels of systems considered in our model

Our first step is going to precise the different actors of the method we propose in this chapter. This method focuses on a specific environment: innovation projects in a small industrial structure. In this environment several systems can be defined. A first level of definition is establishing the enterprise and the different external stakeholders of the innovation as distinct systems. A second level singles out the innovation project system inside the enterprise. In this innovation project system, we can define a project steering committee that is going to be in charge of the main strategic decisions in the project. Finally, at a third level, we can identify two deeply related systems: the innovation development and the innovation development decision support (see Figure 26). The latter includes all resources and activities related to the treatment of support to critical decisions of the innovation project. The innovation development system is going to be managed by the project manager and the decision support system by a decision support officer.

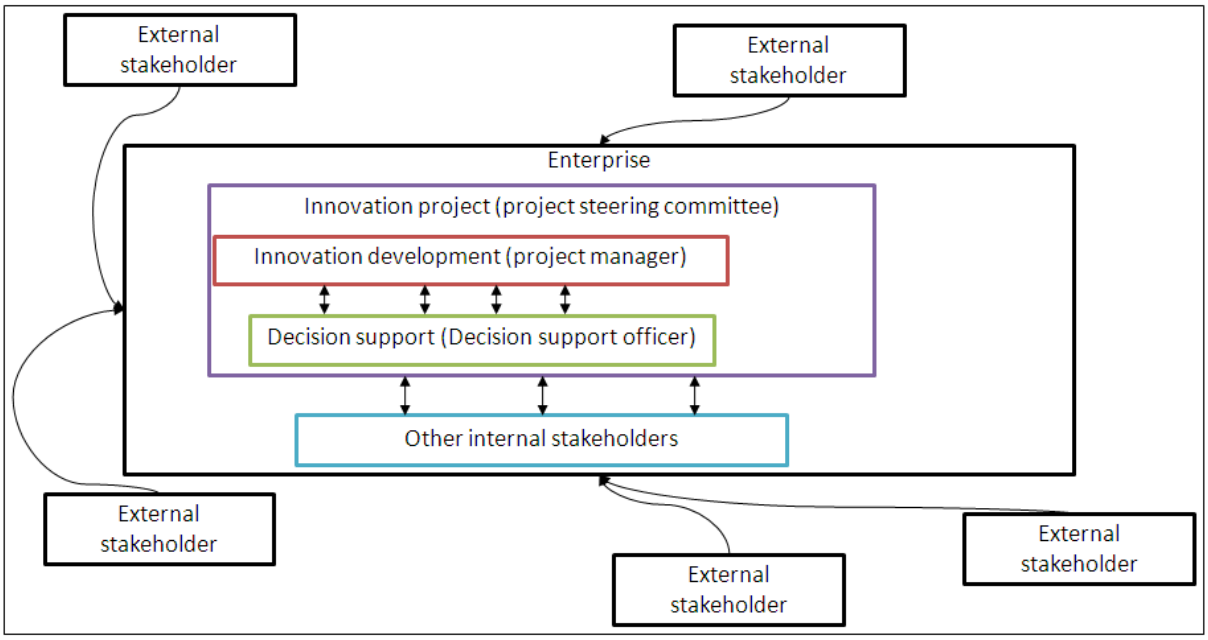

Figure 26. Different systems and actors implicated in our model

In the following, we describe the different steps of the decision support model we propose. These activities are managed by the decision support officer.

2 Preliminary step: Critical decision identification

Our method is designed for a specific kind of environment and a specific type of decision. The first step consists in identifying a decision that would benefit from our method. In many cases the decision-making processes already in place inside enterprise are sufficient. However for some others special care is required. Some decisions in the design process can be called critical. The Committee on Theoretical Foundations for Decision Making in Engineering Design (Committee on Theoretical Foundations for Decision Making in Engineering Design 2001) underlines the special care that must be taken of the "few make or break decisions" in design activities (see Figure 27). Using the business or the product cycle and criticality as criteria, they identify three different kinds of decision in design: routine, significant and make or break decisions.

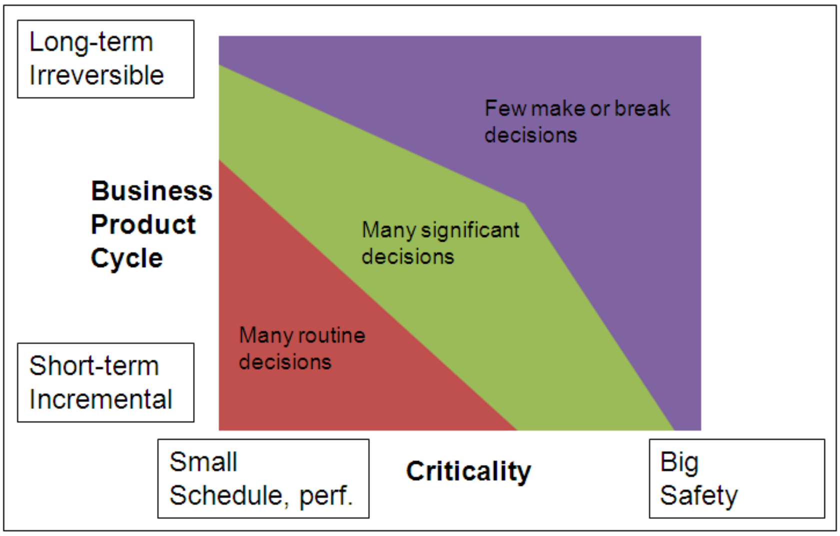

Figure 27. Types of decision in design activities. Adapted from (Committee on Theoretical Foundations for Decision Making in Engineering Design 2001)

This work emphasizes the importance of taking into account the outcomes of decisions when evaluating their importance. Thus, the first criterion we select in order to identify critical decisions is going to be the impact of the decision on the outcome of the project. However, in the very specific context of a disruptive innovation project this is not enough. In order to complete this criterion, our next step is to study the characteristics of critical decisions and find out what specific challenge they represent.

2.1 Characteristics of critical decisions in disruptive technological innovation projects

Because of their disruptive character, in the innovation projects we focus on, three objects usually need to be designed: a product, the production system that manufactures them and a market offer to commercialize them. In order to be thorough in the treatment of decision, it is crucial to note that critical decisions can be located on any of these three design spaces. However, in opposition to classical ones, critical decisions are characterized by an important correlation between these design objects. As a consequence, the knowledge involved in the decision-making process is going to be multiple. In any given design space we defined, achieving a good decision requires the creation of various types of knowledge. This knowledge is not limited to the initial design space, information coming from all three, as well as new knowledge created about the technology performance and the stakeholders of the innovation are required. Likewise, the selection of one alternative has repercussion on activities and other decisions in all three spaces. This necessity to gather information from all three spaces and to take these different spaces into account when studying the outputs of the decision makes critical decision very complex (see Figure 28).

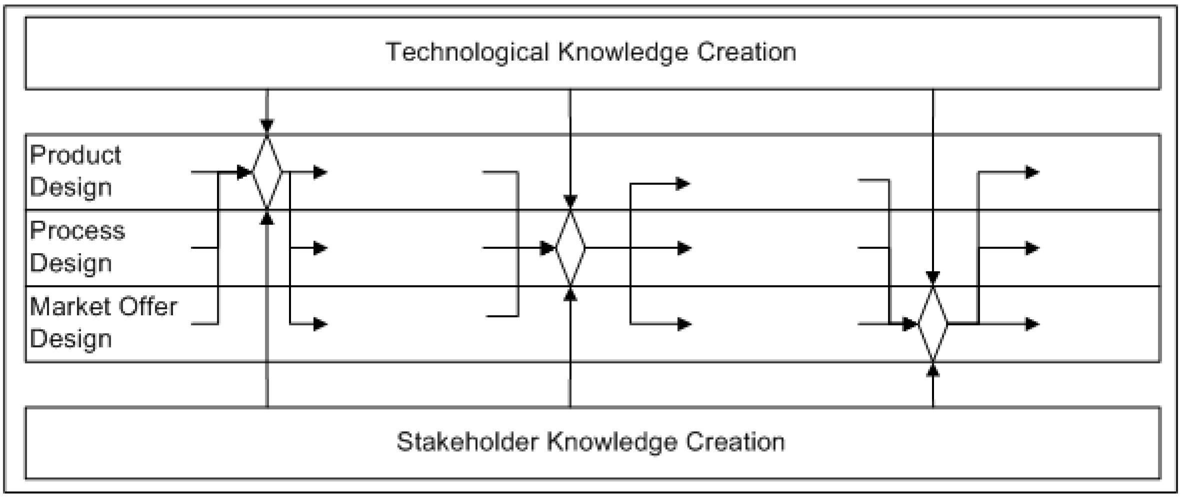

Figure 28. Critical decisions and their links with the multiple design spaces

Furthermore, all the knowledge required cannot always be found inside the company. Some new knowledge needs also to be created in order to deal with the uncertainty inherent to disruptive technological innovations. This uncertainty we have seen is located on two main areas: the technology supporting the innovation and its stakeholders. Thus, we can see that the knowledge involved in critical decision making ranges from very technical piece of data to information involving people and economics.

Furthermore, this diversity regarding the focus of the knowledge involved in critical decisions of disruptive technological innovation projects can also be found regarding the management levels involved. By essence, critical decisions are mainly of a strategic nature. However the important correlation between the operational, tactic and strategic levels of innovation projects makes relevant information coming from all three levels.

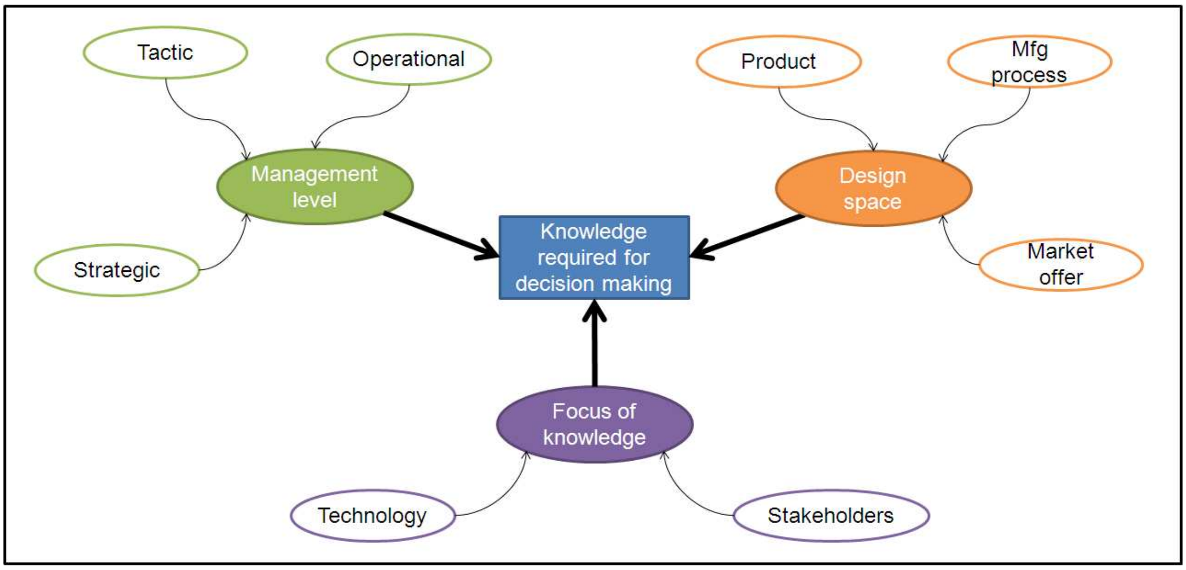

Figure 29. Knowledge and viewpoints required for decision making

This analysis emphasizes the complexity of the knowledge that needs to be available to ensure a good critical decision making (see Figure 29), and thus the viewpoints that need to be taken into account. In addition to the impact of the decision, a second criterion to identify critical decisions can then be the uncertainty regarding its alternatives. Our method identifies value creations and risks threatening these value creations as the key decision factors. Thus, a decision that is characterized on the one hand by a high uncertainty on the value created and risks related to each alternatives and on the other hand that can significantly impact the outcome of project (its value creation potential) would in our opinion benefit from being treated with our method (see Figure 30). As a consequence, for each of these criteria, we define two levels qualifying the low or high uncertainty and impact of a decision. Each innovation project being by nature unique, it is not possible to propose a quantitative criterion that would help discriminate each level in a manner robust enough so it could be adapted to various types of innovation projects. As a consequence, we here made the choice to select qualitative criteria for the definition of each level (see Table 9).

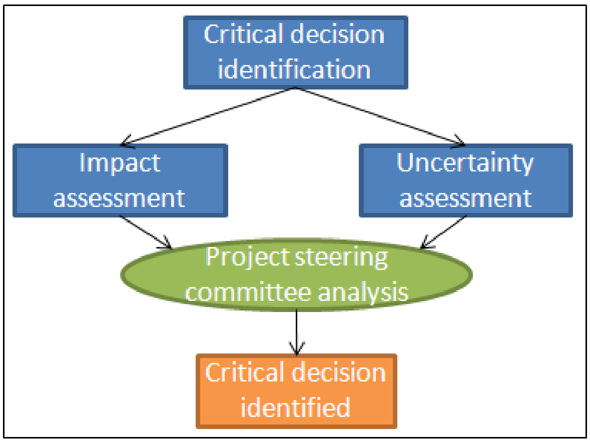

Figure 30. Critical decision identification

2.2 Impact of a decision

The impact of a decision on the outcome of a project is assessed regarding three classic criteria: quality, cost and on-time delivery. Based on these criteria, the impact of a decision can be considered as "feeble" on a project outcome (the impact is known and feeble on the cost, quality and time of project deliverables) or "significant" (the impact is unknown or important on the cost, quality and time of project deliverables). Since a robust evaluation of these criteria is almost impossible in disruptive innovation projects, no precise criterion is given and the choice of being in one or the other category is left to the analysis of the project steering committee.

2.3 Uncertainty on the alternatives solutions

We identified a second criterion to assess whether or not a decision is critical: the uncertainty regarding its alternatives. Even in innovation projects, in some cases, the alternatives to some decision are already well known by the project managers and do not present any problems. When this is the case, decisions are easier to make. At the opposite, not knowing the consequences of the alternatives to a decision makes the selection of a solution very hard. This led us to add the uncertainty related to the alternatives of a decision as a criterion in the selection of critical decisions. A decision can thus be characterized by a "feeble" uncertainty regarding its alternatives (all the alternatives are known as well as the value they create and the risks involved) or by a "significant" uncertainty regarding its alternatives (all the alternatives are not known or, if known, the value they create and the risks involved are unknown).

	Feeble impact	Significant impact
Low uncertainty	The decision is not very important and its consequences are well known	The decision is important but is easy to make since its alternatives are well known
Significant uncertainty	The alternatives of the decision are not well known. However, the low impact this decision have on the outcome of the project make this decision non-critical	The uncertainty related to the alternatives of a decision that impacts the project in an important fashion makes essential the control of the quality and robustness of the decision

Table 9. Criticity of a decision depending on its uncertainty and impact

In the following paragraph, we present the first step of the model we propose to support critical decision making in disruptive technological innovation projects.

3 Problem setting

Once a decision has been identified as critical, the first step in the decision-making process is to clarify the nature and implication of this decision. This step is called problem setting. It regroups the first three steps of Baker's method: define the problem, determine requirements and establish goals. The purpose of the problem definition is to precisely define the perimeter of the decision. In our method this aspect is a part of the goal definition.

3.1 Goal definition

As the purpose of innovation is the creation of value, identifying the goals of the decision comes to establishing the types of value creations (define as the creation of a given sort of value for a given stakeholder interested in this specific value) that can be expected from the decision. Two tasks need to be completed: a study of the different types of value that would follow the selection of an alternative and of the different stakeholders that could beneficiate from these values. This double identification is done in two steps: a preliminary literature review and an interview of the stakeholders of the project.

The aim of the literature review is to identify a first round of stakeholders and different types of values. Interviews then are set up with the first identified stakeholders. These interviews focus on the innovation developed and specifically on the decision treated. They discuss:

- the relation between the stakeholders and the innovation,
- the implications of the innovation and of the specific decision for the stakeholders,
- the stakeholders expectations regarding the decision and the innovation.

The analysis of the verbatim of the interviews can help to:

- identify other stakeholders to be interviewed,
- reformulate and further precise the types of values that could be created,
- potentially already define a number of potential value creations.

Complementary interviews of new identified stakeholders complete the results. Since these interviews are the base of much of the knowledge created, it is essential to interview as many identified stakeholders as possible, in order to ensure the validity of the results. However, it is sometimes not possible to conduct the interviews with some stakeholders (because of confidentiality reasons for example). In these cases, a special care must be taken in assessing the relations between the missing stakeholders and the innovation. This can be done by having experts assessing the expectations of the missing stakeholders regarding the innovation in general and the decision treated in particular, and the impact it can have. The activities that need to be conducted to complete this goal evaluation are summarized in Figure 31.

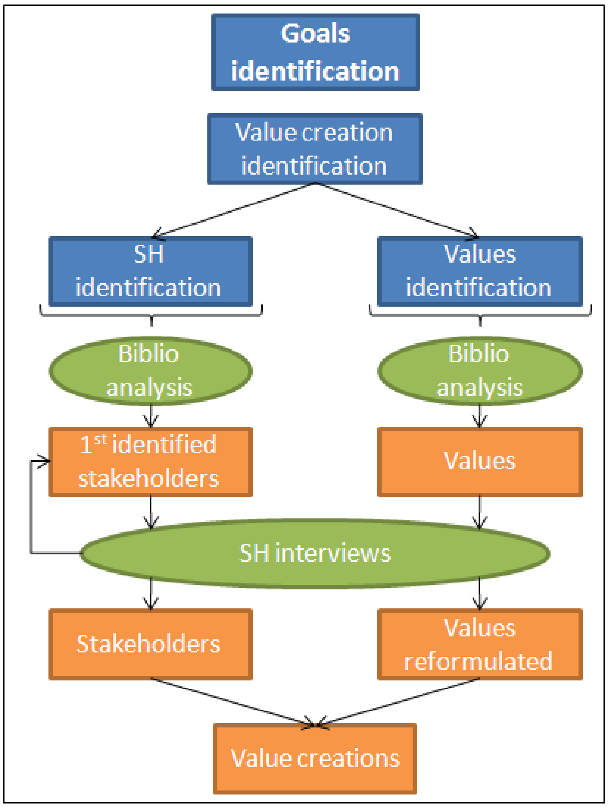

Figure 31. Goals identification

3.2 Requirements identification

The definition of the requirements is based on the previous analysis of potential value creation. Requirements are defined as the minimum value creation for a given stakeholder that needs to be fulfilled in order to ensure its implication in the project. These requirements are partly defined through an analysis of the verbatim of the interviews. A bibliographic analysis including enterprise internal documents (specifications, interface analysis) enables the establishment of the others. These requirements are of multiple natures: product technical performance, EHS performance, quality, etc. (see Figure 32).

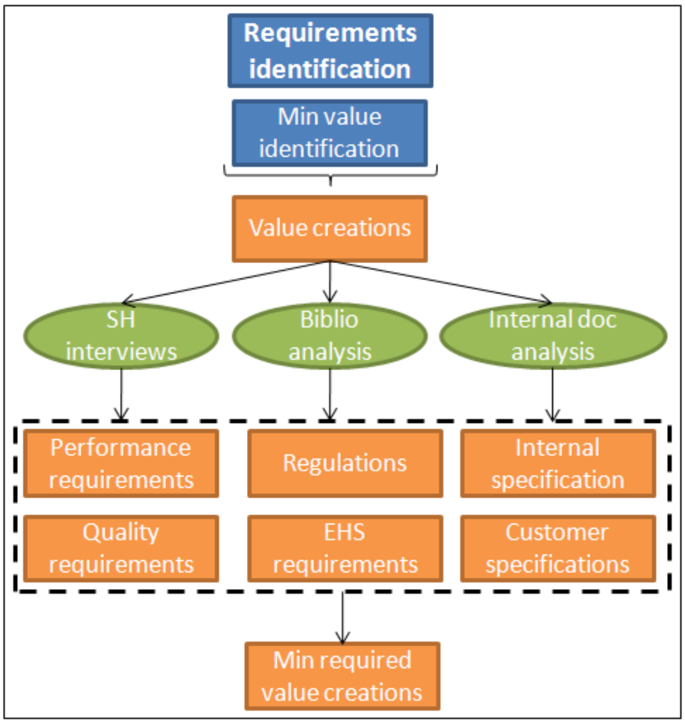

Figure 32. Requirements identification

This phase of problem setting is crucial for the rest of our model. Most of the other activities are based on the intelligence we gather in this step. Once it has been completed, the next step is the identification of the different alternatives that are offered to the decision makers.

4 Alternatives identification

The identification of a vast and rich list of alternatives for decisions in an innovation project induces significant amount in complexity when it comes to the selection of the best one. However, it also decreases the risk of overlooking satisfying solutions. In the specific context of design-related decisions, the process of identification of alternatives comes to the elaboration of several admissible design solutions. Depending on the design space of the decisions (Product, manufacturing process or market offer), the "designers" dealing with these activities are different (sales team for the market offer, R&D teams for the product, operation and methods teams for the production process). Research and development teams focus on the identification of design solutions for a product, production and operation officers for the manufacturing and commercial teams for the market offer. In a review of the different theories on how decision-makers uncover alternatives, Nutt (Nutt 2001) lists six main tactics: Idea, benchmarking, integrated benchmarking, search, cyclical search and design.

- Idea tactics attempt to draw on the knowledge existing inside the firm to uncover solutions that are already developed. People having knowledge related to the decision to make are asked for possible solutions. Discussion and argument lead to the emergence of alternatives that are already well developed. These tactics allow for rapid action and is usually characterized by low development costs.

- Instead on drawing on internal knowledge, Benchmarking tactics propose to go outside the firm to other high performing companies to find solutions that could be valuable alternative for the enterprise. The alternatives generated by this way should be more effective (but not always) because they result from best practices. However their implementation may require more resources.

- Integrated benchmarking tactics are a variation of the benchmarking tactic in which the alternatives is an amalgamation of several external best practices.

- Search tactics are more passive. The need of the firm carefully described is made known to consultants and suppliers that are asked for solutions. The solutions proposed are evaluated to ensure they are admissible and can then be used as different alternative for the decision.

- Cyclical search tactics are the result of an iteration of search tactics combined with a need redefinition to fit with available solutions.

- Design tactics develop new ideas. These new ideas can be generated through creativity cessions or brainstorming. The alternative generated by these tactics are the more apt to be innovative.

A combination of several tactics can be applied in order to broaden the number of uncovered alternatives. The choice of a particular tactic depends on the nature of decision. More precisely, various factors can influence the method that will be used to identify the alternatives to the decision. First, the teams of each design space are not used to the same kind of tools and use some methods more than others (Nutt 2001). Secondly, depending on strategy of the firm, the expectations behind a decision are not the same. Innovativeness can be required for some cases, but for others simplicity will be essential. For some decisions, when the knowledge involved represents a key competitive advantage, internal methods are more adapted. Identifying solutions for a critical design choice in an innovation is unlikely to be outsourced, whereas the identification of capable manufacturing process for this innovation seems more feasible. In a context of a disruptive technological innovation project, the multiple critical decisions may require different tactics. For example, using design tactics for every decision could lead to an explosion of uncertainty, development costs and time. It is also worth to be noted that in an innovation context, the question of intellectual ownership is very sensitive. Search tactics can pose problem from this point of view in some cases. Having a third party developing plausible solution for an innovation product increases the risk of a break of confidentiality that can result in the loss of competitive advantage.

Choosing the type of tactic to implement and the specific tools that are used is a task devoted to the design teams. As we have said, depending on the decision, these design teams can be different (R&D, marketing, sales, operations and methods). Numerous methods and tools exist that focus on the improvement of such tasks. In our work we will not focus on this particular step.

Once the alternatives have be identified, in order to enable a way to compare them, the decision support officer and the project steering committee must select a number of criteria to be used in the evaluations of each alternative.

4.1 Criteria selection

4.1.1 Problems posed by a too rich number of criteria

The purpose of this step is to identify relevant criteria that enable a comparison of the different alternatives to the decision. In this regard, the previous steps have helped to bring to light two major pieces of information: the requirements of the stakeholders, translated into a minimum level of specific value creations and additional value creations that would be desirable for them. From our point of view, this information, in conjunction with an evaluation of the risks associated to each of them is the most relevant that can be provided for the evaluation of the different alternatives of the decision. However, in some cases, this information can be extremely voluminous. This can cause two different problems: capability and readability of the information presented to decision-makers.

4.1.2 Capability

Robustly assessing the different types of value creation is a complex task. An explosion of the numbers of value creations to assess can prove a formidable task, too long and costly for the benefits it would provide. Furthermore, given the fact that the interview of some stakeholders may not be possible, the imprecision associated to these assessment can be of some concern. When it is possible to be relatively confident while dealing with the main types of value creations, in other cases, the robustness of the results can be a major concern. And this is the case if a too great focus is put in the assessment of major value creation for external stakeholders.

4.1.3 Readability

Another problem that can be posed if too many decision criteria are selected is the readability of the decision support information. The purpose of the criteria identified and assessed is to be presented to the decision makers, so they would have access to relevant knowledge that would help them in the selection of an alternative. However there is a limit to the number of information the decision makers can process (Umanath and Vessey 1994; Hwang and Lin 1999; Widman and Warner 2000; Chan 2001; Ruff 2002; Jamieson 2007; Baehler and Scott 2010) . The multiplication of criteria is likely to make more difficult the analysis of the knowledge presented rending the decision support information useless.

4.1.4 Key information

For all these reasons, if they are too abundant, a selection of relevant value creations is necessary. However, this selection is not always required and must be kept to a minimum. This is because the decision can actually be taken on a very few number of discriminating value creations. One must them be careful not to remove such information.

4.2 Selection of the most relevant criteria

If a selection in the criteria is required, it is an activity that needs to be performed with decision makers and the project steering committee. Two kinds of criteria were formulated in the previous phases: requirements and other value creations. The selection can be operated in these two areas.

4.2.1 Selection of requirements as decision criteria

A selection of criteria in the requirements must be done very carefully. This is because any requirements not met by the alternative selected hinder the implication of the related stakeholder in the project. As a consequence, the only requirements that can be suppressed are the ones related to stakeholders that are not important for the project or deemed not desirable by decision makers (see Figure 33).

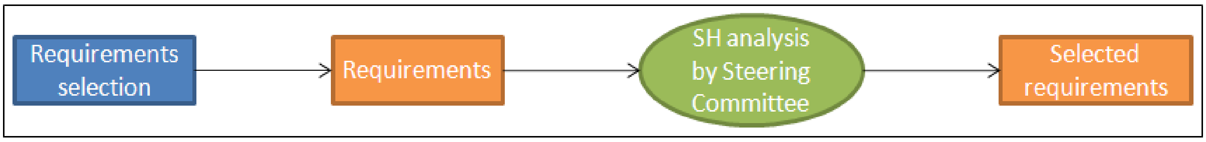

Figure 33. Requirement selection as decision criteria

4.2.2 Selection of value creations as decision criteria

For the additional value creations, the selection must focus on eliminating the less relevant criteria. First, analysis by the project steering committee can bring to light the fact that some value creations are identical regardless of the alternative selected. Such criteria not enable a differentiation between the alternatives to the decision and are put aside.

Once this step is completed other strategies can be used to eliminate less relevant criteria (see Figure 34). This can be done in two ways. The first solution is, on the basis of the verbatim of the interviews to eliminate value creations that are deemed less desirable by stakeholders. This however represents a danger since it is based only on the type and not on the amount of value created. Yet, in some cases, an important amount of the less appreciated type of value can be more desirable than a small amount of a more appreciated type of value.

Lastly, a classification of the relative importance of the stakeholders done by the steering committee can be used to put aside value creations related to insignificant or undesirable stakeholders. Once again this presents the danger of overlooking significant areas of value creation by some alternatives.

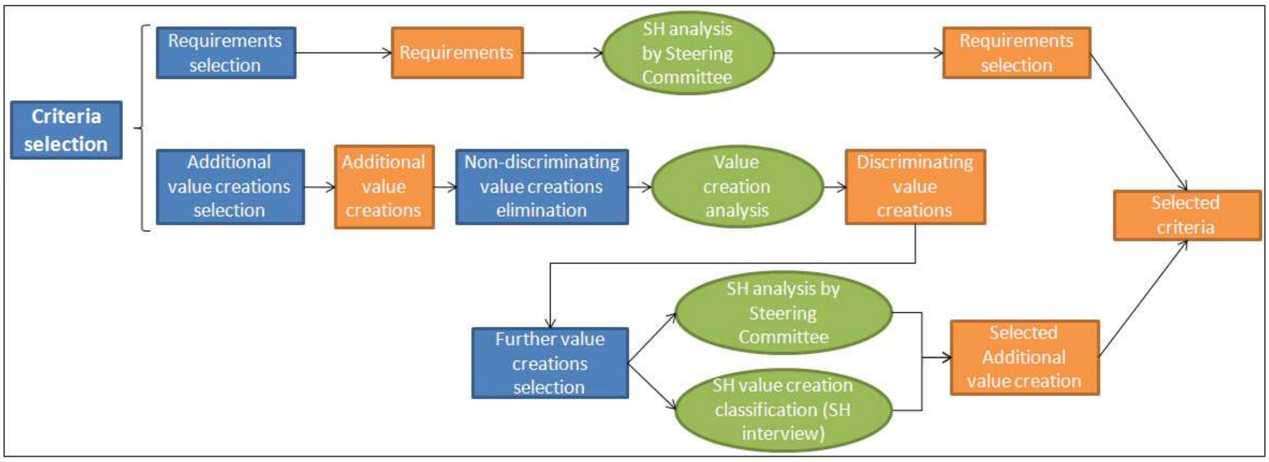

Figure 34. Decision criteria selection

The selection of some criteria over others is a facultative task, only to be completed if the amount of information seems too much to be handled by the decision makers. The criteria that were not eliminated are then used in the next step of the model: the assessment of the value creation and of the risks associated.

5 Value creation and risks assessment

As we have stated in the description of the specificities of critical decisions in disruptive technological innovation, identifying the knowledge that need to be accessed for a good decision making is relatively complex. This knowledge is for some part located inside the enterprise, in the three design spaces, the rest is mainly of two natures: technology-related or stakeholder-related. The work accomplished in the previous steps enables the identification of this knowledge. The assessment of the value creation and of the risks associated is a translation of this knowledge.

5.1 Value creations characteristics identification

The value creations identified in the previous steps can seem very intangible. In order for it to be used as decision criteria, it needs to be measurable. In this regard, it is very important to select for each value creation one or several characteristics that enable their assessment. These criteria must enable:

- A reasonably easy assessment of each value creation, possibly at different timescales.
- A robust and accurate assessment of each value creation (quantitative or qualitative).
- A reasonably easy and synthetic representation.
- An easy comparison between similar value creations (same type of value for different stakeholders, same value creation in different alternatives).

The identification of satisfying characteristics can be easy for some types of value (economic, reliability) but more difficult for other (human well-being, environment). Specific scientific fields exist which focus on this issue. Bibliographic analysis and experts interviews can thus prove to be a good solution to identify characteristics enabling specific value creation measurements. The thesis of Dudezert (Dudezert 2003) presents much insights on the evaluation of knowledge inside enterprises. The works of Harscoet (Harscoet 2007), Le Pochat(Le Pochat 2005) and Leroy (Leroy 2009) present several methods that can be used to assess the environmental impact of a product. Those of Germain et Al.(Germain and Gates 2007) and Déjean et Al.(Déjean and Gond 2003) and the ORSE (Observatoire sur la responsabilité sociétale des entreprises 2003) present an analysis of the ways firms measure their social performance. Finally, the works of Schindler (Schindler 2009), Lebas(Lebas 1995) present different way to measure multi-performance in organizations.

Some other characteristics can also be identified from an analysis of the concrete expectations of the stakeholders of the innovation. Finally, if possible, a validation step with stakeholders should be carried out (see Figure 35). This can help ensure the relevance of the selected measurement criteria.

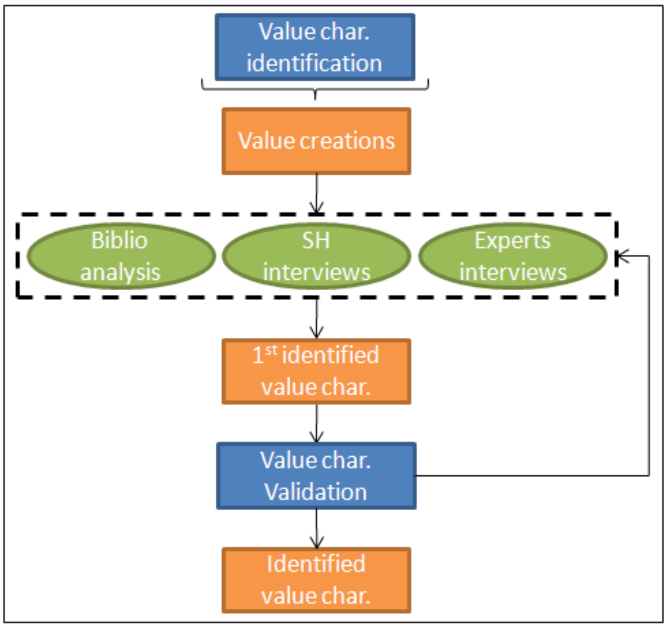

Figure 35. **Identification of value characteristics that enable a robust assessment of value creations**

5.2 Value creation assessment

Numerous value creations have been selected in the previous steps. These value creations represent the interest of a given stakeholder for a specific type of value. The identification of measurement criteria now enables the assessment of these value creations. This assessment must be conducted for each of the alternatives previously identified (see Figure 36). As we have seen, the access to specific knowledge is required to complete this assessment. Some of it is already located inside the enterprise, within the teams dedicated to the design of the product, the production process and the market offer. The rest of the knowledge can be accessed through experts' interviews or needs to be created (tests).

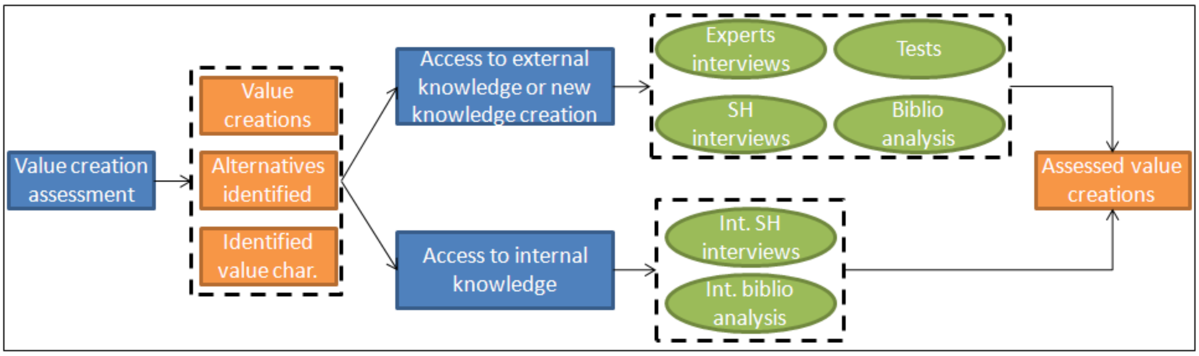

Figure 36. **Value creation assessment through the access to the relevant knowledge**

5.3 Value-creation-related risks analysis

An estimation of the level of value that can be expected by the implementation of an alternative is not sufficient. These value creations are not certain and risks exist that the value created is lesser that expected to significant extant. As a consequence, in addition to the value creation assessment, it is also important to identify and assess the risks threatening the value creation as well. Numerous methods exist that deal with risk treatment. In this work we only present a few non exhaustive samples of the possible tools.

5.3.1 Risks identification

Starting from the finally identified value creations (cf. criteria selection step), the purpose of this phase is to identify, for each of them the potential risk that can lower the value creation. Using tools such as brainstorming, risks typologies, combination of functional analysis and FMEA, it is possible to identify these risks. This step needs to be completed with people having a certain expertise on the stakeholder and type of value that are being focused on (see Figure 37).

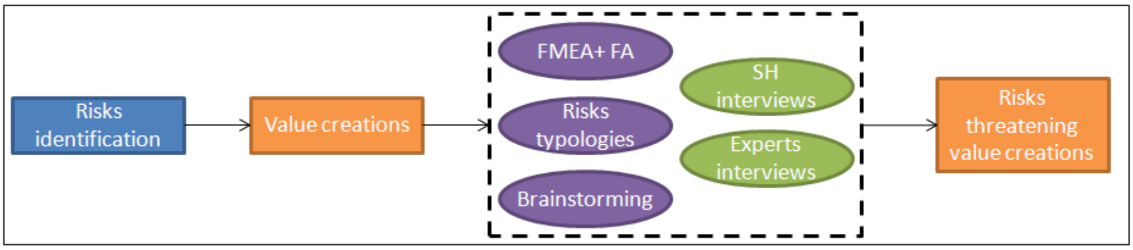

Figure 37. Identification of the risks threatening value creations

5.3.2 Risks assessment

Once the risks have been identified, an assessment of their criticality is required. For this particular task, we adopt the basic formalism of the FMEA. For each identified risk, an estimation of its probability and gravity is performed. The probability of risk occurrence can be evaluated by using experts' opinions, reliability diagrams or Technology Readiness Levels as presented in former paragraphs.

In the gravity assessment phase, the purpose is to analyze the impact a given risk can have on the level of the related value creation. This analysis draws on knowledge from internal and external stakeholder or experts to in order to evaluate the possible degradation of a specific value creation the risk is related to. The value characteristics identified in the previous step can provide a qualitative or quantitative way to asses this degradation (see Figure 38).

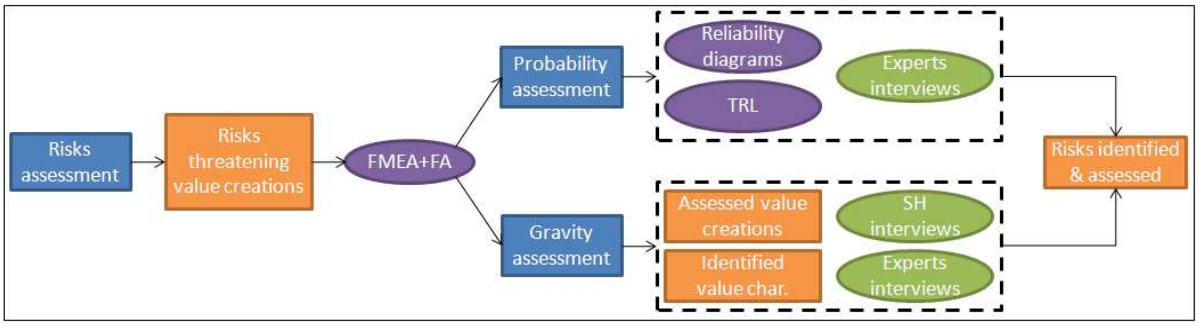

Figure 38. Assessment of the threatening value creations

For purpose of readability, we advocate the use of a five-level scale to represent the probability and gravity assessments. Further criteria could be add in order to characterize the different risks such as the probability of non-detection of the risk or the uncertainty related to the assessment of probability and gravity. However in this context, this information may not be very useful. This is because our purpose here is not only the evaluation of some specific risks, not the full management of the risks associated to the innovation project, a key phase in project management but which doesn't belong to our study.

6 Value creation and risks representation

The value creation and risks assessed during the previous steps needs to enable the selection of an alternative to a decision by the project steering committee. In this regard, this information must be presented in a way that both enable an easy understanding of the main characteristics of each alternative and allows a deeper look in some specific aspects. Because of this, several levels of information display are required.

6.1 Synthetic representation of each alternative from the value creation/risk point of view

What we propose here is a first level of information display that would consist of a summary for each alternative of the value potentially created and related risks. Such summary would be very rich and contain a significant amount of information. For readability purpose, this information is qualitative. The solution we use in this regard is the constitution of a graph presenting the different stakeholders in one axis and the different types of value on the other. Value creations are represented as circles positioned at the intersection of the value type and the stakeholder for which it is created. In order to enable a comparison between different creations of the same value, the size of these circles is related to the amount of value created. In order to avoid cognitive biases that would lead to irrelevant value creations comparisons, a unique five-level scale is used for each type of value creation (see Table 10). By using this scale, we can:

- Represent information on the amount of value creation in an easy way.
- Enable a comparison between same types of values in different alternatives.

1st level	2nd level	3rd level	4th level	5th level
No value creation for the stakeholder	Small value creation for the stakeholder	Medium value creation for the stakeholder	High value creation for the stakeholder	Very high value creation for the stakeholder

Table 10. Five level qualifying value creations

The presentation of these graphs (one for each alternative) can give decision-makers a good idea of the characteristics of each alternative in terms of value creation. In order to represent the risks associated to these value creations, we divided these risks in three categories according to their level of criticity. Risks whose criticity is below eight are qualified as “low risks”, risk whose criticity rates from eight to fourteen are “medium risks”, risks having a criticity superior or equal to fifteen are high risks. This classification is the standard used for risk analysis in internal documents at L’Hotellier. The level of each risk is presented in the graph by a color code (green, orange, red) associated to each value creation circle (see Figure 39).

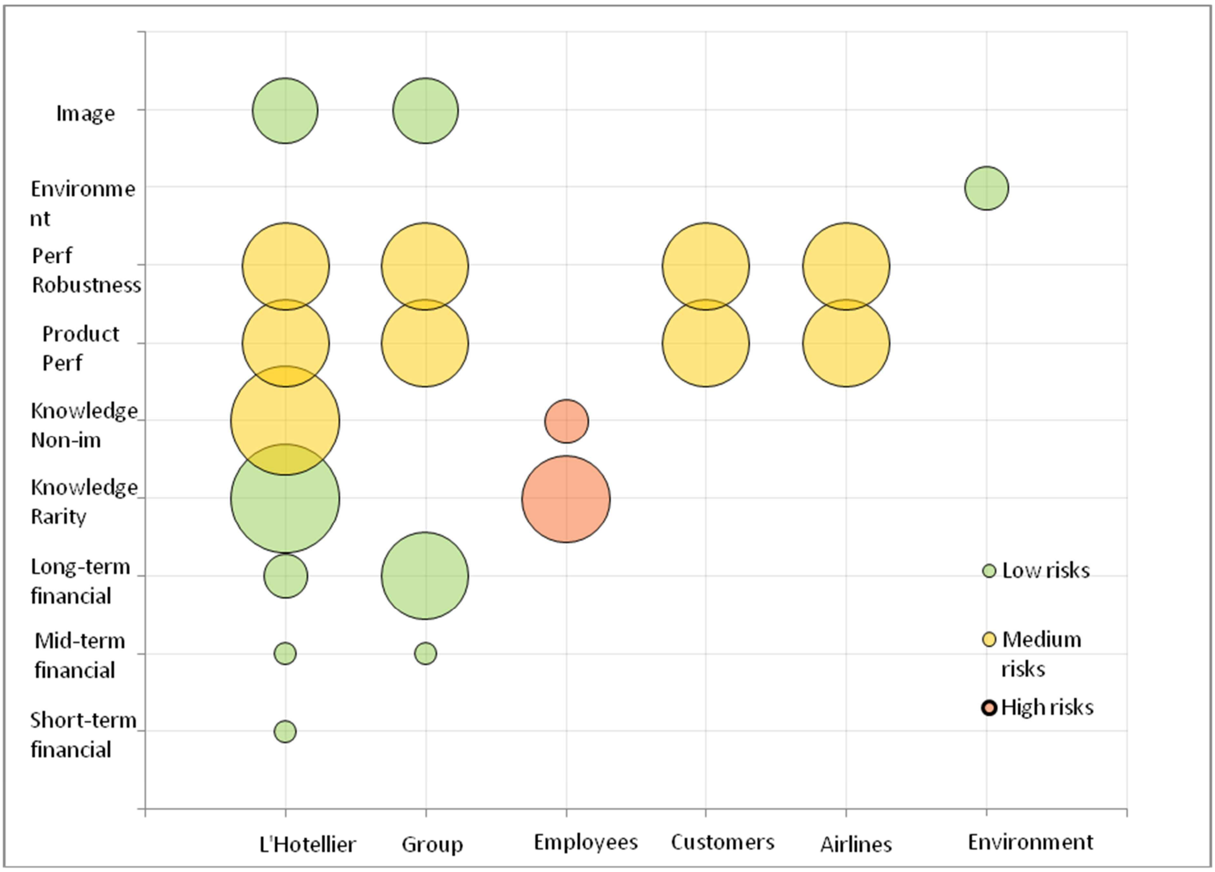

Figure 39. **Representation of value creation and risks associated to one alternative of a critical decision**

6.2 Deeper focus on value creations

This presentation of information is not very precise but it does not need to be. The purpose of this first information presentation is to enable decision-makers to have a first idea of the value creations associated to each alternative. Based on the amount and riskiness of the value creations, some of them can emerge as preferential decision criteria. At this point, more information is required on these value creations in order for decision-makers to have a more precise idea of the advantages and drawbacks of each alternative.

To complete this purpose, we propose the realization of a document for each value creation that would regroup the information (quantitative and qualitative) possessed on this value creation for the alternatives and that led to the realization of the graph. This document would enable decision-makers to have a more precise understanding of the comparison that can be made between each alternative from the point of view of a specific value creation.

6.3 Conclusion

With this, we have to complementary sources of information: on the one hand one graph per alternative that represents value creations and risks, on the second hand we have for each value creation a presentation of a summary of all the information available that enables a precise comparison of each alternative from the point of view of one value creation. Presenting decision-makers with the rich but imprecise graphs and the precise but much more focused summary document enables them to have access to both level of value and to build an inner representation of the possibilities of value creations associated to each alternative that have both qualities: a sufficient level of precision and the framework that enables them to make sense of this precise and focused information (see Figure 40).

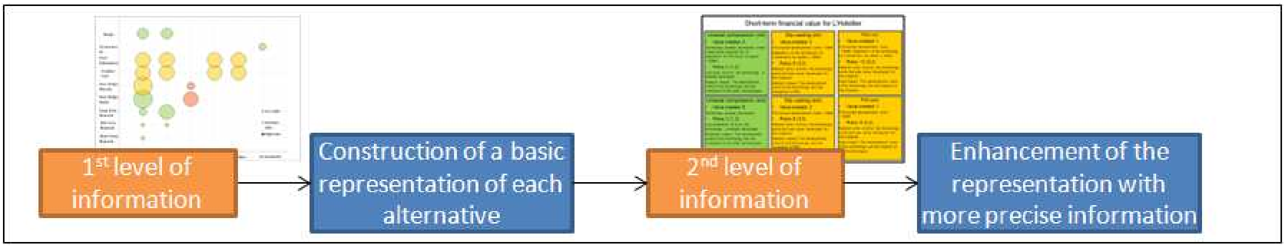

Figure 40. Use of the information presented to construct a detail representation of the alternatives

IV. Protocol

As we have stated previously in the description of our industrial context, this work was conducted as a research action inside a small aeronautics integrator: L'Hotellier. The enterprise was developing an innovation they aimed to implement on some of their products. The PhD candidate was hired to act as a project manager in this development.

1 Experimentation context

1.1 Project history

The ceramic disk project was initiated in year 2002. L'Hotellier's chief technical officer was visiting a supplier facility when he observed the peculiar comportment of some ceramic components. Due to the presence of internal defects, the components were breaking while submitted to an electric current. The idea came to him to use such ceramics to replace the current device used to trigger the opening of extinguishers: pyrotechnical cartridge.

Preliminary studies with consulting companies and ceramic experts were initiated in order to select a concept that would fit the constraints related to the aeronautics industry. This led to a patent deposit in 2004. A study was then subcontracted to a ceramic expert in order to complete a preliminary design of the component. The insufficient performances of the first few prototypes led to a pause in the project. A change in the administration of the company led to the hiring of the PhD candidate with the mission of completing the product design and providing the executive committee with information enabling a decision regarding the market offer to implement.

1.2 Project main phases

The aim of the project is to develop a technological solution for the two main functions of the device controlling the opening of the extinguisher:

- Routine function: maintaining the extinguishing agent inside the extinguisher tank.
- Trigger function: allowing a quick release of the agent from the tank to the pipe system

The activities that led to this development can be regrouped in four different phases. The first preliminary phase was completed before the arrival of the PhD candidate. It consisted in determining the technology that was going to be used for the trigger function. It included the choice of a ceramic material. Several tests were conducted that led to the choice of a first geometry for the ceramic device: the hat shape (see Figure 41).

Figure 41. Hat-shaped ceramic disk

The second phase began with several tests that were performed on the hat shape including pressure resistance test and rupture tests. The rupture tests succeeded in obtaining a clean break of the ceramic disk. However, the pressure test yielded no satisfying results with samples breaking with a 80 bars load where the target is 180 bar. This led to a modification of the shape (see Figure 42). Based on finite element analysis, the areas endure the most stress where identified and the ceramic shape was modified in order to increase its resistance to pressure.

Figure 42. Cup-shaped ceramic disk

This form was tested in the third phase. The mechanical tests where much better than the previous ones with sample withholding 160 bars. However a wide dispersion was noted in the ceramic mechanical properties. Furthermore, the ceramic supplier was experiencing a very high discard rate (>50%). As a consequence, resolution was taken to investigate other manufacturing processes for the ceramic. Rupture tests were also conducted with the aim of finding out the electrical configuration that would enable a clean break of the samples with the lowest amount of energy (see Figure 43). However, the results of these tests were not exploitable. No repeatability in the rupture energy was achieved. This phenomenon was traced to the high dispersion of the mechanical properties of the ceramic and the poor quality of the liaison between the ceramic and the metallic conductors.

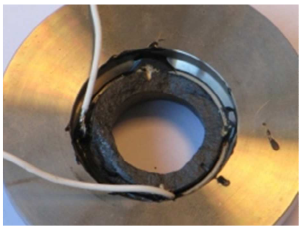

Figure 43. Electrical test conducted on cup-shape ceramic disk

The fourth phase, actually in progress consists of two main activities. The first one is the development of a ceramic manufacturing process that would be capable of producing ceramic disks having a low dispersion in their mechanical characteristics. The second one is the development of a robust method to attach the metal conductors to the ceramic disks. Another smaller activity is a minor redesign of the disk shape that would increase its mechanical strength.

2 Experimentation protocol

2.1 Selection of critical decisions open to experimentation

During the project, several situations seemed to fit for an experimentation of our method. Critical decisions were identified (see Figure 44). First, the detailed choice of the technology supporting the innovation would have been an excellent opportunity to test our method on a product-design-related decision since it presented numerous significantly different alternatives. The choice of a design concept in the early design phases could also have been an interesting possibility. However in these two cases, the decision was already made at the time of the PhD candidate's arrival and not much information available on how it had been completed. Two other critical decisions were afterwards selected: the choice of an industrial ceramic manufacturing process and the selection of the most adapted market offer.

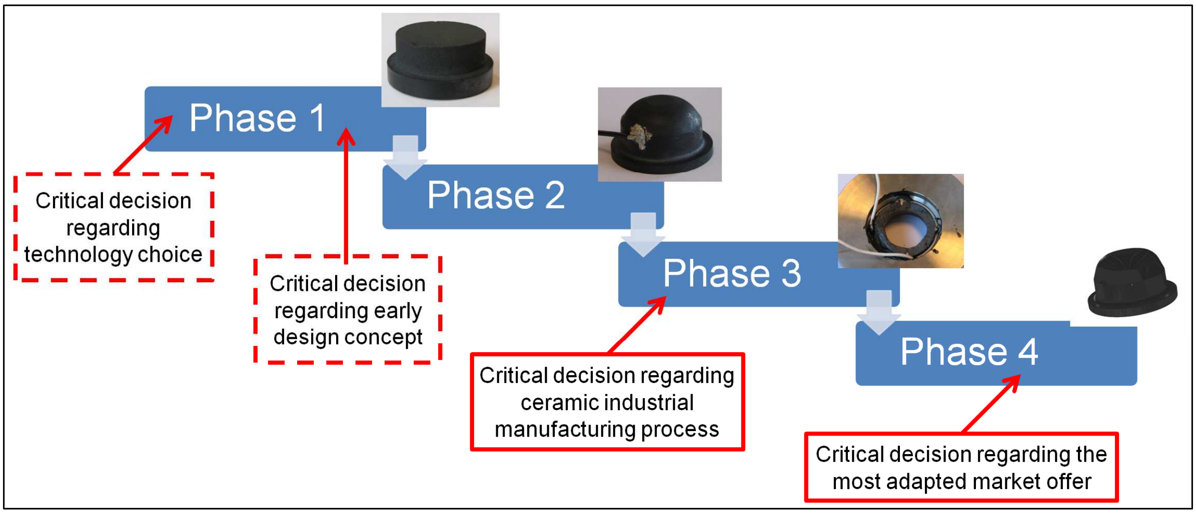

Figure 44. Areas of critical decisions

However, there are limitations regarding our experiments on these decisions. In the case of the selection of the industrial process, the decision was taken at the time our model was developed. We applied "a posteriori" in order to validate the decision and compare the outcome of the classical decision process with a formalized one. In the second case, due to limited amount of information, the decision has not been taken yet. However, we supplied the decision-makers with the current state of information and a model that enable them to update them once more data will be available.

2.2 Actors of the experimentations

In these experimentations, the project steering committee is constituted of six persons. Three of them are the advisors of the PhD candidate. Of these, two are from the Laboratoire Génie Industriel providing the committee with a design science expertise. The last one is from the Laboratoire Structures, Propriétés, Modélisation des Solides, providing expertise on the inner properties of ceramics. The next two members are part of L'Hotellier. The first one, the CFO, was replaced during the PhD by the Chief Commercial Officer due to his departure from the company. The second one is the chief technical officer. The last member is the PhD candidate, also acting as project manager and decision support officer. For each of these experimentations the different steps of our method were implemented. After each of the two decisions, a step of evaluation was conducted in order to facilitate the analysis of the quality of our result and help validate our method.

2.3 Stakeholders interviews

The interviews of the various stakeholders of the innovation are a key step as it enables the gathering of much information. In our experimentations, the conduction of this particular step presents two specificities. Firstly, for confidentiality reasons, in our case only internal stakeholders interviews were possible. We made up for these insufficiencies by interviewing the members of the enterprise that had the most knowledge of these stakeholders. The salesmen were interviewed with a specific focus on the customers and users. The interview of the purchasing manager included a focus on the suppliers.

A second specificity in this interviews phase is to be noted. Although we performed two experiments with our model (manufacturing process decision and market offer decision), the interviews required were only conducted once for the two experimentations. This is because both experimentation deal with the same innovation project. And since the main focus of these interviews is the study of the values created by the innovation, doing this work twice is redundant. We however took care to include in the interviews questions about both identified critical decisions. The verbatim obtained were thus usable for both experimentations (see **Erreur ! Source du renvoi introuvable.**). In some cases, additional interviews were conducted to provide the missing information.

3 Validation

The purpose of these experimentations is to validate how well our model constitutes a satisfying approach to the resolution of our research question. In order to reach this goal, it is essential to have a way to estimate the performance of our model in regard to some criteria.

3.1 Difficulties posed by the validation

Validation is a key issue in engineering design (Barth, Caillaud et al. 2011). In this study, the question of the model's validation was a real challenge. No two innovation projects are alike. It is thus not possible to validate the performance by comparing our results with others, obtained by using different methods. Furthermore, it can take some time for innovation projects to bear their fruits. Our study was limited to three years in which we had to develop a new product, a method and conduct experimentations. Since our results have just been produced (summer 2010 for the first experimentation and summer 2011 for the second one), we have no visibility on what is the long term impact of the decisions. However, the impact of our model can still be observed on the way the decisions are taken. It is based on these factors that we assess the benefits of our method.

3.2 Criteria measuring the performance of our model

The solution we found in order to assess our model was to ask to its different users their feeling regarding its performances. Since the main customer of our method being the project steering committee, interviews of its members were conducted. Verbatim resulting from these was then analyzed to assess the quality of the method. The interviews focused on following subjects:

- The method itself and its use: easiness of implementation and costs
- The results presented at the end of each experimentation
- Adequacy and usefulness of the information presented: are any relevant pieces of information missing or is some information irrelevant or useless?
- Quality of result presented: are there any exactitudes in the results presented?
- Readability of information presented: was the information presented easy to understand?
- Selection of an alternative
- How were the results presented used for the decision?
- What were the other criteria that influenced the decision?
- Were there disagreements between the committee on the alternative to select?
- General impression: what is the committee general impression on the method experimented?

V. First decision: selection of a ceramic manufacturing process

Once a first design of the ceramic component was reached, pressure test needed to be completed. These tests focused on increasing the knowledge available to the project team on the mechanical performance. The objective was to validate that the designed ceramic component is strong enough to withstand the pressure the final component is exposed to. Twenty cup-shaped samples were ordered from the ceramic supplier. The quality of the samples obtained was poor. The requirements in terms of dimension were not respected and cracks could be seen on some samples. The mechanical tests yielded poor results as well, the rupture pressure being significantly inferior to the theoretical value.

Changes in the process included externalization of the machining of the samples to experts did not succeed in reaching a satisfying level of quality. The following series were still presenting significant defects and a very high discard rate. The question of changing the manufacturing process of the ceramic was then raised. The ceramic supplier proposed two possible new processes: the slip casting and the power injection molding (more explanations on these processes below). A small discussion between the chief executive officer, the technical director and the project manager led to the selection of the injection molding. The main criterion that led to the selection of this process was the repeatability. The high expectations of the market in terms of reliability drove the committee to select the process that is a priori the most capable from this point of view. Other aspects were also considered such as the price. However, once it was validated that the final cost per unit objective was reachable through this process, this aspects was no longer the key criterion. Other considerations such as the environmental impact, the types of knowledge created etc. were not taken into account. Our model was applied a posteriori on this decision in order to assess the advantage it would give to decision-makers.

1 Preliminary phase

The first step of our model is the recognition of the critical decision. In our case, this was done a posteriori. The assessment of the criticality of the decision was conducted, and once it had been established, we applied our model to this decision. What we present here is the results of this criticality assessment. This begins with a formulation of the perimeter of the decision. Once this step has been completed, the recognition of the criticality of the decision is based on two criteria: the impact of the decision on the project and the quantity of knowledge available regarding the alternatives of the decision. In the following parts, we present how the decision perimeter was defined and how these two aspects (impact and uncertainty) were assessed.

1.1 Definition of the perimeter of the decision

The question of selecting a manufacturing process for the ceramic was studied by the project steering committee. Two solutions were possible. The first was to continue with the approach that had been adopted till then: the selection of a manufacturing process dedicated to the design phase that does not need to manufacture big series, the selection of an industrial process being left for future steps of the project. The second approach was to select a manufacturing process that would have the capability to produce components for the design phase as well as for the production phase.

The choice was taken to select a process that could be also used in the production phase. The main reason for this was knowledge-related. This ceramic is a material whose use is very uncommon. As a result, its properties (mechanical, electrical) are not well known. Furthermore, the impact of the manufacturing process of the material on these properties is also unknown. If the process used is not the same between the design and the production phase, the properties of the final products may be significantly different from the prototypes. As a consequence, it may not be able to perform its functions. Its design parameters are based on knowledge gained during the design phase that may not be applicable on product manufacture with a different process. We also studied the possibility to keep the same manufacturing process in order to have an element of comparison for the value creations of the other manufacturing process and to validate that a new process would be worth the change.

1.2 Critical decision identification

1.2.1 Impact assessment

Our model proposes to assess the impact of a decision on a project based on the classical quality, cost and on-time-delivery triptych. This impact can be considered “feeble” or “significant”. An assessment of these three aspects was performed a posteriori by the project steering committee. Based on the expertise of the members, the following results were found:

- From the quality point of view, the selection of a manufacturing process obviously has a significant impact. Since this selection concerns the process that will be used to manufacture the final product, the capability and robustness of this process will impact the quality of the products commercialized. The final manufacturing cost of the product is also impacted by the choice of a manufacturing process.
- From a cost perspective, the impact is not decisive. The differences of price for developing manufacturing technologies for this ceramic is not that high compared to the total cost of the project.
- Finally, from a time perspective, this decision has an impact on the project. For the development to go on, knowledge on the behavior of this ceramic is required and cannot be obtained without performing tests. The time required to develop the technology and the rapidness of the manufacturing process will impacts how quickly these tests will be performed.

This analysis shows that the decision of selecting a manufacturing process for the ceramic component impacts significantly the quality of the outcome of the project. The decision can thus be critical if it is also characterized by a high uncertainty on its alternatives.

1.2.2 Uncertainty assessment

Once the impact of the decision on the project is assessed, the focus is put on the degree of knowledge available on this decision. If the alternatives of this decision are fully known, the choice is relatively easy to make. However, if it is characterized by a high uncertainty, it is much more complex if there is no information on which a choice could be based. In our case, the only pieces of information available on the possible alternatives were based on previous propositions made by the ceramic suppliers. However, the implications the selection of one industrial process would have on the final outcome of the project were not known by decision-makers. The uncertainty is significant regarding the alternatives of the project.

As a consequence, based on our criteria, this decision was identified as critical (see Figure 45). The importance of its outcome and the low amount of knowledge available makes it complex enough to require a specific focus.

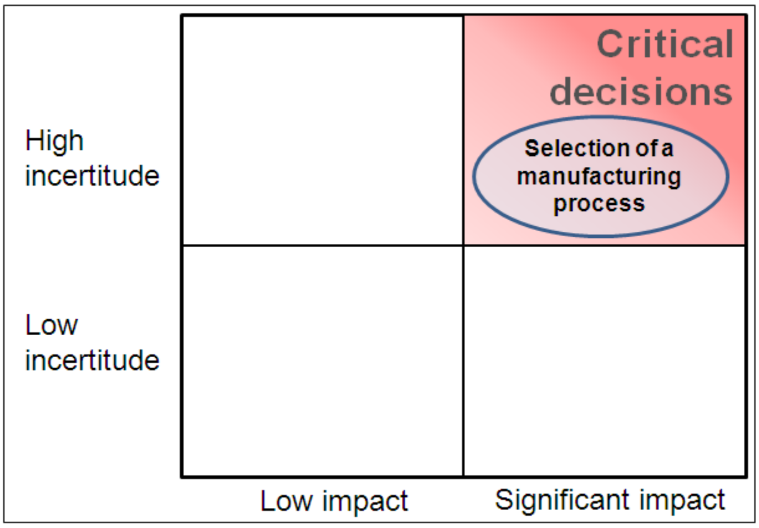

Figure 45. Criticality of the first decision

2 Problem setting

The previous step led to the identification as a critical decision of the selection of a suitable manufacturing process for the ceramic. According to our findings in preliminary chapters (problematic and model presentation), this decision is complex and important enough so its control is necessary to ensure the good development of the project. As a consequence, we experimented our method on this decision.

The second phase of our method is the setting of the problem. It is based on the analysis of the values that can be created by the innovation and on its requirements. This problem setting is presented in two steps. In the first one, we present a preliminary analysis of possible values that can be created by the innovation. In the second step, we present an analysis of its stakeholders. We combine these analyses to identify possible value creations for our innovation. In a second step, we adapt this pre-study to the decision treated. We precise the values and stakeholders considered.

2.1 Values creations of the innovation: preliminary study

We defined a value creation as the creation of one type of particular value for a given stakeholder. The identification of value creations requires a twofold study of the values that can be created by the innovation and of its stakeholders. This identification of the value creation is done in three steps. First, possible types of values and stakeholders are identified through a bibliographical analysis. Then the interviews of the identified stakeholders lead to:

- A more precise formulation of the types of values that can be created by the innovation,
- The identification of the expectations of the stakeholders regarding the values created by the innovation

In the next paragraphs, we detail this study.

2.1.1 Bibliographic analysis

A bibliographic analysis is completed in order to identify different stakeholders and types of values. This analysis is detailed in our problematic investigation in the second chapter of this document. The literature shows that multiples values can be created by an innovation. We listed economic values, quality, on-time delivery, knowledge, quality of internal communication, ethical values and environmental values. A similar focus on the possible stakeholders of an organization enabled the identification of the following stakeholders: the organization itself, suppliers, customers, final users, the market, competitors, shareholders, employees and finally a generic stakeholder called the humanity. These values and stakeholders are regrouped in Figure 46.

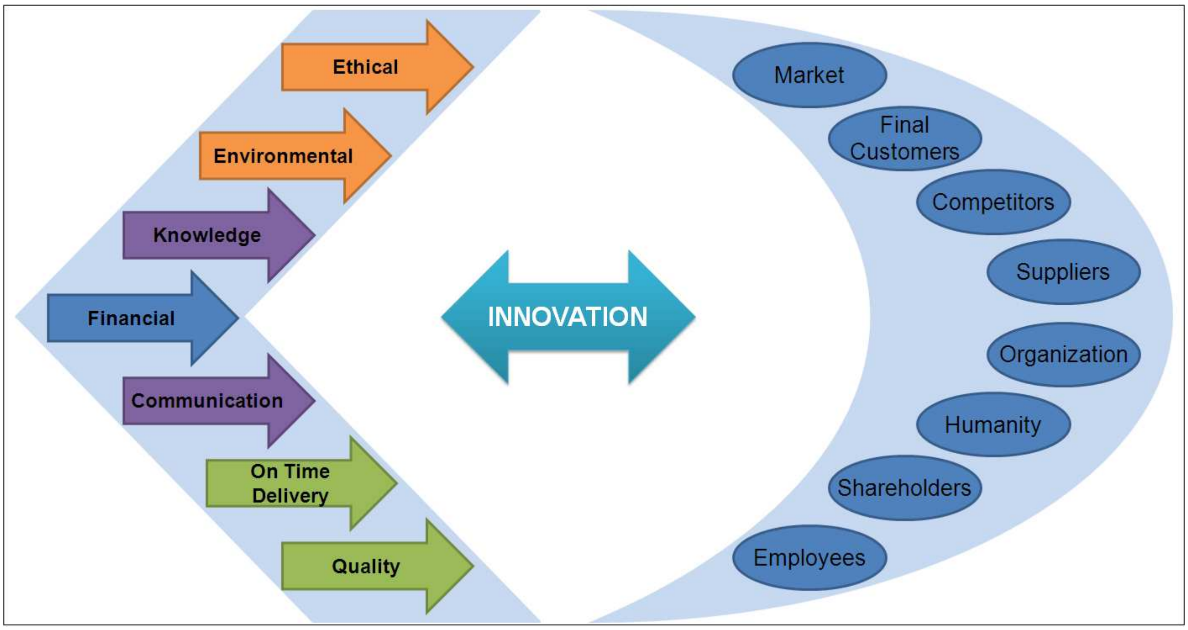

Figure 46. Values and stakeholders identified in the literature

2.1.2 Interviews

The bibliographic review led to a first formulation of possible stakeholders and values related to our innovation project. To gain more precisions on these stakeholders and their expectations in terms of value creations, interviews were conducted. For confidentiality reasons, it was not possible for us to discuss much the innovation outside the enterprise. As a consequence, we only interviewed internal stakeholders. However, in order to access a maximum knowledge on the expectations of the external stakeholders, we took care to interview people inside the enterprise who are used to work with these stakeholders. Thanks to their specific knowledge they were able to transmit a good idea of the expectations of some external stakeholders.

Nine persons were interviewed: the chief executive director, the technical director, the chief financial director, the operations director, the commercial director and two people of his team, the quality manager and the purchasing manager. We had the objective of accessing knowledge in all the areas of the enterprise in order to have a view as complete as possible of the impact of the innovation. A discussion as free as possible was established with the interviewees. The discussion was centered on a few selected fields (see**Erreur ! Source du renvoi introuvable.**):

- The current cash cow product, its characteristics, benefits and drawbacks.
- The market that the firm addresses currently with this product and its position.
- The innovation developed, its characteristics, benefits and drawbacks.
- The internal and external stakeholders of the innovation, their characteristics and the reasons of their interests.

In the following part, we present a summary of the results of these interviews. We first present our analysis of their verbatim regarding the innovation, the cash-cow product it aims to replace and the markets addressed. Base on this, we propose different types of values that the innovation can create. Then we present an actualized list of stakeholders identified and analysis their relations regarding the innovation. Based on this analysis, we bring to light the expectations of the stakeholders in terms of values created by the innovation

2.1.3 *Product, innovation and market*

The interviews shade light on the different specificities of the innovation, the changes it brings compared to the current product and the different markets that they address.

- Current product: The current product relies on a technology that is several decades old. No innovation has been carried out on it for a long time. It is characterized by a very high reliability, which is identified as one of the most important value created by this product for the customer.
- Market: There are two different markets: the original equipment manufacturer market (OEM) and the repair market. The most profitable of these for the firm is the repair market. It brings high margins that balance a certain lack of profitability in other products and increases the volume on which development and qualification costs can be amortized. However the company faces competitors who copy its product at a lower cost and gain significant market shares. As it would be much harder to copy, the new product would enable an important economic value creation for the company and for some of its clients who also sell spare parts.
- Innovation: It is characterized by a high degree of technical incertitude. The technology innovation is not well controlled by the industrial partner that manufactures the key component. However this technological challenge ensures the company a safe advance on its competitors.

Crossing this analysis with the values found in the literature, we precised the list of the possible values first identified. The notion of image value was added. The ethical value was replaced by well-being, a term that better precise the type of ethical values that our innovation can create. Finally, the on-time delivery value, and the quality of communication were suppressed since our innovation does not provide additional creations of these values.

2.1.4 *Relation between the stakeholders*

Having precised the types of values that can be created by the innovation, we then focused on the stakeholders that benefit from these value creations. The interview enabled a reformulation of the previous list of stakeholders. New stakeholders were identified, such as certification authorities, public authorities. We replaced the “shareholders” by the American group L’Hotellier is a part of and the “humanity” by the environment. Based on the results of the interviews, we analyzed the relations of these stakeholders (see Figure 47).

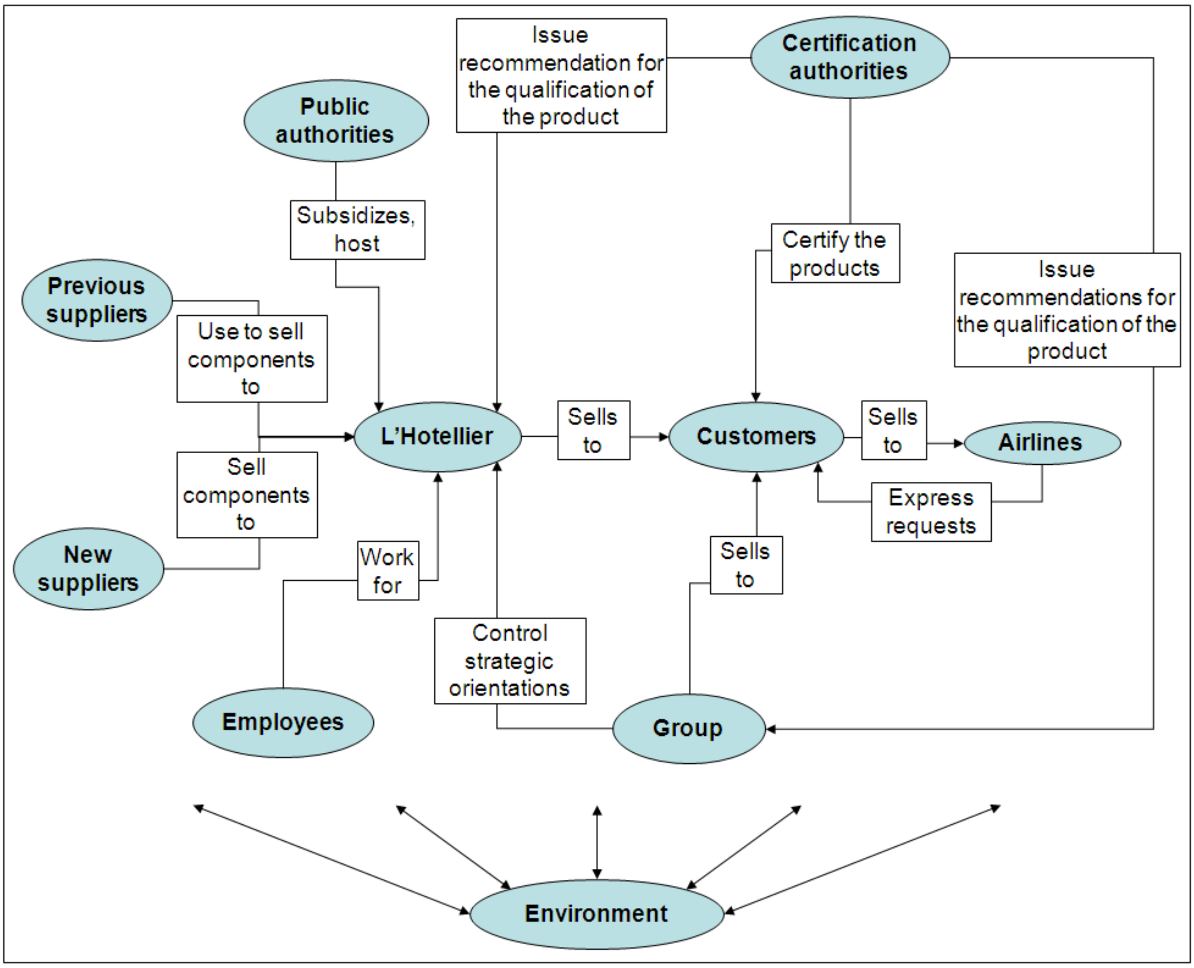

Figure 47. Relations between the stakeholders of the innovation

2.1.5 Value creation identification

This analysis of the different stakeholders and their relations in the innovation system gives us a clearer understanding of this system. It helps to extract from the interviews the expectations of the different stakeholders. These expectations are presented below with the related types of value expected.

- L'Hotellier's employees: The innovation would bring safer conditions of work for a few numbers of them currently working with pyrotechnical devices. It would also be a sensible recognition of their know-how by the group that owns the company (values: well being and knowledge) .
- L'Hotellier: It would bring them a competitive advantage as well as a better image in terms of innovation and environmental impact in a market that demands it. It would ensure a higher market share in the repairs market and could help the firm increase its market share in the OEM market. The company would also be allowed to cut on some investments related to employee safety. Finally, L'Hotellier would gain an expertise in this product. The successful development of the innovation would also give evidence of the value they add to the group and increase the innovative image of L'Hotellier regarding its suppliers (values: financial, knowledge and image).
- Customers: Innovative products would ensure a better impact on environment in a context of strengthening regulations. It would save them some logistics costs, increase the safety of their employees and diminish the related costs. It could also decrease the mass of a minor system in their products. They expect from this new product the same high level of quality than from the previous one. Finally, suppressing pyrotechnical devices from the aircrafts also increase their image (values: financial, quality and image).

- Group: They could also use the innovation on their products with the same advantages as their filial (values: financial, knowledge and image).
- Public authorities: It would decrease some safety related risks in the location of the firm's premises (values: ecological and well being).
- Certification authorities: They are responsible for the certification of the aircrafts. As such, it is based on their recommendations that a new component is validated or not. They have no particular interest in the introduction of the innovation (values: quality).
- Former product suppliers: The innovation being launched would induce a decrease of the business our firm has with them. If the technology is still used on other products, this could lead to an increase of their selling prices. However, the L'Hotellier only represents only a small part of their total business (value: financial).
- New Product suppliers: They would gain a new business and possibly access to a new technology (value: financial and knowledge).
- Competitors: they could lose market shares with the introduction of the innovation (values: financial).
- Airlines: they use the final aircrafts. They would be interested in the reduction of purchasing and maintenance cost due to the introduction of the innovation. Finally, suppressing pyrotechnical devices from the aircrafts also increase their image (values: financial and image).
- Environment: replacing the pyrotechnical cartridge by a ceramic compound would diminish the quantity of lead released in the environment (value: ecological).

By crossing these expectations with the value that we had identified, we were able to represent a first cartography of the possible value creations of the innovation (see Figure 48). This first list of stakeholders and value creations was validated with the steering committee of the project that regroups actors from all trades in the company, in order to ensure that the representation we have of the context of the innovation is accurate and understandable.

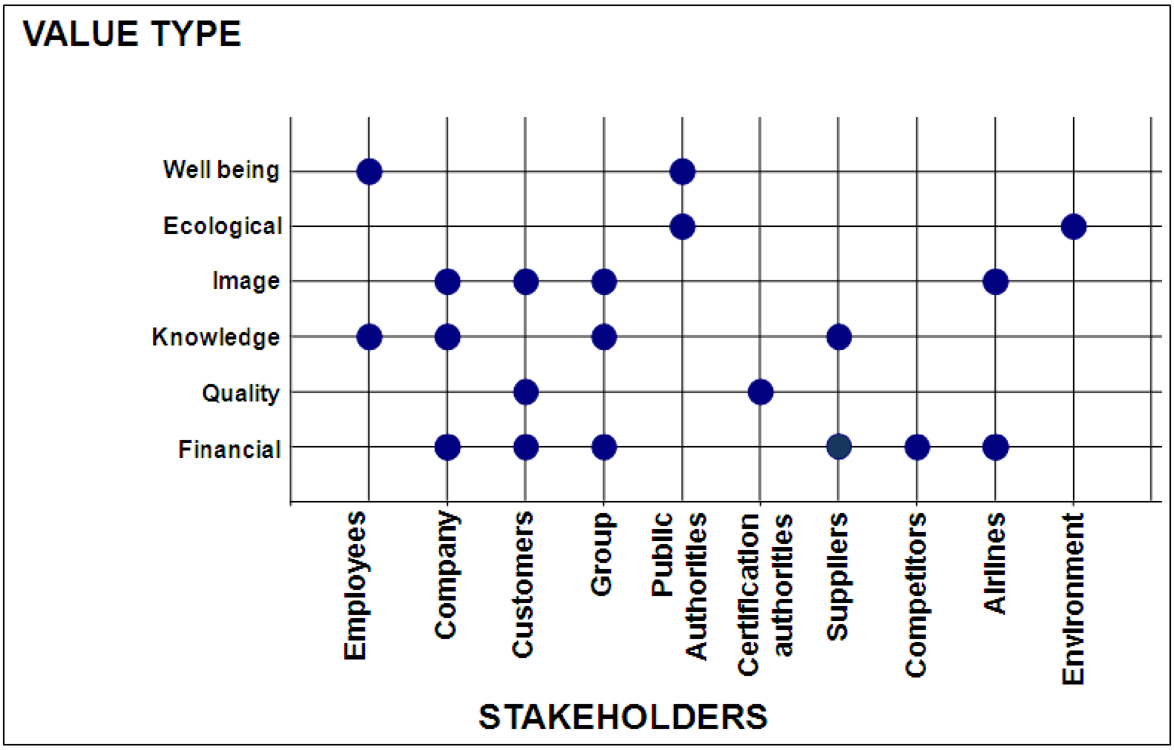

Figure 48. Possible value creations by the innovation

2.2 Adaptation to the selection of a manufacturing process for the ceramic

This preliminary analysis gives a relatively good comprehension of the different actors of the innovation and of their motivations. It served as a base to precise the problem setting related to our specific decision. By crossing this analysis with the specificities of the decision treated we were able to identify the values creations concerned by the decision and analyze its requirements (Figure 48).

2.2.1 Value creation identification

The preliminary analysis provided us with a list of possible value creations. We first re-precised these possible value creations. Since we are dealing with the development of a technology, the question of the initial investment was deemed very important. This led us to refine the economic value by precising if this financial value is short-term (following year), mid-term (next three years) or long term (next ten years). The importance of the reliability of the product was also an important point raised in the interviews. This led us to precise the notion of quality value. We detailed the performance of the product (does it accomplish its function) from the robustness of this performance (is it durable).

2.2.2 Requirements identification

For some of these value creations, a minimum level is required. Solutions are not acceptable if they do not comply with this minimum creation of value. The identification of these requirements is done through the interviews of the stakeholders and a possible analysis of some specifications. In our cases, a requirement expressed was for the selected process to be usable for the industrial production of the ceramic component. A second requirement was that the process should ensure that all samples produced should be compliant with the specifications. Finally, the process should not require too many actors to be implemented in order for the firm to be able to control this key knowledge.

3 Alternatives selection

Once this problem setting phase had been completed, possible alternatives for the decision were searched for. In this case, of the six tactics proposed by Nutt (Nutt 2001) to uncover the alternatives of a decision (idea, benchmarking, integrated benchmarking, search, cyclical search and design), only the search tactic was used.

The focus of the decision being the selection of a manufacturing process for a technical ceramic, expert's knowledge was required. In addition to that, since no process adapted to the ceramic currently exists, the implication of an external actor able to perform this technology adaptation was required. The choice was made to ask the current producer of ceramic to propose different solutions.

3.1 Alternatives identifications

Based on the prevision quantity planned for the production phase and on the shape of the ceramic component, the search for alternatives led to the identification of three possible technologies for the formation of this ceramic: the uniaxial pressure (the technology currently used), the slip casting and the powder injection modeling. For each alternative, two solutions were studied: the production is done by L'Hotellier or by an external supplier. We present the three technologies in the following paragraphs. This presentation is based on the books Engineering Materials Science from Ohring(Ohring 1995)and Physical Metallurgy and Advanced Materials Engineering from Smallman and Ngan (Smallman and Ngan 2007) .

3.2 Uniaxial compression or die pressing

3.2.1 Process presentation

The uniaxial compression is the manufacturing process currently in use at the moment of the decision. It is very simple but can be very efficient depending on the type of ceramic is used on and the usage that is required. In this process, the ceramic powder, usually characterized by a relatively high granulometry (around a few micrometers) is mixed with a small quantity of binding agent. The mix is then pressed in simple shape. The result is a crude sample called "green body". Its cohesion is assured by the presence of the binding agent who holds the ceramic powder together. In some cases (depending on the type of material), the ceramic compound is then hard enough to perform small modification of its form. The next phase is a two-step thermal treatment. The first step enables the elimination of the binding agent. The second step, the sintering, is a high-temperature treatment. During this step, the ceramic shrinks. It causes the hardening of the ceramic that reaches its final density. Finally, machining is required in order to give the component its final shape (see Figure 49).

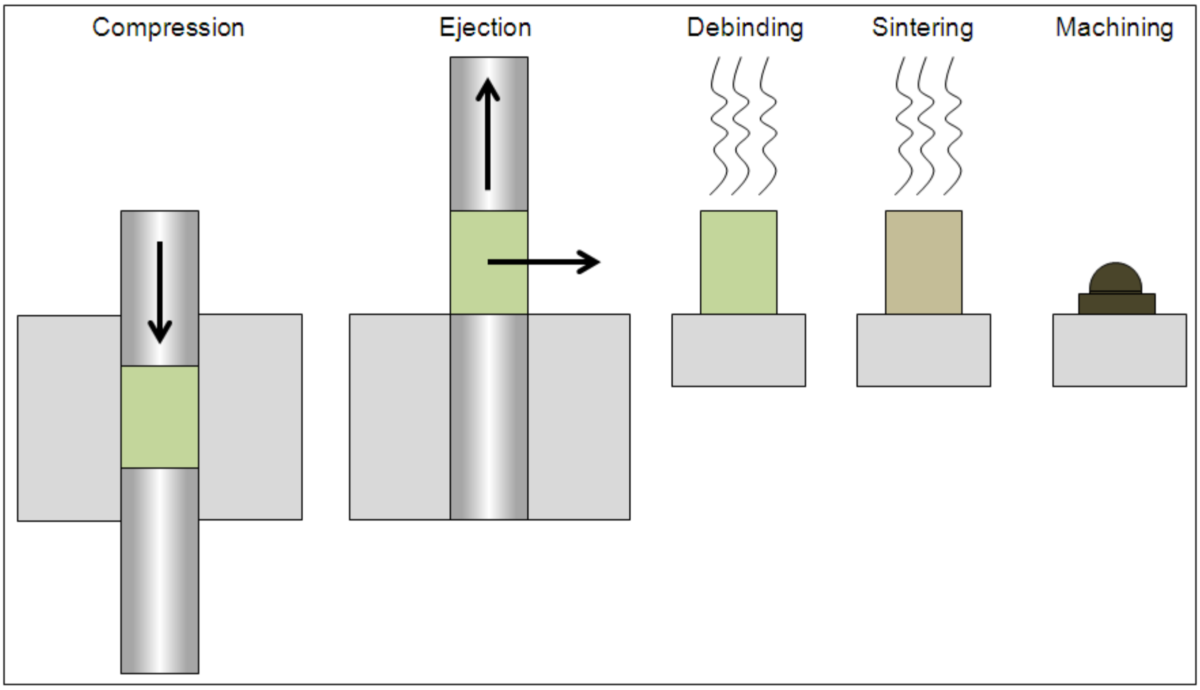

Figure 49. Uniaxial compression process main steps

3.2.2 Industrial analysis of the process

This process is very often used in the industry; the forming material required is relatively simple which makes this technique generally less expensive than others. However, from a quality point of view, the important machining required post sintering can induce cracks in the ceramic. In addition to that, the ceramic being compressed only on one direction, its mechanical properties are not homogenous. During the sintering phase, this can lead an inhomogeneous shrinkage of the ceramic. The combination of these two parameters makes the repeatability of this process possibly mediocre. This process is adapted to the manufacture of relatively small series (a few thousand pieces per year). Finally, it is to be noted that the sintering process is very complex. The elaboration of a solution that enables a good control of both the shrinkage and the density of the ceramic during the sintering is very complicated.

3.3 Slip casting

3.3.1 Process presentation

Slip casting is a technique used in the industry to make thin ceramic shell-shaped objects. A ceramic slurry or slip is constituted with a mix of ceramic powder, binding agent and a liquid solvent. This slurry is poured inside a mold made of porous plaster. Thanks to this porosity, the liquid part of the mix is absorbed. The excess of slurry is then removed. Once this is completed, the ceramic is left to dry. At the end of the drying phase, the ceramic has retracted and can then be removed from the mould. The component is then sintered at a high temperature (see Figure 50).

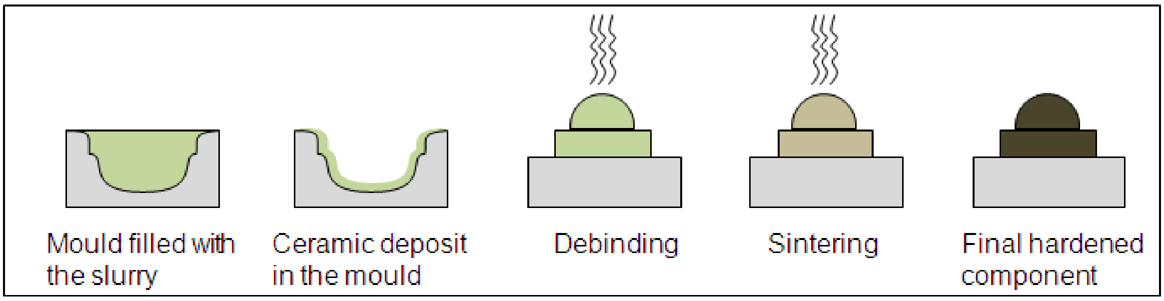

Figure 50. Slip casting process main steps

3.3.2 Industrial analysis of the process

The application of this process is usually manual. In order to ensure good results, an important know-how is required throughout the process. Furthermore, due to the complexity of this process, the repeatability is not very good and the discard rate can be relatively high. The mechanical properties of the ceramic are however much more homogenous than in the case of uniaxial compression. As for uniaxial compression, the sintering represents a very complex step. This industrial process is adapted to the manufacture of small series (a few thousand components a year). As for the uniaxial compression, the investments in material required by this process are not very high.

3.4 Powder injection molding

3.4.1 Process presentation

The powder injection molding process requires heavier machinery. An organic binder is added to the ceramic powder in order to obtain a mix with a relatively low viscosity. This mix is then filled inside an injecting screw. Inside this screw, the mix is heated and injected in pre-heated molds. The components once ejected go through a thermal or chemical debinding process. After this step, due to the action of the temperature or the chemical solvent, the entire binding agent has been removed from the ceramic part which can then goes through the sintering process (see Figure 51).

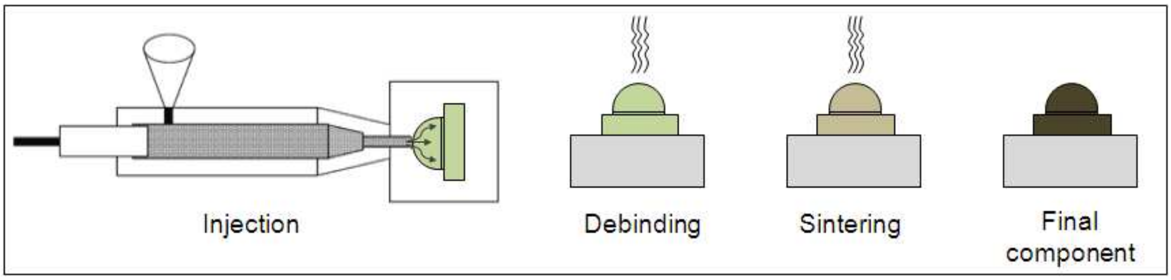

Figure 51. Powder injection molding process main steps

3.4.2 Industrial analysis of the process

The materiel required for the injection molding process is the heaviest of the three processes considered. The forming process (injection of the mix in the mold) is fully automatic which leads to a good repeatability of the process. It also ensures a good homogeneity in the repartition of the mechanical properties. As for the other processes, the sintering represents a very complex step of the process. Furthermore, it can sustain very high production rate. The powder injection molding process is adapted to important series (superior to ten thousand pieces per year).

4 Criteria identification

Once different alternatives for the decisions had been identified, we studied the specificities of each of them. Based on this analysis, we intended to reduce the number of value creations that need to be studied. Diminishing this number makes the assessment of the value creations easier. But, in addition to this reduction of the analysis work that needs to be completed, decreasing the number of criteria also eases the decision for the project steering committee. With less information to process, selecting the preferred alternative is simpler.

However, this shouldn't be done if key information is neglected. That is why every decision of not taking into account a possible value creation as a criterion is carefully weighted in order to ensure that decision-makers are presented with all relevant information. In this case, we chose not to focus on some stakeholders that were not very impacted by the decision.

First, we made the choice not to study value creation for the former and new potential suppliers. This is due to the fact that for the current supplier of pyrotechnical components, the selection of any of the manufacturing process for the ceramic has the same impact. For the possible value creations for future suppliers also, with the information we currently have, the choice of an alternative doesn't make an important difference. For similar reasons, we also choose not to focus on the values that can be created for the civil authorities. The main impact for them is the suppression of pyrotechnical components, not the selection of one of the ceramic manufacturing process whose impact for the collectivity is sensibly the same.

The creation of values for the certification authorities were not studied as well. As we have said, the certifications authorities' role is to provide guidance and advice on the suitability of a given component on an aircraft and at a larger scale to certify the aircraft. As such, they do not have much particular expectations regarding the innovation. Likewise, they cannot provide much to it. Furthermore, by taking into account the identified requirement and the customer's expectations regarding the reliability of the product we ensure that it reaches a sufficient level of quality to satisfy them. Finally, we also did not focus on the creation of value for the competitors. At this stage of the project, the information we gathered cannot show that the selection of one alternative amongst the others would influence possible value creations for the competitors.

5 Value creation and risks assessment and representation

The values creations we identified and re-formulated are to be used as decision criteria. Amongst all these, we identified some that could not provide differentiating information amongst the alternatives and put those aside. We now have a set of valid decision criteria. The next phase consists in the evaluation of these criteria for each alternative and their representation so they could help decision-makers.

5.1 Risks and value creations assessment

In order to help to decision-makers in critical decisions in innovation projects, we propose to provide them with a representation of the values that the innovation can create and the risks that are associated to these value creations. The assessment of these values and risks is done in three steps. First, each value is characterized by factors that enable its assessment, then based on the evaluation of the characteristic factors, the value creations are assessed. Finally, for each value creation, the risks associated are studied.

5.1.1 Value creations characteristics identification

Assessing value creations is essential in order to provide helping information for decision-makers. However it can be complex since a “creation of value” is a relatively abstract criterion. In order for their assessment to be possible, they need to be characterized by more concrete factors. As often as possible, we tried to identify quantitative factors to characterized possible value creations. However, in some cases, it was not possible and we had to settle down for quantitative evaluations. These characteristics are detailed below (see also Table 11):

- Short-term financial value: The short-term value creation of a process is characterized by the cost of adaptation of this process to the ceramic material considered.
- Mid-term financial value: The mid-term value creation of a process is characterized by the amount of investment required in order to deploy it.
- Long -term financial value: The long-term value creation of a process is characterized by the final manufacturing price of the ceramic component.
- Product performance: The product performance is characterized by its mechanical properties: its flexural strength, Young modulus, the homogeneity of its properties and the probability to have critical-sized cracks.
- Performance robustness: The performance robustness is characterized by the repeatability of the process.
- Knowledge: Following a resource based view approach; depending on the stakeholders concerned, we propose the rarity and inimitability of knowledge as the key characteristics. The rarity of the knowledge is key for the employees as it represent an asset that they can value with their firm, whereas the inimitability of the knowledge is key for the firm that does not want its innovation to be copied.
- Image: The creation of image value can be assessed by the low-tech or high-tech image associated with other applications of each process.
- Ecological value: The ecological value is characterized by quantity and the toxicity of the by-products used in the process. Another factor can be the usage of heavy machines in the process.
- Well-being: Finally, the well-being creation is characterized by the danger the operators of the process are exposed to.

Values	Assessable characteristics
Financial	Process adaptation costs, industrial investments required, final component cost
Product performance	Flexural strength, Young modulus, iso-repartition of its characteristics probability of cracks
Product performance robustness	Repeatability of the process
Knowledge	Rarity and inimitability of knowledge involved
Image	Low-tech or high tech image associated with other application of the process
Ecological value	Quantity and environmental impact of the materials used for each process. Use of machines
Well being	Danger of the materials used

Table 11. Assessable characteristics of each value creation

5.1.2 Value creation assessment

Once we had identified characteristic factors for each type of value, we assessed separately each type of value creation for all alternatives. We present here only a sample of this assessment; the financial values (see Table 12). The assessment of other value creations can be found in the annexes of the document (see **Erreur ! Source du renvoi introuvable.**).

The short term financial value only concerns one stakeholder: the enterprise. It is characterized by the cost of adaptation of the process to our ceramic. The development cost for the uniaxial compression is very low since it has already been developed. Adjustments need to be made to the existing process but the total amount is inferior to twenty thousand Euros. Our ceramic has never been formed with a slip casting process. Thus the research and development cost associated to the adaptation of this process are higher. An estimation of these costs was performed by the ceramic supplier for a total of sixty thousand Euros. The same estimation performed for the powder injection molding was one hundred and twenty thousand Euros.

Mid-term financial value is created for L'Hotellier and for KAD, the American group. This creation is characterized by the investment costs required to manufacture ceramic components. Since the prices of the different pieces of equipment have a wide range of price, this evaluation is only qualitative. In the scenarios where the ceramic components are manufactured by an external supplier, the cost is identical and very low for all the technical solutions. However, if the components are manufactured by L'Hotellier these cost are much higher since every solution requires a sintering furnace, a very expensive piece of equipment. These investments are even higher for the case of the powder injection molding process where an injection press is required. This value creation is identical for both stakeholders.

Finally, the long term financial value is created for L'Hotellier and for KAD. It is characterized by the future unit costs of the ceramic components once they are commercialized. Once again, for this value creation there is not enough information at this stage of the project to have a precise estimation of the future unit costs. However, comparisons can be made between these costs, based on the size provisional production volumes of L'Hotellier (around six thousand pieces per year) and KAD (around fifty thousand pieces per year) and on the capacities of each process. In addition to this, based on previous experiences, the uniaxial process is likely to be characterized by a high extra cost of poor quality. Based on this criterion, we can postulate that for L'Hotellier, the most expensive solution is the uniaxial compression (adapted for medium series around a few thousands) followed by the injection (adapted for series superior to ten thousands) then the slip casting (adapted for medium series around a few thousands). For KAD, the most expensive options should be the uniaxial compression, followed by the slip casting, the injection as the most adapted process should be the cheapest option.

	Process adaptation cost	Investment costs	Unit manufacturing cost
L'Hotellier	Uniaxial Compression (UC): 20 000 € Slip Casting (SC): 60 000 € Powder Injection Molding (PIM): 120 000 €	External alternatives: no investment cost Internal alternatives: UC << SC < PIM	SC < PIM < UC
Kidde Aerospace and Defense	Non applicable	External alternatives: no investment cost Internal alternatives: UC << SC < PIM	PIM < SC << UC

Table 12. Assessment of financial value creation for L'Hotellier and Kidde Aerospace and Defense.

The main conclusion of the assessment of other values are that the injection molding present a large advantage over the over two technologies from the point of view of the product performance and performance robustness. It is also associated to high technologies applications and thus would create more image value. The ecological value is significantly greater for the uniaxial compression. From the knowledge point of view, all internal solutions present a high level of value creation since every process requires the use of rare and non-imitable knowledge, at least for the ceramic sintering process. At the opposite, all external alternatives are characterized by a low knowledge value creation.

From the risk point of view, the value creation in terms of product performance and performance robustness all present a significant level of risk (medium risks). Knowledge values created for the employees in all internal solutions are characterized by high risks since this new knowledge would probably be acquired through the hiring of new resources expert in this field and not through the formation of the current employees.

5.1.3 Risks identification and analysis

For each of the value creations, we then have performed a risk analysis. We have identified the main risks threatening this value creation and assessed their probability and impact on a scale of one to five in order to calculate their criticity (see Table 13). We adopt here this relatively simple scale adapted from the FMEA (see II.3: Risk threatening value creation in innovation projects) to better fit with what is usually done inside the enterprise. Once again, we only present here a sample of the work performed: the risk evaluation conducted on short-term financial values creation.

Risk probability evaluation			Risk impact evaluation	
1	Rare		1	Insignificant
2	Unlikely		2	Minor
3	Possible		3	Moderate
4	Likely		4	Major
5	Almost certain		5	Catastrophic

Table 13. Risk probability and impact evaluation scales

For each industrial process we identified one major risk: underestimating the cost of adaptation of the process to our ceramic. For the uniaxial compression, we assessed the probability of this risk as rare, since this technology is already in use for our ceramic. Since the adaptation costs are relatively low, the impact of the apparition of such a risk would also be quite low. For the slip casting and the powder injection molding, the probability of underestimating the development costs is higher since there is no example of usage of these technologies to manufacture our ceramic. However, there is no particular factor that makes the cost evaluation uncertain. The impact of a cost misevaluation was assessed based on the estimated development costs. The impact of a significant misevaluation should be higher on the powder injection molding process characterized by high development cost.

5.2 Value creation and risks representation

Once the task of value creations and risks assessment has been completed, the results must be presented to decision-makers. The presentation of this information needs to be easy to read and understand by decision-makers. Its main objective is to enable an easy comparison between the different alternatives. This is not possible if we want to keep a high level of detail on the different value creations and risks. Too much information would be presented at the same time which would hinder the faculty of decision-makers to process it. As a consequence, we decided to present two different levels of information. The first level presents for each alternative a summary of the value creations and risks. A second level details for each couple value/stakeholder the value created by each of the alternatives and the risks associated.

5.2.1 Value creations and risks summary for each alternative

The low level of information admissible for the presentation of each alternative overview requires that the presented information be of a qualitative nature. The constitution of this summary requires that the different types of value creations be represented on a similar scale. This is done in order to avoid cognitive bias caused by a too big difference between the representations of the different value, and that could lead to irrelevant comparisons. We choose to establish five levels of value creations that can enable a clear comparison between a given value creation in the different scenarios that were presented in the earlier chapter detailing our model (see Table 10).

Based on the assessment we conducted, we provided each value creation with a note ranging from one to five. The representation of the risks associated to each value creation is based on their criticity previously assessed. We compiled this data with excel spreadsheets and created a graph per alternative representing the value creations as circles at the intersection of a value type and a stakeholder. The level of value creation is represented by the size of the circle. A color code represents the criticity of each value creation (see Figure 52 and Figure 53). The value creation representations for the six alternatives are presented in the annexes (see.

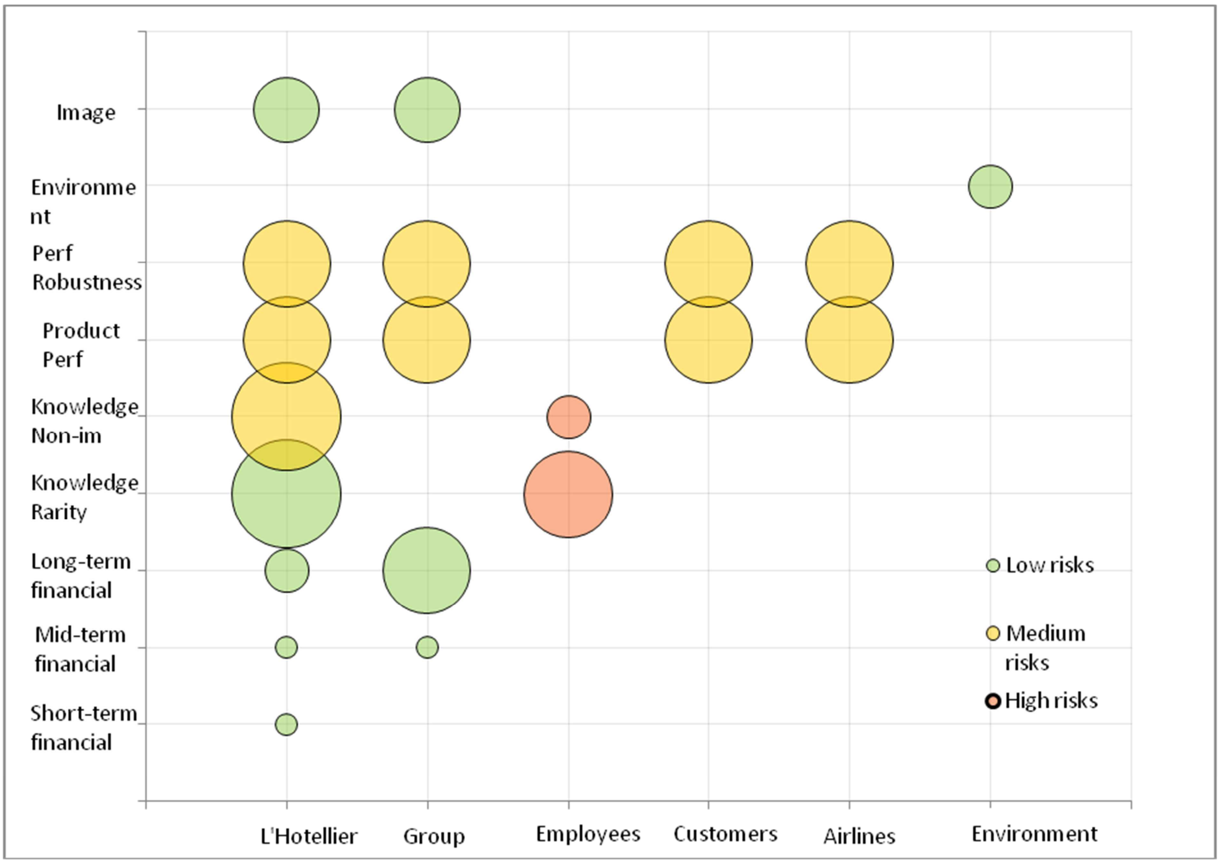

Figure 52. **Value creations summary for the powder injection molding alternative (internal option)**

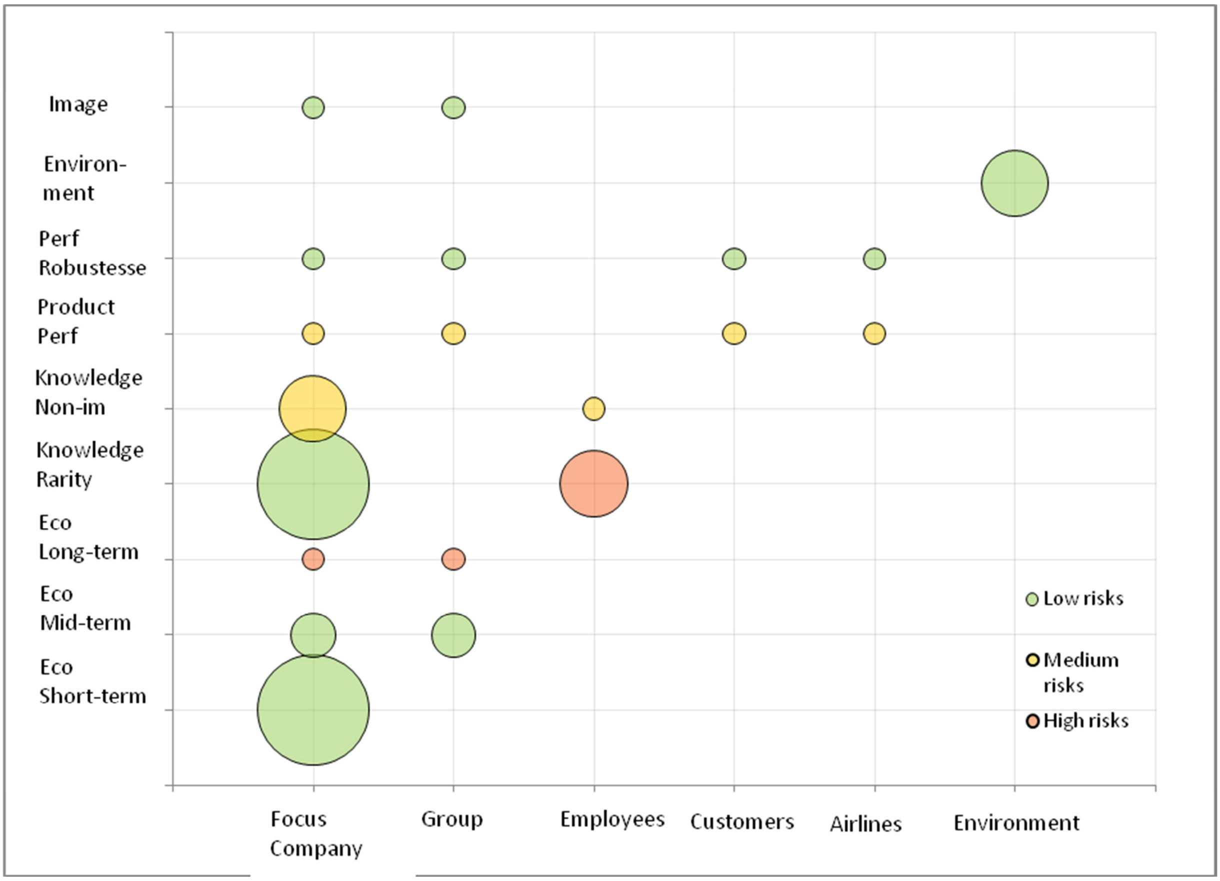

Figure 53. **Value creations summary for the uniaxial compression alternative (internal option)**

5.2.2 *Deeper focus on risk and value creations*

This first presentation of information is essential in order to give to the decision-makers an overview of the value creations and risks associated to each alternative. However, it cannot be sufficient to make a decision. A deeper analysis of each alternative based on more detailed information is necessary. The purpose of this second level of information presentation is to be able to compare as precisely as possible the different alternatives for a few specific value creations that are deemed the most important. This second level regroups and synthesizes for one value creation the information that led to the construction of the first graphs (see Figure 54).

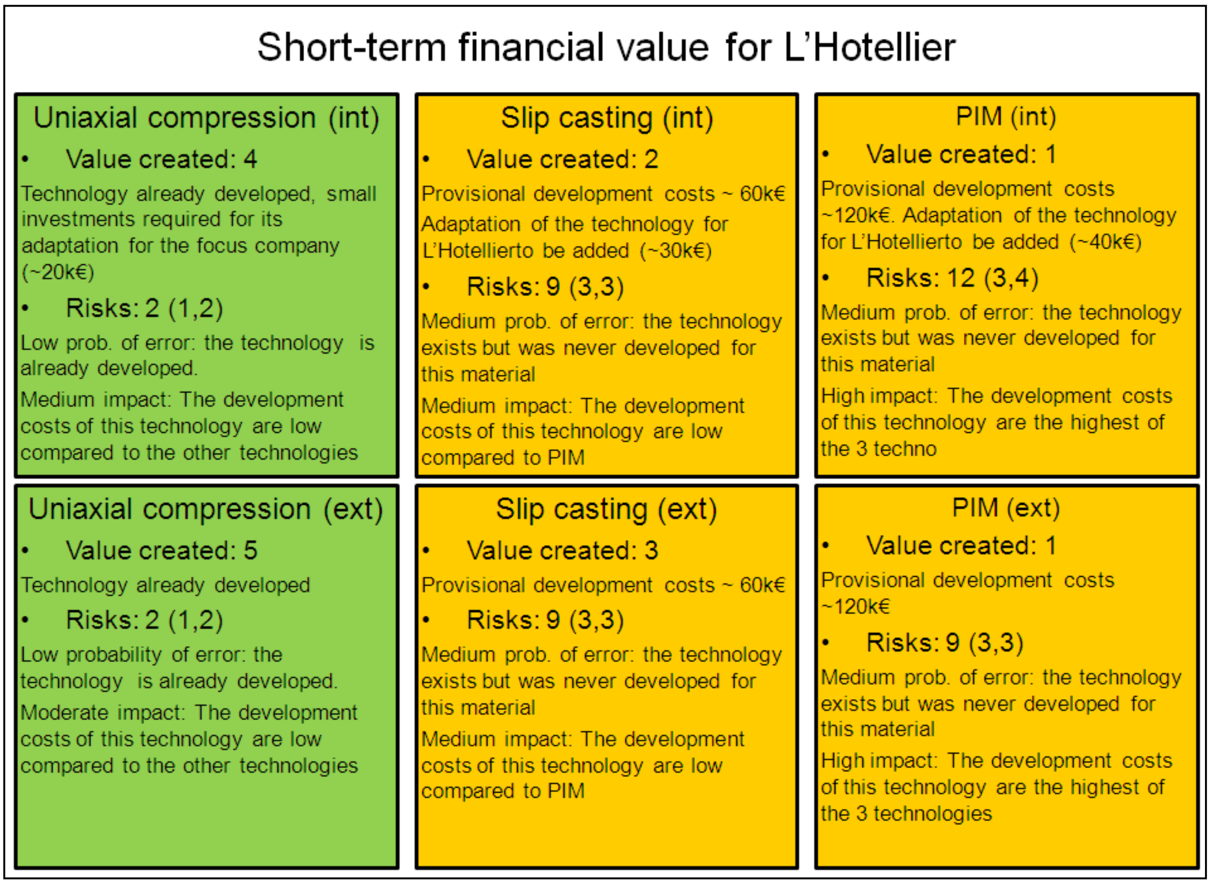

Figure 54. Synthesis of information about short-term financial value creation for L'Hotellier.

Numbers after value created represent the level of value creation (cf. Table 10); Numbers after risks represent the criticity (probability, impact) (cf. Table 13).

The possibility of making connections between the two levels of information is essential. That is why we chose to link those two media. The final document presented is a series of graphs presenting value creations and risk for each alternative, where each circle representing value creation contains a hypertext link pointing toward the document synthesizing the information on this value creation for all the alternatives. More results are present in the annexes.

6 Analysis

By comparing the situations before and after the application of our model we can see that our approach significantly increase the level of information available to decision-makers. In one case the only information available is limited to the costs of development of each solution and to an estimation of the level of quality of the outcome. After the application of our model however, we have a larger estimation. The economical aspect is diversified into short, mid and long-term financial value creation. The quality is refined into product performance and performance robustness. Other aspects such as ecological values, image and knowledge are also taken into account. The stakeholders studied are not limited to the enterprise and the customers but include the employees, airlines, the group Kidde and the environment.

We presented to decision-makers this work done on the value creations associated to each alternative. A discussion with decision-makers based on the presentation of this information led to the justification a posteriori of the selection of the injection process. The product performance and performance robustness values created and the non inimitability of the knowledge involved represent the key criteria of this decision. Even if the decision taken would have been the same with or without our model, the supplement of information presented is helpful and could have changed the decision. As such, we can justify that our model is useful to assist decision-makers by providing them with an increased level of information.

VI. Second decision: selection of a market offer for the innovation

One of the preliminary objectives of the thesis was to help decision-makers to select the best alternative for the introduction of the innovation. We thus decided to make of this a second case of experimentation for our model. Since the development of the product is not yet finished at the end of the thesis, the innovation development is still characterized by a significant uncertainty. For some aspects, the information necessary for a comfortable taking of this decision are not yet know. Some critical economic and industrial parameters such as the manufacturing cost of the product and the admissible life duration of the product are not known. Providing decision support in such a case is not easy. The approach we adopted is to deploy our model on this decision, knowing that some hypotheses are made and some parameters assessed with high uncertainty. An economical model has been constructed to enable an actualization of the value creation previsions as soon as more precise estimations of key parameters are available.

1 Preliminary step

As defined in our method, our model begins with a preliminary step in which the perimeter of the decision is defined. Once this perimeter is defined, it is then possible to evaluate the character critic of this decision by studying the impact it has on the project and the uncertainty associated with this decision.

1.1 Definition of the decision perimeter

The definition of the innovation process ranges from the conception of the product to its introduction on a market. The decision on which we focus now touches the limit of this definition: the value chain of the innovation and the market offer associated to the customer end of this value chain. The perimeter of the decision as defined by the project steering committee is very wide. The objective is to define the most adapted value chain of the innovation developed. Specifically, the definition of this value chain should enclose the definition of the market offer (product, price, maintenance, lifecycle). The focus ranges from first and second rank suppliers to final users. It takes economic as well as technical considerations into account.

However, based on previous analysis work and in order to simplify the parameters of this decision, this perimeter was restrained. We choose not to focus on the whole supply chain of the innovative product but only on the key component: the ceramic sample. After a rapid analysis of the types of extinguishers the innovation is adapted to, we made the choice to restrain the perimeter of the end of the value chain by limiting our focus to the two main customers of L'Hotellier. This choice also restrained the types of final users. In the rest of this chapter we refer to this decision as value chain selection.

1.2 Critical decision identification

Based on this definition of the perimeter of the decision, we can assess its criticity. Do decision-makers have enough information and knowledge to treat this decision easily?

1.2.1 Impact assessment

First, we begin by the evaluation of the impact of this decision on the performance of the project, represented by its cost, quality and on-time delivery.

- From the cost point of view, the impact could be relatively important. The life duration of the product is an important part of the market offer. A market offer based on a very long life duration of the product could lead to a redesign of the product in order to be able to ensure the life duration promised to customers.

- Likewise, a redesign of the product aiming to increase its life duration would impact the duration of the project
- Finally, from a quality point of view, the final success of the project is impacted by this decision. The choices of the market offer and of the value chain highly impact the profitability of the innovation.

As we can see, without much surprise, this decision has a very important impact on the outcome of the project.

1.2.2 Uncertainty assessment

In addition to the impact of the decision on the project, a second criterion is needed to define a decision as critical: the uncertainty associated with its alternatives. In our case, in addition to the high impact the decision has on the project, its alternatives are not well known. Every member of the project steering committee has his own idea of possible alternatives but no concrete information is really available and no common discussion on this topic has been undertaken. As a consequence, with a high uncertainty and a significant impact on the outcome of the project, this decision can be classed as critical (see Figure 55). Based on this evaluation, we can postulate that the application of our model to this method can bring a lot of value to this decision.

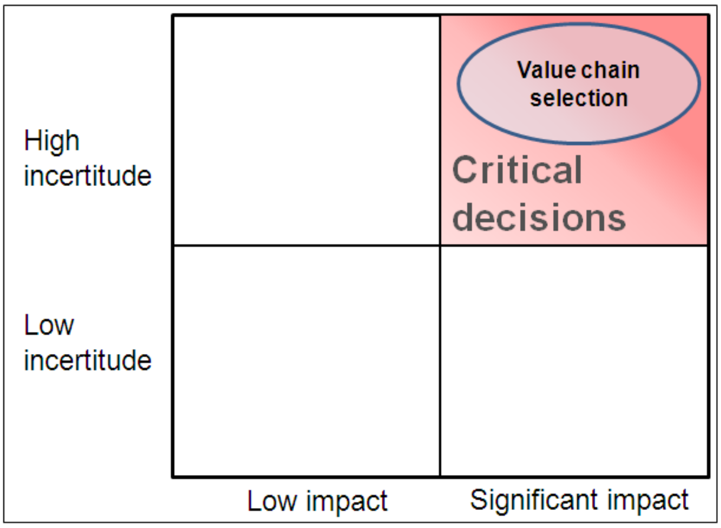

Figure 55. Criticality of the second decision

2 Problem setting

Once the decision has been identified as critical, our model proposes a first step of problem setting in which the goals and requirements of the project are clarified. For the completion of this step, we based our work on the analysis previously completed about the possible value creations of the innovation identified during the problem setting phase of the first experimentation (see V.2.1: Values creations of the innovation: preliminary study)

2.1 Values identifications

The analysis completed in the former experimentation led to the identification of possible value creations by the innovation. The results of this analysis are summed-up in a grid presenting which kind of value can be created for which stakeholder (see Figure 48*)*. In the following part, we start from these preliminary result and adapt them to the specific case of the selection of the value chain.

2.1.1 Value creation identification

A first adaptation regards the stakeholders identified. The choice was made to make a distinction between different types of customers. The ceramic disk is design to be first implemented on different aircrafts: business jets and helicopters. These two markets have some key differences regarding the lifecycle of the product. For the helicopter market, extinguishers need to be revise every five years and pyrotechnical cartridge have a life duration also of five years. For business jets, revisions need to be performed every five years and pyrotechnical devices have a life duration of ten years. The difference of life duration is due to difference in the level of stress endured by the components depending on the type of aircraft. In addition to that, the commercial offer for the aftermarket is not the same for the two markets. Due to this diversity, we chose to distinguish two customers: helicopter manufacturers and business jets manufacturers. Likewise a distinction was made in the end user category between helicopter and business jets end users.

Regarding the different types of values, as for the selection of the manufacturing process, we chose to make a distinction between two types of quality value: the performance of the product and the robustness of this performance. We also chose to only consider well being as a social value created.

2.1.2 Requirements identification

Requirements in the industry usually refer to technical items. In the case of the selection of a value chain, these requirements are also of a different nature. A first requirement for L'Hotellier is to keep the same level of financial benefit. For L'Hotellier's customer the requirements are: no prices increase over five percent, no degradation of the technical performances, no price increase of the maintenance cost over five percent, no augmentation of the mass of the product over twenty grams.

3 Alternatives selection

This problem setting phase is essential as a preliminary work for the selection of alternatives. It enables the teams responsible for the selection of these alternatives to have a clear vision of the stakes of the decision. For the decision on the selection of the value chain, the tactic used to uncover alternatives was a mix between the design and search tactics. This subject being to strategic to subcontract it, it had to be dealt with internally which ruled out the search and cyclical search solutions. Moreover, the characteristic of a value chain are very context-related. As such, benchmarking techniques (benchmarking, integrated benchmarking) are not very useful for its definition. External knowledge is not applicable to this context-related problem.

The method adopted was a classic two steps divergence-convergence approach (see Figure 56). In a first divergence step, the levers that could be used to differentiate the alternatives were identified, leading to an arborescence of possible alternatives. Due to their too great number, in a second convergence step, some were eliminated for logical reasons. Finally, a choice was done amongst the last ones in order to have a workable number of alternatives. The selection was done with objective of cover different cases in order to enable decision-makers to see the influences of the differentiating parameters.

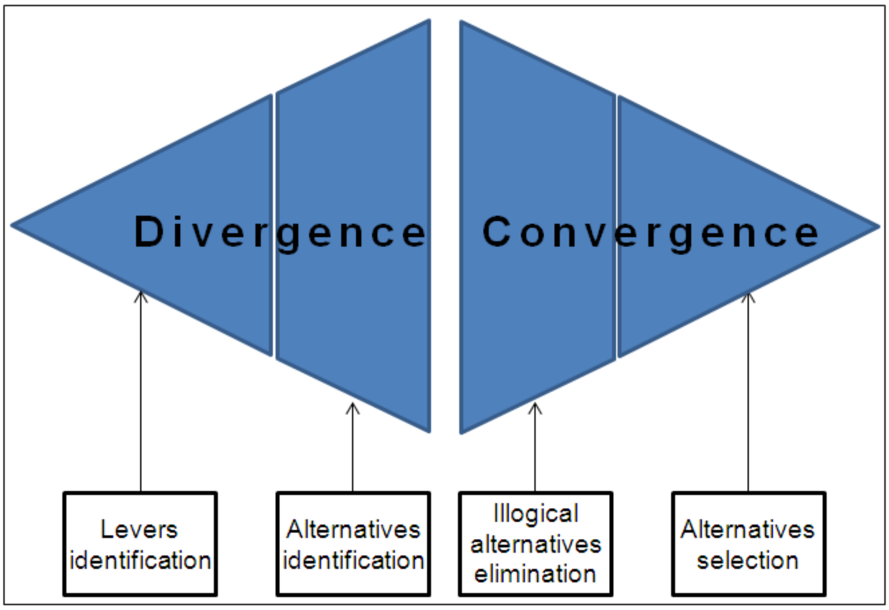

Figure 56. Divergence-Convergence alternatives uncovering and selection process

3.1 Alternatives identification

The first divergence step begins with the identification of the levers that can lead to the generation of alternatives. This phase was done in a brainstorming session with the chief executive director, the commercial director and the technical director. The perimeter of investigation was divided in two parts: the supply chain of the ceramic disk and the market offer. The ceramic disk manufacturing process is formed of three main different steps: the powder elaboration, the ceramic component manufacturing and the ceramic disk assembly (see Figure 57).

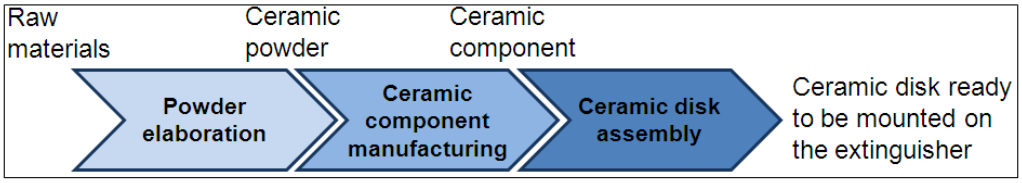

Figure 57. Ceramic disk manufacturing process

Regarding the ceramic disk supply chain, this session led to the identification of three levers: the number of ceramic powder suppliers (one or two external suppliers), the number of ceramic components suppliers (done by L'Hotellier or by one or two external suppliers) and the localization of the ceramic disk assembly process (is it done by L'Hotellier or not).

Regarding the market offer, one lever was identified: the time of compulsory revisions for the extinguisher. As we have seen, currently the situation is quite complex for the customers, with different lifecycles for extinguisher and cartridges (five year life duration for helicopter cartridges versus ten for business jets, five-year compulsory revision for extinguishers).

With the introduction of the ceramic disk though, the only relevant parameter is the time before the revision since the disk has to be changed during each revision. For this lever, two possibilities were retained. In the first one the disk need to be changed every five years, which mean the extinguisher has to be sent back as often. For the second one, the time before the compulsory revision is set to ten years.

The applicability of these alternatives is however conditional. The first one requires that the ceramic disk life duration is longer than five years for helicopters and ten years for business jets. The second one requires that the time before revision for helicopter extinguishers be extended to ten years and that the life duration of the ceramic disk for helicopters and business jets is longer than ten years. With this final lever, we have four parameters that can vary in the value chain in order to generate alternatives (see Figure 58).

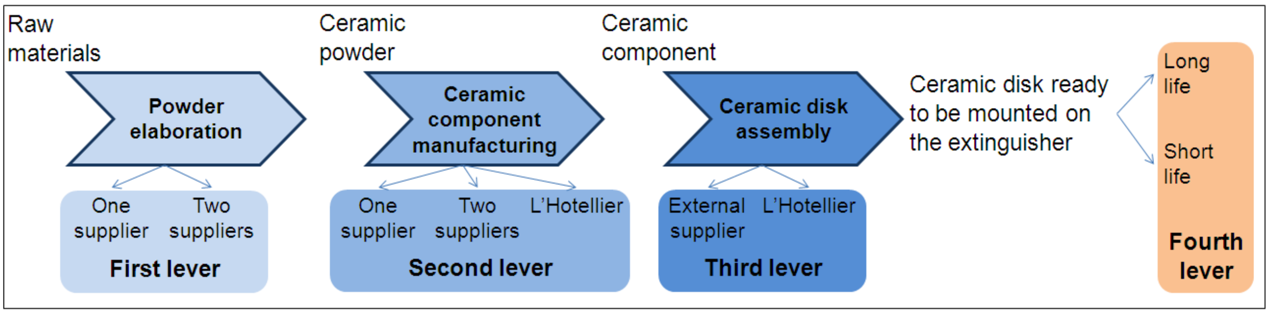

Figure 58. Levers enabling the generation of alternatives to decision

These four identified levers can be combined to generate possible alternatives (see Figure 59).

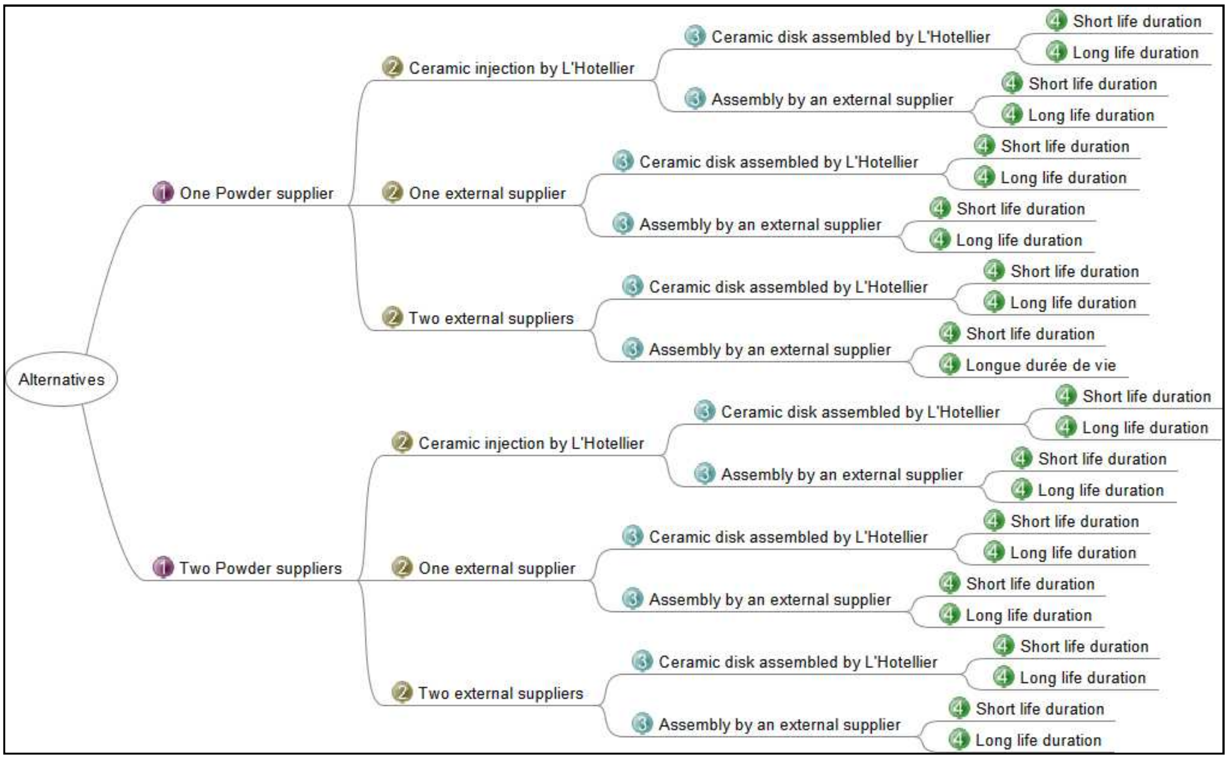

Figure 59. Mindmap of the different alternatives

3.2 Selection of relevant alternatives

The previous step has led to the identification of possible alternatives for our decision. However, the number of these alternatives is too big and the investigation of the value creations for all of them would take too long. As a consequence, we decided to select only a sample of them. First, we eliminated the solutions that seemed illogic: we assumed that if the ceramics are injected by L'Hotellier, the ceramic disk will not be assembled by an external supplier. This led to the elimination of four alternatives. After further discussion with the project steering committee, the decision was taken to abandon all cases where the ceramic is injected by L'Hotellier. This hypothesis being thought of as unrealistic since the manufacturing of ceramic is far from the core business of the company. This enabled to put four more alternatives aside. Then, in order to reach an acceptable number of alternatives (around six) we selected candidates that enable a wide covering of all the possible solutions. The selected alternatives are presented below.

- Integrated value chain, short life duration (see Figure 60) is characterized by a minimum number of suppliers. There is one supplier for the ceramic powder and one for the ceramic component (possibly being one and the same). The ceramic disk is assembled by L'Hotellier and has a short life duration (five years for helicopters and ten for business jets).

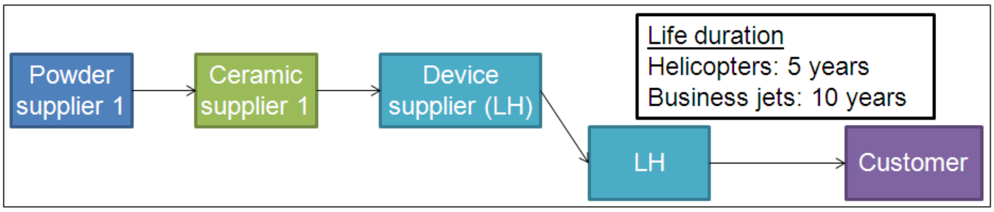

Figure 60. Integrated value chain, short life duration

- Integrated value chain, long life duration (see Figure 61) is characterized by a minimum number of suppliers. There is one supplier for the ceramic powder and one for the ceramic component (possibly being one and the same). The ceramic disk is assembled by L'Hotellier and has a long life duration (ten years for helicopters and ten for business jets).

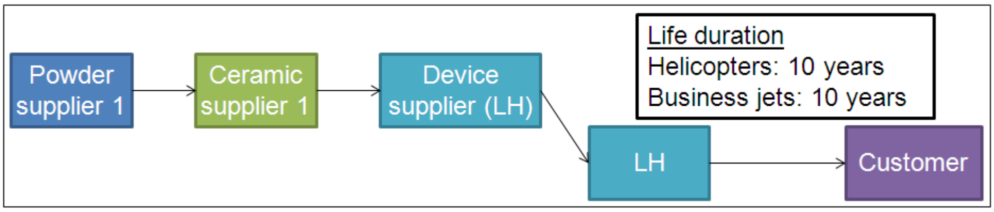

Figure 61. Integrated value chain, long life duration

- Simple value chain, short life duration (see Figure 62) is characterized by a small number of suppliers. There is one supplier for the ceramic powder and one for the ceramic component (possibly being one and the same) and one for the assembly of the ceramic disk. The ceramic disk has a short life duration (five years for helicopters and ten for business jets)

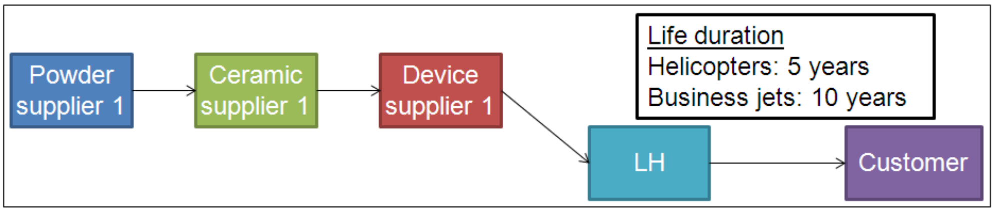

Figure 62. Simple value chain, short life duration

- Simple value chain, long life duration (see Figure 63) is characterized by a small number of suppliers. There is one supplier for the ceramic powder and one for the ceramic component (possibly being one and the same) and one for the assembly of the ceramic disk. The ceramic disk has a short life duration (ten years for helicopters and ten for business jets)

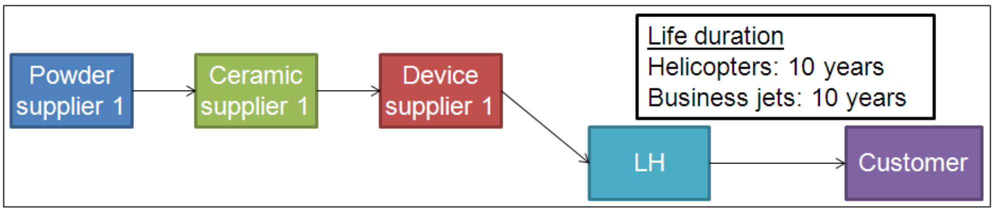

Figure 63. Simple value chain, long life duration

- Doubled value chain, short life duration (see Figure 64) is characterized by two suppliers both for the ceramic powder and for the ceramic component (possibly being one and the same). The ceramic disk is assembled by an external supplier and has a short life duration (five years for helicopters and ten for business jets)

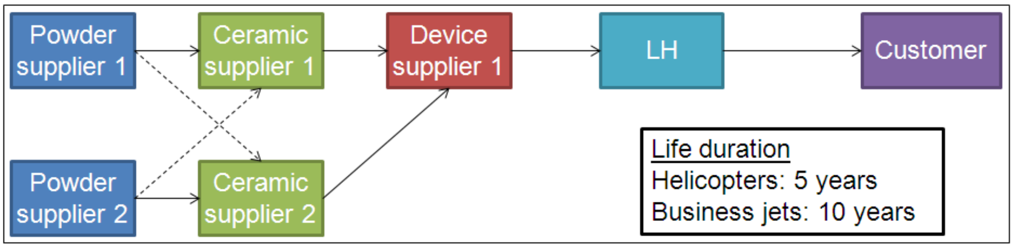

Figure 64. Doubled value chain, short life duration

- Doubled value chain, long life duration (see Figure 65) is characterized by two suppliers both for the ceramic powder and for the ceramic component (possibly being one and the same). The ceramic disk is assembled by an external supplier and has a short life duration (ten years for helicopters and ten for business jets).

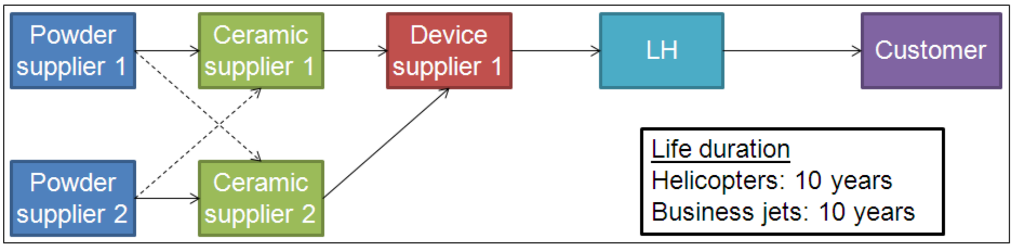

Figure 65. Doubled value chain, long life duration

In order to be able to assess the benefits that the innovation could bring compared to the current situation, a final alternative was added: the current solution based on pyrotechnical cartridges. These alternatives are summed up in the table below (see Table 14).

Alternative	2nd rank supplier	1st rank supplier	Assembly	Life duration (helicopter, jet)
Integrated value chain, short life duration	1	1	L'Hotellier	(5 years, 10 years)
Integrated value chain, long life duration	1	1	L'Hotellier	(10 years, 10 years)
Simple value chain, short life duration	1	1	External supplier	(5 years, 10 years)
Simple value chain, long life duration	1	1	External supplier	(10 years, 10 years)
Doubled value chain, short life duration	2	2	External supplier	(5 years, 10 years)
Doubled value chain, long life duration	2	2	External supplier	(10 years, 10 years)
Pyrotechnical cartridge current value chain	1		L'Hotellier	(5 years, 10 years)

Table 14. Alternatives selected for the decision

4 Criteria identification

With the possible value creations we enumerated in the problem setting, we have a set of criteria that can be used to assess each of the alternatives that were identified in the previous phase. As was done during the previous decision, a selection can be done in these criteria in order to have a final selection of criteria small enough so the information presented to decision-makers is easily processed and the analysis of the alternatives do not take too much time, but high enough so no key pieces of information are overlooked.

Firstly value creations for some stakeholders were not taken into account. The civil authorities are not a very important stakeholder of the innovation project. It is not much impacted and is not prone to impact much either. As a consequence, this stakeholder was not studied. Likewise, as in the previous decision, the value creations for the certification authorities were not studied. Once again, the competitors were also not considered; the impact the selection of one or the other alternatives on L'Hotellier's competitors is not important enough to be considered as a decision criterion.

The suppliers were also not considered as key stakeholders. The current supplier of pyrotechnical devices would not suffer much from the adoption of the ceramic disk since L'Hotellier only represents one of its minor customers. Regarding future suppliers, we only have little information at the moment regarding the impact each alternative has on them. It was acted that at the moment, the priority should be the selection of the best alternative regardless of the impacts on suppliers, keeping in mind that this "best alternative" may need to be adjusted in the future to take into account specificities of the suppliers.

5 Value creation and risks assessment and representation

Based on this value creations identified, we aim to present sufficient information to decision-makers so they can easily select the alternatives that better fit the strategy of the enterprise, ensuring the most adapted value creation. To more steps are required to make this possible: the assessment of the value creations and risks and their representation. We detail these two last steps in the following paragraphs.

5.1 Risks and value creation assessment

5.1.1 Value creations characteristics identification

As we stated in the previous decision, the assessment of value creations requires first the identification of assessable characteristics for each value creation. Once these characteristics have been identified, the value creations are assessed based on these characteristics and risks are analyzed for each of the value creations (see Table 15). These characteristics are detailed below:

- Financial value: different factors exist to represent this value creation depending on the stakeholders. For L'Hotellier and KAD, we choose to characterize it by the gross margin on the whole lifecycle. For the customers, it is characterized by the purchasing price and by the maintenance price for end users.
- Product performance: The product performance is characterized by its mechanical properties: its flexural strength, Young modulus, the homogeneity of its properties and the probability to have critical-sized cracks.
- Performance robustness: The performance robustness is characterized by the dispersion of the manufacturing process and the difference between estimated life duration of the components and the time of use before the compulsory revision.
- Knowledge: As for the previous decision, we follow a resource based view approach. Since the only stakeholders for which knowledge value creation is taken into account are L'Hotellier and KAD, we adopt the rarity and inimitability of the knowledge as the characteristics criteria for knowledge value

creation. They determine whether other companies will have access to the technology used and would be able to copy the product.

- Image: The creation of image value is assed based on the ecological image and innovation image associated to the alternatives.
- Ecological value: The ecological value is characterized by the amount of lead released by a product during its life (other factors were investigated such as energy and carbon dioxide but did not lead to significant differences)
- Well-being: Finally, the well-being creation is characterized by the danger the operators of the process are exposed to.

Values	**Assessable characteristics**
Financial	Margin, purchasing cost, maintenance cost. The evaluation of these factors required the construction of an economic model (excel spreadsheets) assessing the total lifecycle costs and benefits for L'Hotellier and its customers.
Product performance	Flexural strength, Young modulus, iso-repartition of its characteristics probability of cracks.
Product performance robustness	Repeatability of the process, margin on the estimated life duration.
Knowledge	Valuability, rarity and inimitability of knowledge involved.
Image	Innovation and ecological image of the elements of the value chain.
Ecological value	Lead azide released during the lifecycle.
Well being	Danger of the materials used.

Table 15. Values and their assessable characteristics

5.1.2 Value creation assessment

In this step, for each type of value and stakeholder, the amount of value created is assessed. As for the previous decision, we only present here a small sample of the value creation assessment: the knowledge value creation for L'Hotellier. We made the choice to assess the knowledge value creation based on the rarity and inimitability of the knowledge.

- No ceramic disk: In this alternative there is no knowledge value creation. The knowledge use is not rare (the pyrotechnical technology is well-known and widely used for these applications) and easy to imitate since the key component (the pyrotechnical device) is produced by many suppliers.
- Integrated value chain, short or long life duration: the knowledge created on the ceramic manufacturing process is valuable. It is very rare since only one supplier possess this knowledge. The effort put in the development process prove that the knowledge is hard to imit.
- Simple value chain, short or long life duration: Same as above. The knowledge associated to the assembly process is not key compared to the manufacturing of ceramic. Thus, the knowledge value creation can be considered identical as for the integrated value chain (no difference for the activity related to the key knowledge).

- Doubled value chain, short or long life duration: As above, the knowledge created on the ceramic manufacturing process is valuable, rare and hard to imit. However, the number of supplier is doubled which cause a decrease in the rarity of the key knowledge.

5.1.3 Risks identification and analysis

Once the level of each value creation has been assessed, the risks associated to each value creation can be analyzed. As in the first decision, the risk analysis is based on a five-level analysis grid that enables the evaluation the probability of occurrence and the impact of each identified risk. Below we present the risk analysis associated to the knowledge value creation

Since there is no real knowledge value creation for the alternative based on pyrotechnical device, no risks are associated. However, for the other scenarios, one major risk is identified: the copy of the ceramic disk. For all ceramic-based alternatives, the impact of this risk is major. The fact that the ceramic disk is hard to copy is one of its most important competitive advantages. It enables L'Hotellier to secure the totality of the aftermarket of their products, when today only sixty percent of this aftermarket is controlled.

Two causes could exist for this risk: the development of an adequate technology by competitors or their access to L'Hotellier's technology. The first cause can be qualified as "rare" since the technology behind the ceramic disk is relatively complex. Developing this process would be long and costly. To save this time and costs, competitors could also tray to access the technology already developed. In the case of a simple or integrated value chain, this risk could be qualified as "rare". With only one supplier, providing that the right confidentiality precautions are taken, accessing the technology would be hard. In the case of a doubled value chain, however, the probability of this risk would be slightly increase and could be qualified as "unlikely". The total risk criticity associated to each alternative is the sum of the criticity of the two risks.

5.2 Value creation and risks representation

After the value creations and the risks have been assessed, the next step is the representation of this information to decision-makers. According to our model, this representation has two distinct levels. The first level presents the general value creation and risk level associated with each alternative (see Figure 66 and Figure 67). It is realized through the compilation of the different data on excel spreadsheets. This imprecise view serves as a framework for the decision-makers to access the second level that presents for each value creation the comparison of the level of this value creation and risk associated to each alternative.

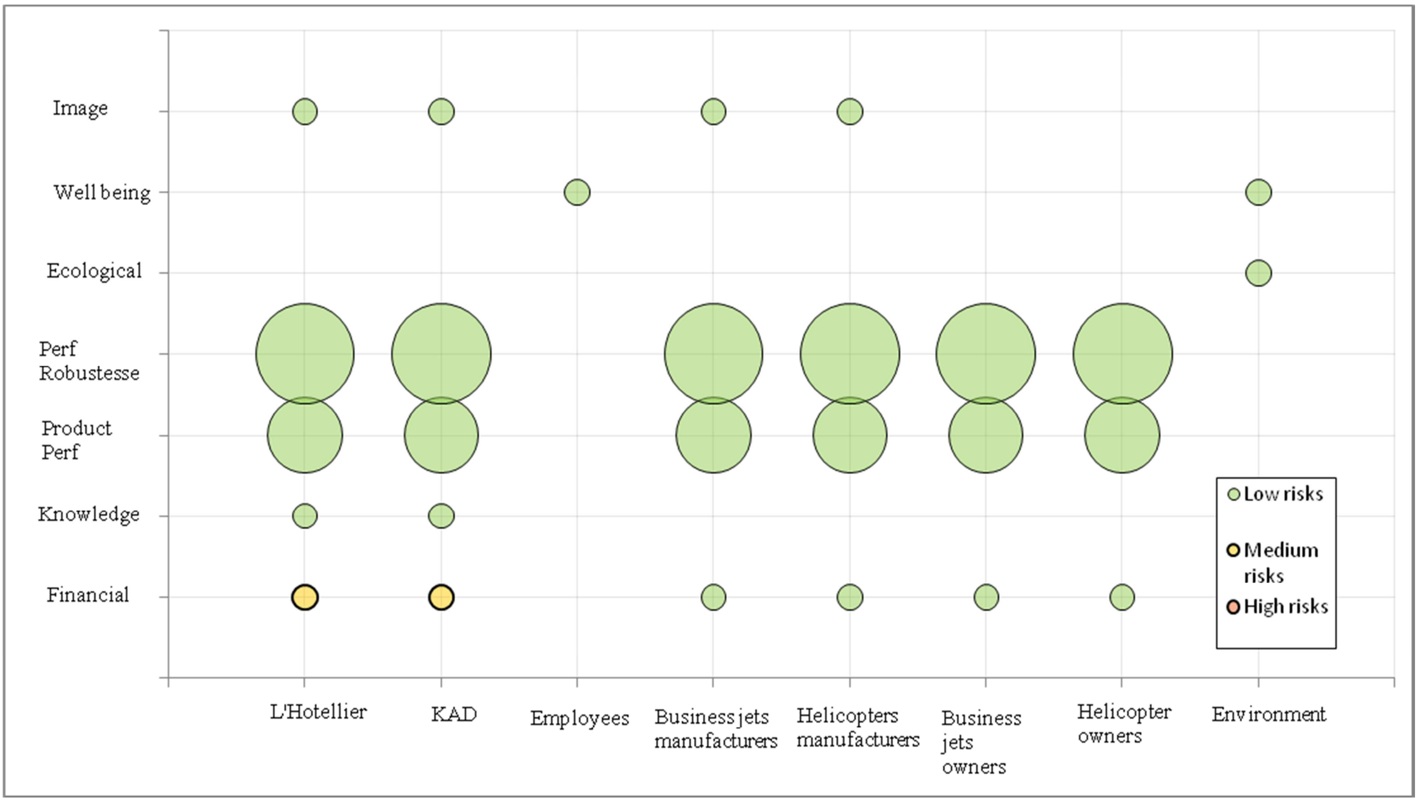

Figure 66. Value creation summary for the value chain based on the pyrotechnical technology

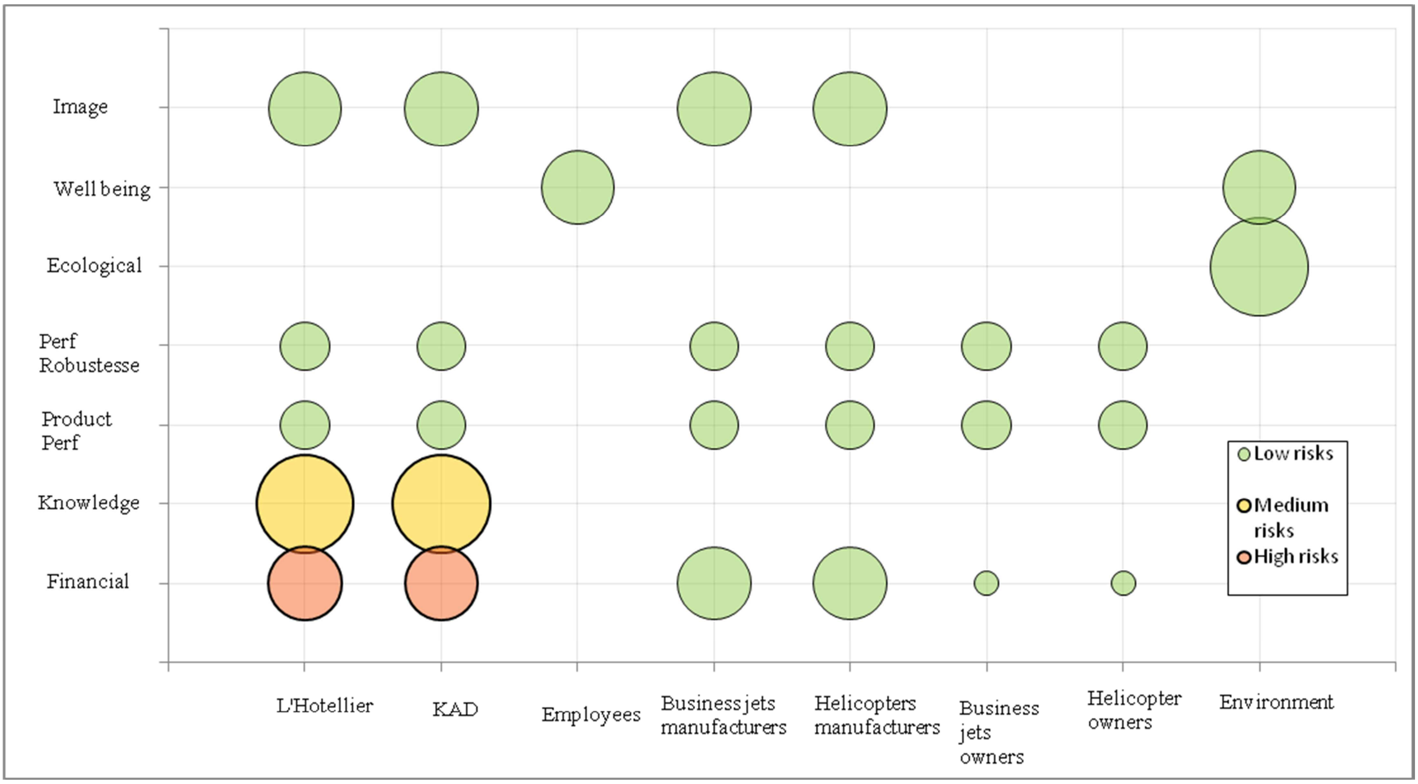

Figure 67. Value creation summary for the integrated value chain short-life duration

The analysis of the other value creations Show that the alternative based on the pyrotechnical solution present the less risks but is however characterized by a low value creation. For the financial value creation, the pyrotechnical alternative is characterized by a moderate risk caused by potential innovation from competitors and new regulations. All other alternative present high risks. The main cause of these risks is a cost misevaluation that would threaten the profitability of the innovation (high criticity for all non-pyrotechnical alternatives). Other risks associated to financial value creations include penalties due to poor quality (lower criticity for market offer based on a short life duration of the ceramic disk) and supplier defects (lower criticity for doubled value chains).

The product performance and performance robustness value creations are higher and less risky for the pyrotechnical solution. It is lower and more risky for market offer based on a long life of the ceramic disk. The ecological and well-being value creations are higher for the non-pyrotechnical alternatives with low risk associated in all cases.

6 Outcome of the decision

At the moment, this decision has not yet been taken. The development of the injection process has taken a little more time than expected and, due to economical reasons, the project has been put on hold. Due to these reasons, some of the relevant data for the application of our model such as the manufacturing costs of the ceramic devices and the failure rate of the component after endurance test cycles equivalent to five and ten years. Without these pieces of information, the decision cannot be taken. These points are crucial enough so that such uncertainty is not acceptable. In addition to that, the urgency of this decision is not very high. Other aspects (development of a mold for the ceramic component, validation and qualification tests) needs to be performed before first offers need to be submitted to the customers.

As a consequence, we leave behind us the excel application that calculates the lifecycle costs and benefits for L'Hotellier and its customers, the manufacturing cost being one of the inputs (as well as euro/dollar rate, the end of life cost the ceramic disk and the selling prices of the component). We also leave the other excel application that will enable the value creations to be updated once more information will be available.

VII. Results analysis

This experimentation we conducted brings some light on the value that our model can create. In this chapter, we analyze the results of our experimentation in order to validate the benefits of our model. We discuss these qualities in two steps (see Figure 68). First, we begin by analyzing how our model enabled the resolution of L'Hotellier's problem. We show that it did constitute an adequate response to our research question in this particular case. Then we adopt a larger point of view and study the qualities of our model in a general environment. Have we created some scientific value with the elaboration of this model?

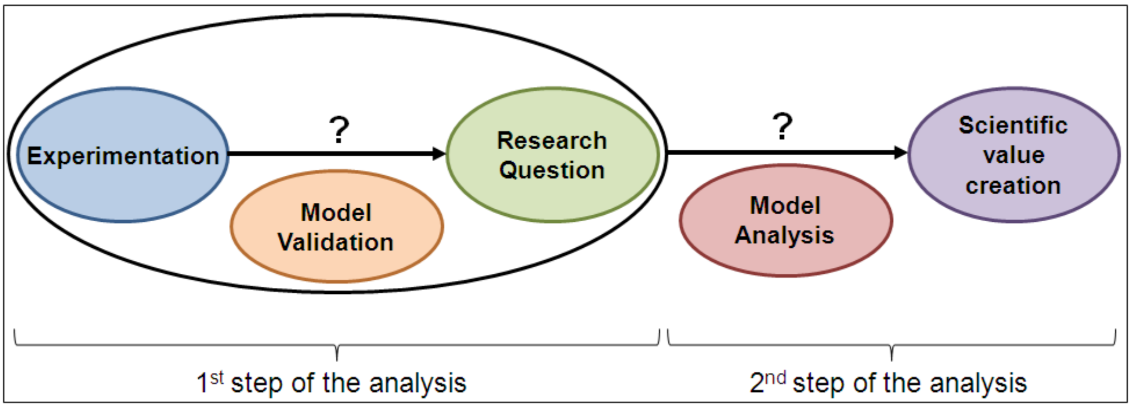

Figure 68. Two steps of the analysis process

1 Model validation

In this first step, we study the results of the experimentation we conducted with L'Hotellier's innovation project. We analyze how our action helped the enterprise solved its problem: the management of a disrupting technological innovation. The approach we follow in order to do this is to go back to our research question and validate that our model constitute a satisfying answer to this research question in the case of L'Hotellier. To structure this validation process, we have divided the research question into four main aspects.

1.1 Main aspects of the research question

An analysis of our context and an investigation of our problematic led to the formulation of the following research question.

Research question: *How can we help a SME to manage a technological disruptive innovation project while taking into account a complex value creation, a point of view enclosing the whole value chain and the product it supports, this with a scope ranging from operational to strategic management levels?*

In this first step of our analysis we must assess how the use of our model during the experimentation that we conducted constitutes an adequate response to this research question. In particular, we assess the quality of this response based on four different aspects of our research question (see Figure 69):

- Helping to manage a disruptive technological innovation project: the first purpose of this model is to assist a project steering committee in the management of an innovation project.
- Taking into account complex value creation: our model claims a value approach; one of its specificities is that it aims to take into account value creation in a wide and complex form, including different stakeholders and different types of value.

- Enclosing the whole value chain and the product it supports: we identified the necessity for any model that aims to manage the value creation of an innovation project to have a large focus including the product developed and its value chain.

- Having a scope ranging from operational to strategic management levels: in addition to the product/value chain focus, we identified that managing an innovation project requires to take into account the operational, tactical and strategic levels of the project.

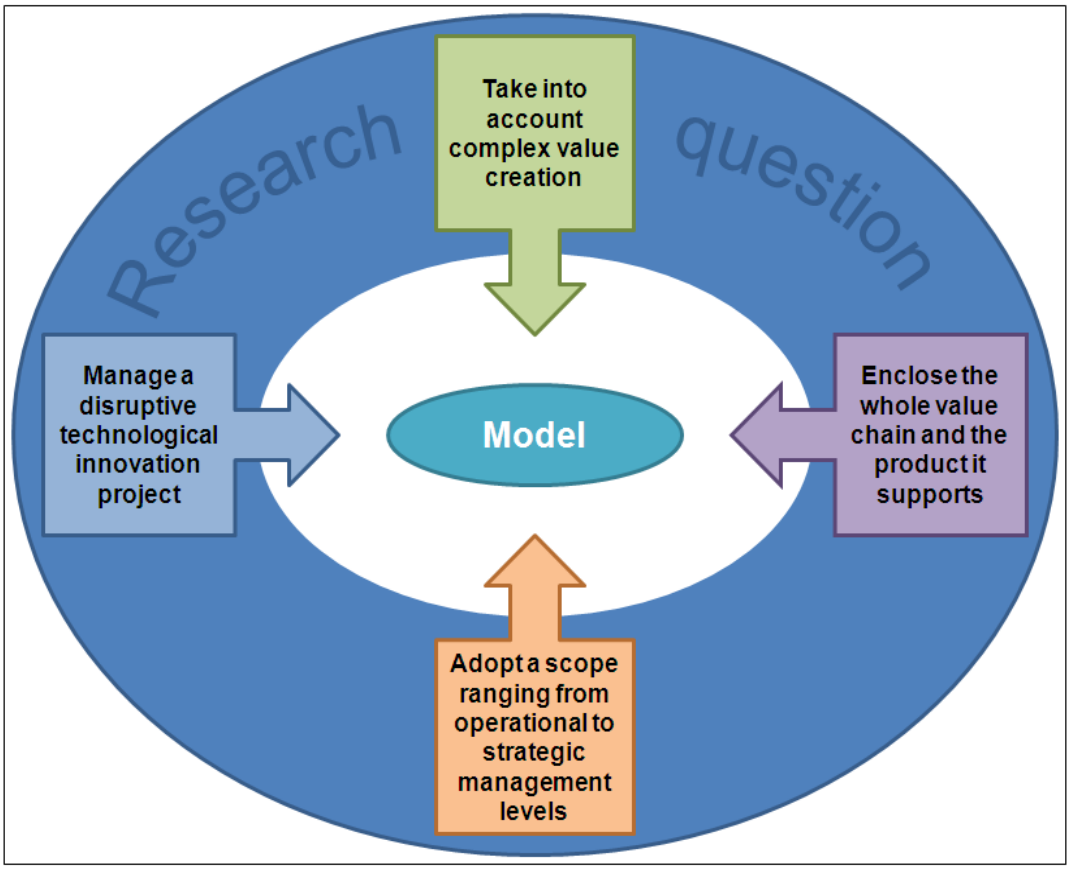

Figure 69. The model as an answer to the research question

In the next paragraphs, we analyze how well did our model fared regarding these criteria. First, we begin by studying how well our model achieved the objective of taking into account complex value creations.

1.2 Complex value creations

The representation of complex value creation is the base of our model. Our preliminary study identified six different types of value and ten stakeholders. A total of twenty possible value creations were identified. However, what is interesting is the impact the presentation of these value creations have on the decisions. In order to assess this, we investigate each of the two decisions on which our model was applied. In each case, we investigate the number of value represented and study how these value creations representations were used as decision criteria by decision-makers.

1.2.1 Complex value creation in the selection of a ceramic manufacturing process

In this first decision, the initial number of values identified was further increased. Financial value was refined into short-term, mid-term and long-term financial value (see V.2.2.1: Value creation identification). The quality value was also refined into product performance and performance robustness. On the other hand, some other possible value creations were not studied, such as the ones related to the suppliers, civil and certification authorities and competitors. We ended up with nine different values and six stakeholders, this for a total of twenty different value creations. This proves that our model did take into account complex value creations.

However, more than the brut number of value creations represented, the main question is the impact of the representation of these complex value creations. Was it useful for decision-makers? Feed-back interviews conducted amongst them show that even if the representation of profiles of value creations and risks associated to each alternative of the decision takes time to fully understand, it is valuable. Even if the decision was finally based on a small number of criteria (mainly performance and robustness in this case), the other elements are also pertinent and could have been determinant.

As a conclusion, we can say that presenting this wide view of the possible value creations would have enabled decision-makers to select the most relevant decision factors based on their experience and know-how. As such, this richness in the value creation presented is useful; not directly since only a small part is used as decision criteria but it makes the identification of the relevant criteria possible.

1.2.2 Complex value creation in the selection of a value chain for the innovation

In the second decision we also began by refining the value creations taken into account. Due to differences in the product lifecycle, a distinction was made between the different types of customers (helicopter and business jets manufacturers). Likewise, we made a distinction in the end-users between customers of the helicopter manufacturers and business jets manufacturers. As for the first decision, the quality value was refined. A difference was made between product performance and performance robustness. After the identification of alternatives, we made a selection between the criteria that were going to be studied and presented for the decision. The choice was made not to take into account the value creations related to certification and civil authorities, competitors and suppliers. We ended with eight stakeholders and seven different types of value, this for a total of twenty seven different value creations.

As we have said in the chapter presenting the experimentation, for this decision, no choice was made between the alternatives. There is still too much unknown in the main parameters of the decision: the possible life duration of the ceramic disk, the manufacturing cost. The value creations that are characterized by these parameters (financial values, product performance, and performance robustness) are key criteria in the making of the decision. The assessment of these value creations as key criteria is possible only because the presentation of information on the value creations enabled decision-makers to prioritize the decision criteria.

1.2.3 Conclusion

In these two examples, we have shown that thanks to our model, the decision-makers have been presented with the numerous value creations associated to each alternative of the decision. This information is taken into account in the decision process. This experimentation shows that presenting this information is helpful. Even if the limitations of the experimentations did not enable to prove the success of this model (because of time-related and project related constraints), it does present some points of interest. First it decreases the chance to forget key criteria in the decision-making process (knowledge value creation in the first decision for example). Secondly, presenting the possible value creations helps decision-makers to identify the most important of them that is decisive in the decision process.

1.3 Value chain and product focus

The second aspect of our research question our model has to answer is its capacity to adopt a focus wide enough so it includes the innovative product and its whole value chain. To demonstrate this, we base our analysis on the study of the design spaces impacted by the decision. The two dimensions (product and value chain) can indeed be found in the representation of the different design spaces of an innovation project (product, process, market offer) that we detailed in the chapter III.2.1: model presentation (see Figure 70).

Based on the study of these design spaces, the following part analyzes how the double focus product/value chain is present in our experiment.

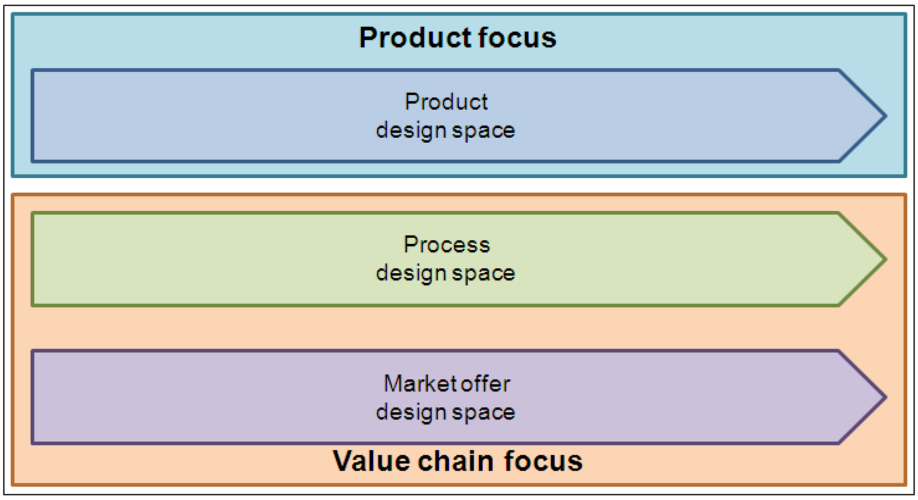

Figure 70. Product and value chain focus in the three design spaces of the innovation

1.3.1 Value chain and product focus in the selection of a ceramic manufacturing process

As we have said in the presentation of our model, critical decisions in an innovation project are characterized by the fact that they are related to different design spaces: on the one hand the product, on the other the process and the market offer, both related to the value chain. The first decision we studied mainly focus on the process design space. However it draws inputs from the other spaces and yields outputs that impact all three spaces. By studying these inputs and outputs, we can demonstrate how the double focus product/value chain is present and valuable in this decision.

The inputs of this decision come from the three spaces. From the product space come specifications regarding the product size and expected performance. From the process space, we have specifications regarding the process itself (protection of the key knowledge, possibility of implementing the process inside L'Hotellier's facilities). Finally, we have customer and users expectations that come from the market offer design space (size of the series, expected level of quality).

The outcome of the decision was the selection of the powder injection molding process. This selection impacts the three spaces. It impacts the product itself (surface state, mechanical properties and shape to a minor extent), the process (injection, level of quality controls) and the market offer (dimension of series, life duration). All these aspects were treated in our model and are detailed below.

- Product focus: The specifications in terms of mechanical resistance are taken into account in the definition of the requirements of the decision (see V.2.2.2: Requirements identification). The identification of the product performance and the performance robustness as key value creations is also an example of the product-focus that we adopted (see V.2.2.1: Value creation identification). This product focus can also be seen in the information we presented to decision-makers. The evaluations of the alternatives for these value creations yield different results (see the value creation summaries on Figure 53: Value creations summary for the uniaxial compression alternative (internal option)).

- Value chain focus: This value chain focus can be found in the process and the market offer design space.

    - Process design space: some of the requirements of this decision are obviously related to the production process: applicability in L'Hotellier's facility, protection of the key knowledge (see V.2.2.2: Requirements identification). The identification of possible solution is also process related (see V.3: Alternatives selection). Our model also takes the process design space into account in the assessment of the value creations, for example in the assessment of the mid-term financial values (see V.5.1: Risks and value creations assessment). All these aspects are part of a value chain focus.

- Market offer design space: the expectations of the customers are taken into account in the elaboration of decision criteria, particularly the expectations in terms of quality (see V.2.2.2: Requirements identification). The production volume required was also a significant variable of the decision process. It is based on this estimated data that we assessed the possible long-term financial value creation (see V.5.1: Risks and value creations assessment). The consequence of the decision also impacts the market design space. The selection of the most capable process may enable a market offer based on longer life duration for the ceramic disk. The cost of the component can also be impacted by the manufacturing process selected. Even if they were not kept as final decision criteria, these aspects were identified during the decision process (see V.2.2.1: Value creation identification) and presented to the project steering committee in the phase of selection of decision criteria.

These relations between our decision and the three design spaces reflect the double focus product/value chain we adopted (see Figure 71).

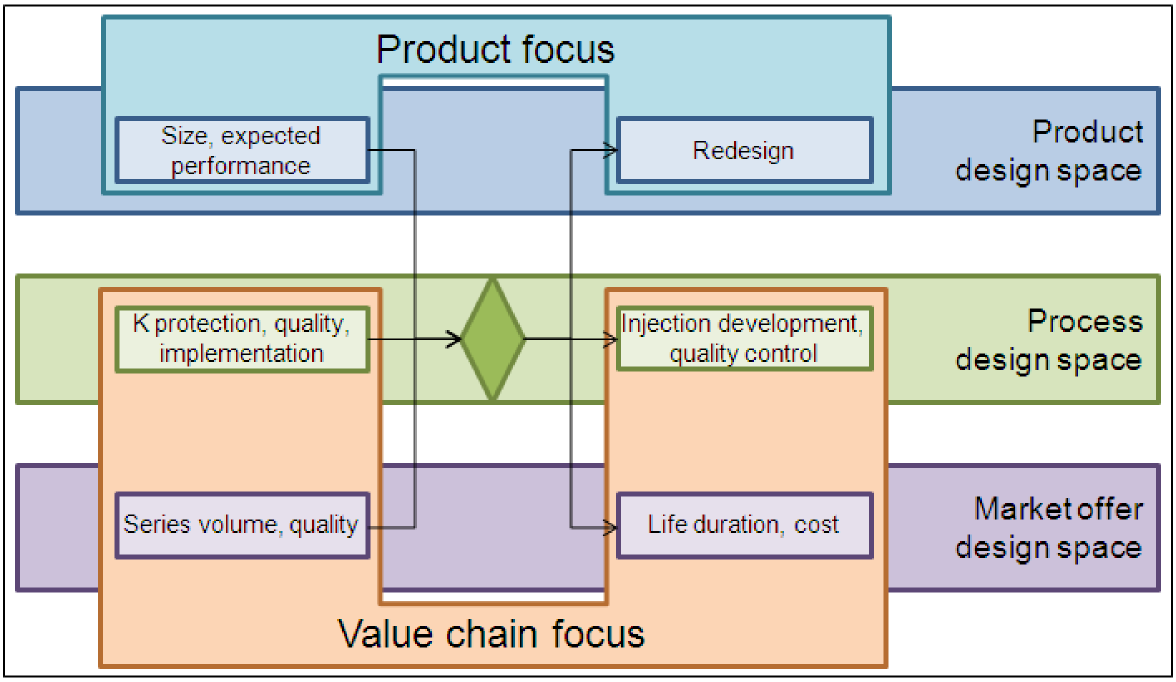

Figure 71. Product – Value chain focus in the 1st decision

In the next part, we repeat the same evaluation process for the second decision: the selection of a value chain for the innovation.

1.3.2 Value chain and product focus in the selection of a value chain for the innovation

The selection of a value chain for the innovation was identified as a critical decision. As such, it is characterized by an important relation is has with the three design spaces. This decision requires as inputs information coming from these design spaces: the product (type of extinguishers compatible, life duration), the process (manufacturing cost, size of series and key actors of the process) and market offer (customer and user need, current market offer). Likewise, there are also impacted by the selection of an alternative. A decision of continuing with the pyrotechnical devices would drastically impacts all spaces since it would mean the interruption of the three design processes. The impact of the selection of any other alternative would be smaller but still very significant. New design actions would have to be implemented on the product (validation and robustification of mechanical properties), the process (implementation, identification of potential suppliers) and the market offer (selection and further development of an offer for the supply and maintenance of the product).We detail below the way our model treats all these aspects.

- Product focus: Two main pieces of Information come from the product design space. The first one regards the types of extinguishers that are compatible with the ceramic disk. From this identification a list of the potential customers of the ceramic disk can be deduced (see VI.1.1: Definition of the decision perimeter). This information is useful to identify possible value chains and their specificities. The second one is related to the performance of the ceramic disk and its variation depending on the maintenance offer that is selected: short or long life (seeFigure 66: Value creation summary for the value chain based on the pyrotechnical technology and Figure 67: Value creation summary for the integrated value chain short-life duration).

- Value chain focus: Once again, this value chain focus can be found in the process and the market offer design space.

    - Process design space: a major input of the decision process is the identification of the main steps of the production process. Having identified the type and number of actors that could be part of the production process enabled the elaboration of the different alternatives (see VI.1.1: Definition of the decision perimeterand VI.3: Alternatives selection).

    - Market offer design space: in the selection of the value chain for the innovation information from the market offer design space is very important. A major input of this decision is the characteristics of the current offer. By presenting it, we give decision-makers an element of comparison (seeFigure 66: Value creation summary for the value chain based on the pyrotechnical technology). Furthermore, analyzing it enables to identify areas where improvement would be possible. It is by studying the current process and crossing this with the customer and end-users needs that we identified the possibility of increasing the life duration of the extinguishing system (see VI.3.1: Alternatives identification). The impact the decision has on the market offer design is also taken into account in our model. The outcome of this decision is the selection of a value chain, which include the selection of a type of supply and maintenance offer. The alternatives presented (see VI.3.2: Selection of relevant alternatives) constitute a first definition of the directions that the market offer design process should investigate.

As for the previous decision, these relations between the three design spaces that are at the center of our model reflect the double focus product/value chain (see Figure 72)

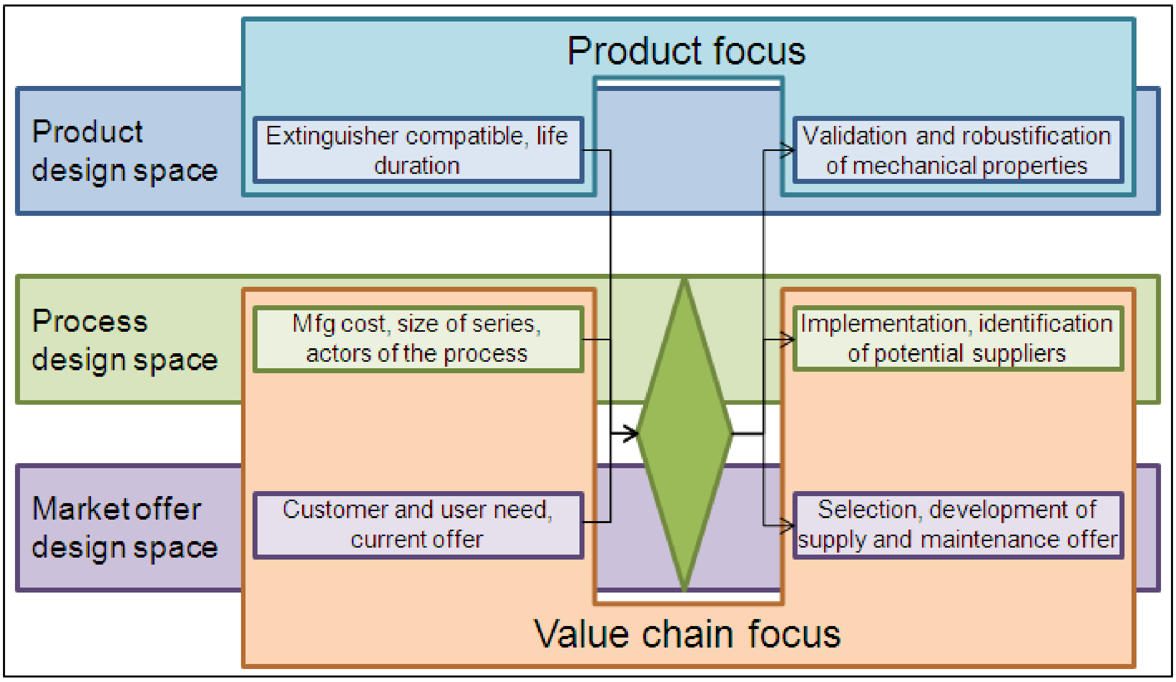

Figure 72. Product – Value chain focus in the 2nd decision

1.3.3 Conclusion

In this part, we have chosen to demonstrate the presence of a double focus product-value chain adopted by our model by showing that it takes into account the three design spaces: product, process and market offer. These three spaces including all required aspects of the product and value chain focus. We have analyzed how the three design spaces contribute to and are impacted by the decision. This has been done for the two decisions that we acted on. The results of this analysis show that in both cases, information coming from the three spaces is used as inputs to elaborate the alternatives of the decision. In addition to that, we have shown that each decision impacts the three design spaces and that these impacts are assessed in our model.

1.4 Operational, tactical and strategic focus

This double focus product-value chain is completed by a wide perspective regarding the management levels. In the next paragraphs, we show that our model treats all three management levels: strategic, tactical and operational. For each of these levels, we detail the aspect of each of the two decisions that belong to these levels and that were taken into account in our model.

1.4.1 Strategic focus

We defined the strategic level as the level where the main orientations of the enterprise are decided and note that at this level, little information and experiences are available. Several aspects of the two decisions we studied belong to this level.

- Selection of a manufacturing process: One aspect belongs to the strategic management level in this decision; the role of L'Hotellier in the supply chain. Studying the possibility for L'Hotellier to add the manufacturing of ceramic to its industrial activities (see V.3.1: Alternatives identifications) is a very strategic question.

- Selection of the value chain for the innovation: The question discussed by this decision is the replacement of a cash-cow product by an innovation. This question is a strategic decision: is L'Hotellier willing to accept the risk of sacrificing a cash-cow product in order to possibly strengthen its position on its market by the introduction of the ceramic disk? Another strategic dimension is the question of the maintenance requirements. Today all the firms positioned on this market have similar offers in terms of product life duration and frequency of compulsory maintenance. The fact that some alternatives are based on an extension of the life of the product sold (see VI.3.1: Alternatives identification) is a strategic issue. Introducing an offer that requires less revision would significantly impact the extinguisher market.

1.4.2 Tactical focus

The tactical level is the level where actions are devised to sustain the strategy of the enterprise at a lower scale. Information and experience exist at this level but are not directly available. This tactical level is taken into account by our model. It can be found in several aspects of our two decisions.

- Selection of a manufacturing process: In the alternatives studied, some are based on “low-cost” process; other are more “high-technology (see V.3.1: Alternatives identifications). Their performances are not equal either. The selection of one solution above the other belongs to the tactical level. It is a way to sustain the strategy of the enterprise (high-tech image, focus on the performance of the products in order to limit the number of revisions). The assessment of the image value creation (see V.5.1: Risks and value creations assessment) is another example where this aspect is taken into account.

- Selection of the value chain for the innovation: One of the main examples of tactical aspects of this decision can be found in the phase of elaboration of the alternatives (see VI.3.1: Alternatives identification). By presenting alternatives characterized by different levels of integration of the production and by a different numbers of first and second rank suppliers, we propose different tactical position. The selection of one of the different alternatives of supply chains is a tactical decision. It is a part of a larger strategy of the enterprise (externalization or integration of the assembly, securization of the supply chain).

1.4.3 Operational focus

Finally, the operational level includes all aspects of the day-to-day life of an organization, routine decisions where information and experience is at hand. In our case, both the decisions have several operational implications. In order for an alternative to be implemented after its selection, operational level actions are required. But where our model takes into account the operational level is on taking into account the operational specificities of each alternative in the assessment of the value they can create.

- Selection of a manufacturing process: The selection of the injection process and implications on the operational level. It opens new actions that need to be completed in order to develop a reliable production process for our ceramic. This decision is also based on operational considerations such as the complexity of the various steps of the different processes that can influence the repeatability of the process (see V.3: Alternatives selection).

- Selection of the value chain for the innovation: As for the other decision, the selection of a value chain has operational consequences. Actions and tests must be set to study and demonstrate the resistance of the ceramic; a reflection must be engaged on the possibility of reducing the maintenance of the extinguisher to fit the longer life of the ceramic. And once again, this selection is based on operational aspects: the time and costs required to perform the maintenance operations for the financial value creation, the possibility of applying a quality control process to ensure no flawed components leave the enterprise for the quality value creation, etc.

For each level of management we can find in both experiments examples of aspects issued from each level that were used to create and assess the decision criteria. In addition to that, we showed that in each case, the selection of an alternative has consequences on all the level of management.

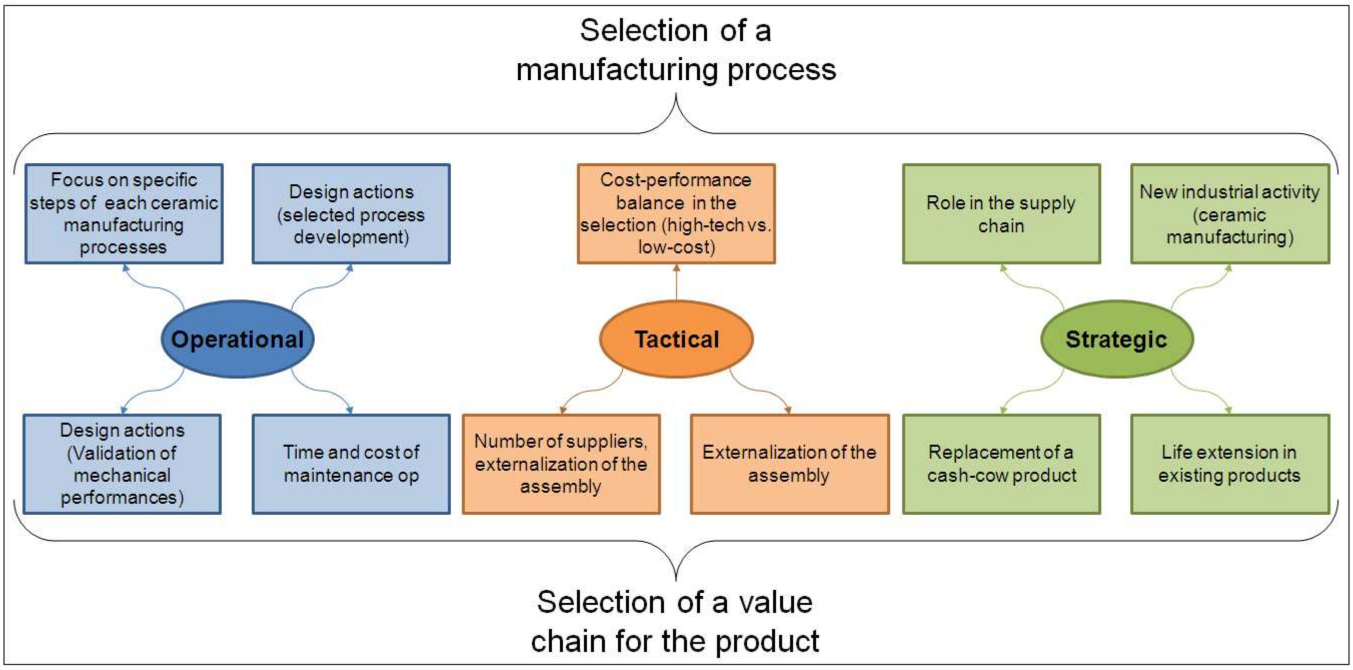

Figure 73. Elements of operational, tactical and strategic view in the experimentation

1.5 Innovation project management

The last paragraphs have shown that our model takes into account complex value creations, that it includes focus on both the product and the value chain that support it and that it is related (it impacts and is impacted) to all the management levels. What we want to study now is, beyond the respect of these requirements, how well did this model helped to manage the innovation project.

It is difficult to assert that our model was helpful in the management of the project. This project is not finished and according to the previsions, a couple of years will still be necessary to complete it. The consequences of the project are thus hard to asses at the moment. However, we can state that our model had an impact on the way the project was managed and that this impact was positive. These benefits can be traced down to two causes: the formalization of the decision process and the wide point of view adopted in the analysis of the decisions.

1.5.1 Formalization of the decision process

As we have said in the context analysis, SMEs are often characterized by informal processes. In the case of L'Hotellier, we have seen that this informal aspect is limited. The exigencies of the customer in terms of quality are very heavy which implies a certain level of formalization of the processes. In addition to that, standards design processes have been introduced by the American group to further reinforce this quality in the processes (see I.1.3: Company development processes). However, when it comes to the decision process, very few standards exist. The only example of standardized decision processes is the "passports" that condition the passage of one phase to another. However, this activity is only a go-no go decision in which no different alternatives solutions are studied.

As a consequence, the use of our model enabled to formally conduct the main decisions of the project. A specific care was taken in the identification of different alternatives of the decision and in their evaluation, which positively impacts the management of the project by increasing the quality of the solution selected and its legitimacy. In this regards, we can say that the usage of our model was helpful for the management of the project.

1.5.2 Rich analysis point of view

In addition to this formalization of the decision process, the second source of value for the project management that our model brought is the richness of view point adopted. Design decisions in L'Hotellier are classically based on two factors: cost and performance. Our model adopts a wider point of view and proposes other types of values as decision criteria. A wide approach is also adopted regarding the stakeholders of the project. We identified and took into account several stakeholders (see V.2.1.2: Interviews and V.2.1.4: Relation between the stakeholders) were design projects in L'Hotellier usually focus only on the enterprise and the customer.

All this increased the quality of the information available on the different alternatives. Thanks to this richness, the project steering committee is able to see the impacts of the decision on all three design spaces, which helped them in the management of the project. This truly makes the taking of critical decisions a way to control the orientation of a project.

1.6 Conclusion

As a conclusion, we can see that the application of our model in this innovation project shows great promises. The formalization of the decision process increases the quality of the decision. The identification of the alternatives is done more systematically. The richness of the analysis performed in the evaluation of these alternatives enables decision-makers to adopt a very large point of view while selecting an alternative. It ensures that the selected solution is more adapted to the enterprise in terms of value creation on the whole project level and not only locally. On this project, our model constitutes an appropriate answer to the research question.

However, it is essential to validate that this model could also be a good answer to our research question in other contexts. How can we validate its quality in a more general context? In the next part, we tackle this issue and study the scientific value created by our research.

2 Value created by the model

We have seen in the last part that the richness and the interest of our model in this particular context. The question now is the value created beyond this specific application. To assess this, we first go back to the hypothesis we formulated at the end of our problematic chapter. We show that our experimentation validate these hypotheses. This proves that our model is capable of creating value in the management of a disruptive technological innovation project in a SME. This value is based on three aspects: the representation of a mix of complex value creations and risks as an enhancement of the quality of decision-making, the use of decision-making as an help to project management and the implication of numerous and diverse actors of the innovation projects in the decision process as a factor of agility of the project management. These aspects constitute the framework of an iterative innovation project management model based on the control of the critical decisions.

2.1 Hypothesis validation

After an analysis of our problematic and an elaboration of our research question, we formulated hypothesis that served as a base for the construction of our model. This hypothesis is recalled below.

Hypothesis: In a context of disruptive technological innovation projects in SMEs, presenting information about the diverse value creations (different types of value and different stakeholders) and the risks related to these value creations is benefic for the decision-making process. The decision-making process is improved due to the fact that:

- More relevant information is available for decision-makers.
- The decision-making process is formalized and at least partly rationalized.

- The people involved in this decision making-process cover most of the point of views of the main actors of the enterprise.

2.1.1 Relevance of the information presented to decision-makers

As we have seen, our model is based on the presentation of the different value creations and risks associated to each alternative of the decision. The implications of the critical decision in disruptive technological innovation projects go beyond the sole financial or technological aspects (usual decision criteria in L'Hotellier's product design projects). As a consequence, decision-makers should have knowledge of all these implications. By including a wide variety of values in the information presented, we enable decision-makers to a wide and rich understanding of the implications of the decision.

Furthermore, the information presented do not only concerns the enterprise or even its customers. By presenting the value created for all the stakeholders, we further broaden the view of the decision-makers. This can help decision-makers to predict future reactions of the stakeholders and possibly avoid problems with neglected stakeholders.

2.1.2 Formalization and rationalization of the decision-making process

SMEs are usually characterized by a low formalization of their processes, decision processes included. We have seen that this is the case for L'Hotellier's product development project, where the only formalize decision are high-level, concerning go-no go of a project. By applying our model we changed this in our innovation project. The application of our model on the two decisions of the project identified as critical help to increase the formalization of these decisions and enabled to partly rationalize them.

We have shown in our bibliography on decision-making that the rationality of decision-makers is limited since he is subject to many biases and only have a partial view of the total relevant information. Even if our model does not take a specific care in the limitation of possible cognitive biases from the decision-makers, we increased the rationalization of the decision by presenting a wide range of information. This limits the bounded rationality of the decision-makers by increasing the information they have access to. This information is presented gradually (identification of areas of value creations in the problem setting phase and selection of the most relevant in the criteria identification phase, presentation of a summary of the value creations and risks and detailed presentation of each value creation in the last phase) so the amount of information presented is always small enough to be easily assimilated by decision-makers.

2.1.3 Actors of the decision

One of the key objectives of our model is to supply decision-makers with the most complete view of the decision possible. To accomplish this, pieces of information are gathered from multiple sources in the problem setting phase. In our experimentation, these sources were all parts of L'Hotellier but were from different trades. We took care to cover the different aspects of the activity of L'Hotellier. Thanks to this, the information available to decision-makers is very rich and regroups multiple points of view.

Furthermore, the decisions are taken by a steering committee that also regroups various competencies and viewpoints. One member of this committee is the final decision-maker (the CEO in the case of L'Hotellier) but the decision is still based on the joint analysis of the different members of the committee. Even if the decision is finally made by one person, it is based on information coming from multiple and various sources. This organization makes the decision more robust since the different competencies present between the decision-makers enable to correctly interpret the consequences of all the elements of decision presented.

By this analysis, we show that the hypothesis on which our model is based is valid. In the next part, we develop the implications of these hypotheses. For each of them, we underline the scientific value creation that our model can claim. We show that put together, these value creations validate the capability of our model to provide an agile management of disruptive innovation projects in SMEs.

2.2 Availability of relevant information for decision-makers

2.2.1 Rationalization of a multi-criteria decision space

We have described above the merits of presenting decision-makers rich information that concern the most important stakeholders of the projects, the values (of all kinds) they can benefits from and the risks associated to these values. This is essential in a complex environment such as disruptive innovation projects. The uncertainty associated to the disruptivity of the innovation makes the access to such information essential. In order to select the most adapted solution for the decision, a simple mono-criteria view is not sufficient. It is necessary for decision-makers to be able to apprehend the complexity of all the decision criteria. By rationalizing the multi-criteria decision space through the identification of value creations and risks, our model makes this possible.

2.2.2 Providing insights on possible futures of the innovation project

Providing decision-makers with this information gives them a wider view on the consequences of the alternatives. The presentation of the value creations generated by the project and risks associated enlighten the possible futures of the projects. This improves the quality of the decision (see Figure 74). The decision is not optimized locally but it is seen as a step of the project. The information presented enable decision-makers to adopt a larger project perspective. From the decision-making assistance point of view, we have a robust model that ensures a good quality of decision. This is a necessary condition to be able to steer the project through the control of its critical decisions.

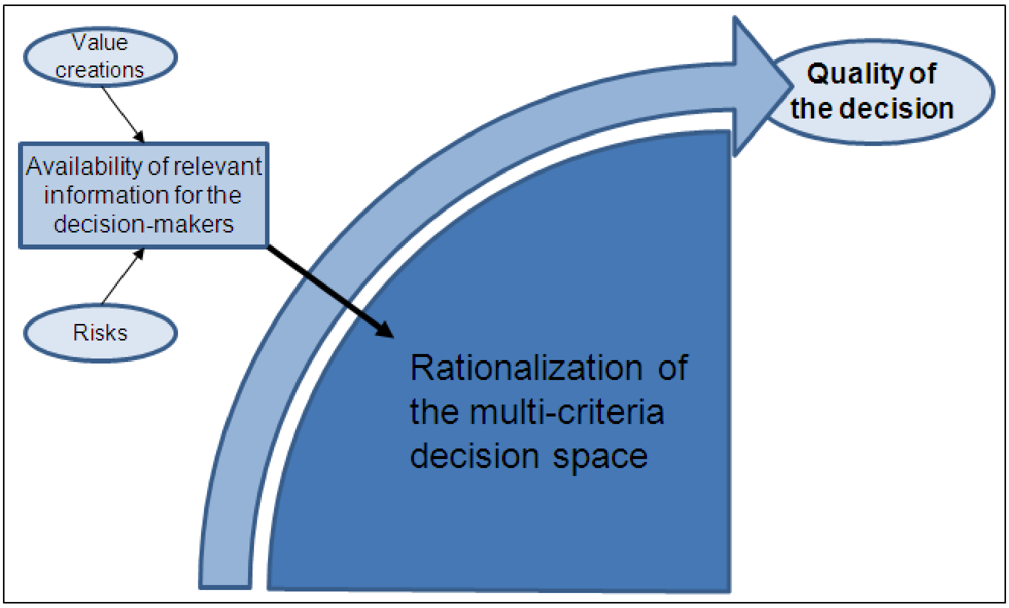

Figure 74. Increase in the decision quality through the rationalization of the multi-criteria decision space

2.3 Formalization and rationalization of the decision-making process

With the identification of value creations and risks associated to each alternatives of a critical decision, we enhance the quality of this decision and ensure the fact that this decision is not locally optimized but taken in a project perspective. Thanks to this, we propose to use the control of critical decisions to steer the innovation project process.

2.3.1 Steering the innovation project process through the control of critical decisions

We have shown that the innovation project can be decomposed into three design spaces: the product, the production process and the market offer. Since a decision process is a succession of decisions, we can argue that the management of each decision is equivalent to the management of the project. However, the complexity of formalizing and controlling each small decision is too important to be adopted. As a consequence, what our model proposes is to limit this formalization and control to the main critical decisions of a project. In controlling these decisions, we ensure the general steering of the innovation project. The content of the project itself is not defined by our model. However, as we have seen the decision taken is based on a rich information mix:

- Coming from all three design spaces (product, process, market offer) including focus both technological and commercial aspects
- Related to all three management levels (strategic, tactical, operational)
- Gathered amongst people from different trades

Likewise, the activities of the project are impacted by the decision taken. The impacts of the decision on the operational, tactical and strategic levels ensure that the making of the decision plays its steering role in the project (see Figure 75).

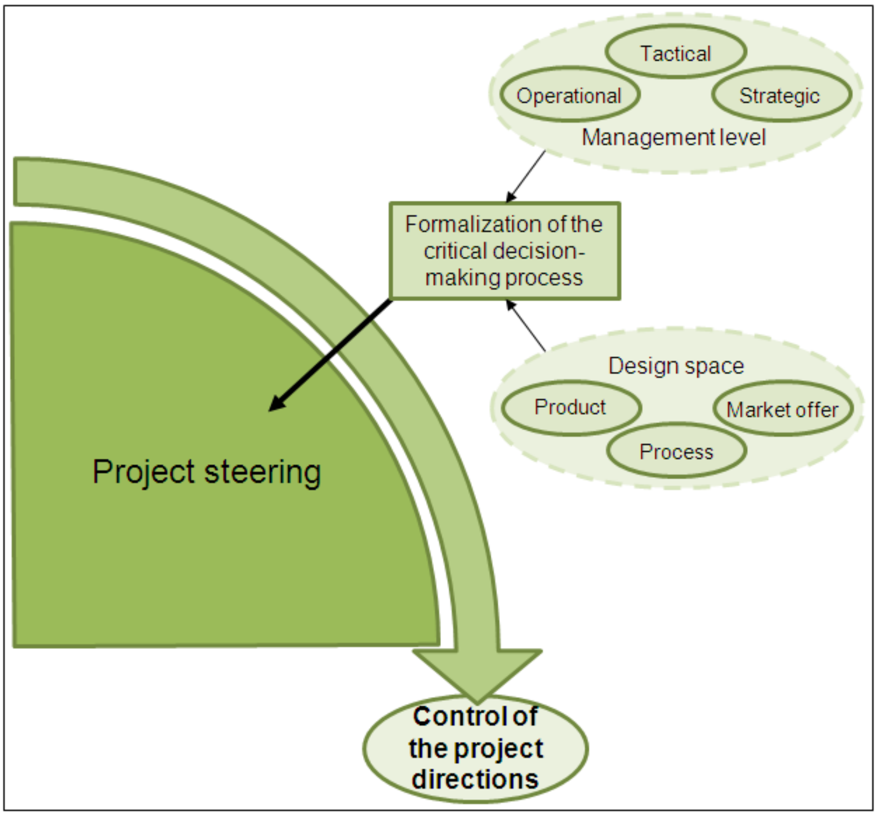

Figure 75. Project steering through the Formalization and rationalization of the decision-making process

2.3.2 Position of our model

At the beginning of our document, we identified several well known innovation process models and underlined their limitations in the treatment of disruptive technological innovations in SMEs. At the conclusion of this context analysis we proposed to conduct the innovation in a project mode and to pilot this project through the control of decisions. It is the purpose of our model. As such, it is not located at the same level as the design and innovation process models. It does not define main tasks of the process or the content of specific activities. Even if it is in close relation with the operational and tactical levels, our model is located at the strategic level. It helps to define the orientation of the project and ensure that this orientation is followed throughout the various critical decisions. However it does not defines the different steps of the project.

As such, it can be associated to various project management models. In particular, the value creation method and tools that we identified in the construction of our problematic are complementary with our model. They can be used in specific activities to ensure that the orientation taken in the decision phase is maintained during the project.

2.4 Trades of the people involved in critical decision-making

By focusing our intervention at the steerage level, we ensure that our model does not hinder the flexibility of the innovation development process. One of the most important advantages of SMEs in the industrial world is their flexibility. Their processes are not fully formalized and the communications between the actors of a project is mostly informal. All this increases the agility of their management.

2.4.1 Actors of the model

In addition to this low level of prescribtivity that preserve the flexibility of the development process, our model can claim a capacity to adapt to multiple situations. Our model aims to present decision-makers with rich information on the problematic of the decision. This information is extracted from interviews of the various actors of the innovation projects. Being able to access this information gives our model robustness and agility.

Furthermore, our model proposes that decision-makers regroup actors familiar with the different trades of the company. This further increases the agility of our model. It ensures that the decision-makers have access to the right know-how and knowledge to best understand the different problematic of a decision. This double variety in the actors of the decision in our model (during the information gathering process and the selection process) ensures its adaptability.

2.4.2 Iterations in the project steering

Steering a project through the control of the critical decisions also present another advantage: it formalizes the steering process as an iterative process. Corrections to the original orientation given to the project are possible in the further critical decisions. In some cases, major changes in the innovation context can rend the orientation of the project obsolete. Such changes would automatically be the source of new uncertainty. This uncertainty and the doubts that can arise on the course of the project would induce new critical decision-making. This new decision is based on the new innovation context and as such would lead to the selection of the solution the most adapted to this new context, thus correcting the initial course of the project.

These three factors, the low level of prescribtivity, the large amount of knowledge and know-how our model access and its iterative mode of functioning make our model agile in the steering of innovation projects (see Figure 76). In is robust and can adapt to new situations as well as important changes in a given situation.

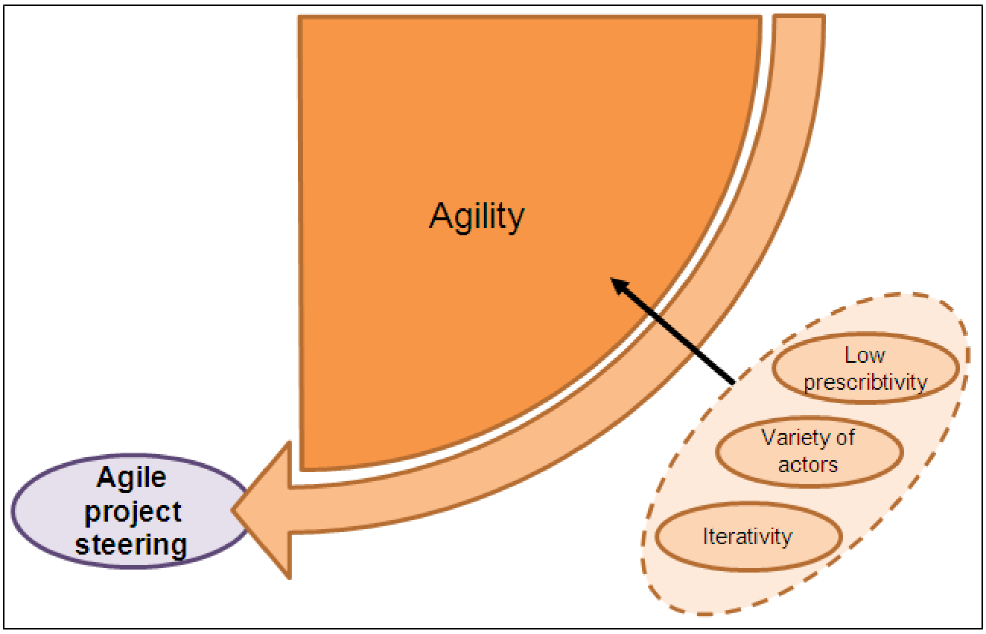

Figure 76. Agility of the model

3 Conclusion

In this chapter, we underlined the fact that the implementation of our model was an adapted answer to our research question. It is applicable and present assets whose interests have been theoretically and locally demonstrated. We showed that the four different aspects of our research question (helping to manage a disruptive technological innovation project, taking into account complex value creation, enclosing the whole value chain and the product it supports, having a scope ranging from operational to strategic management levels) were well treated in the experimentation of our model on L'Hotellier's innovation project.

This local success was assessed at a larger scale by the study of our hypotheses (amelioration of the decision making process through: more relevant information is available for decision-makers, formalization and at least partial rationalization, point of views of the main actors of the enterprise covered by the people involved in this decision making-process). We first showed that these hypotheses are validated by our experimentation. Then by studying the implication of these hypotheses, we showed that, thanks to the multi-value point of view it adopts, our model enables an agile steering of disruptive technological innovation project (see Figure 77).

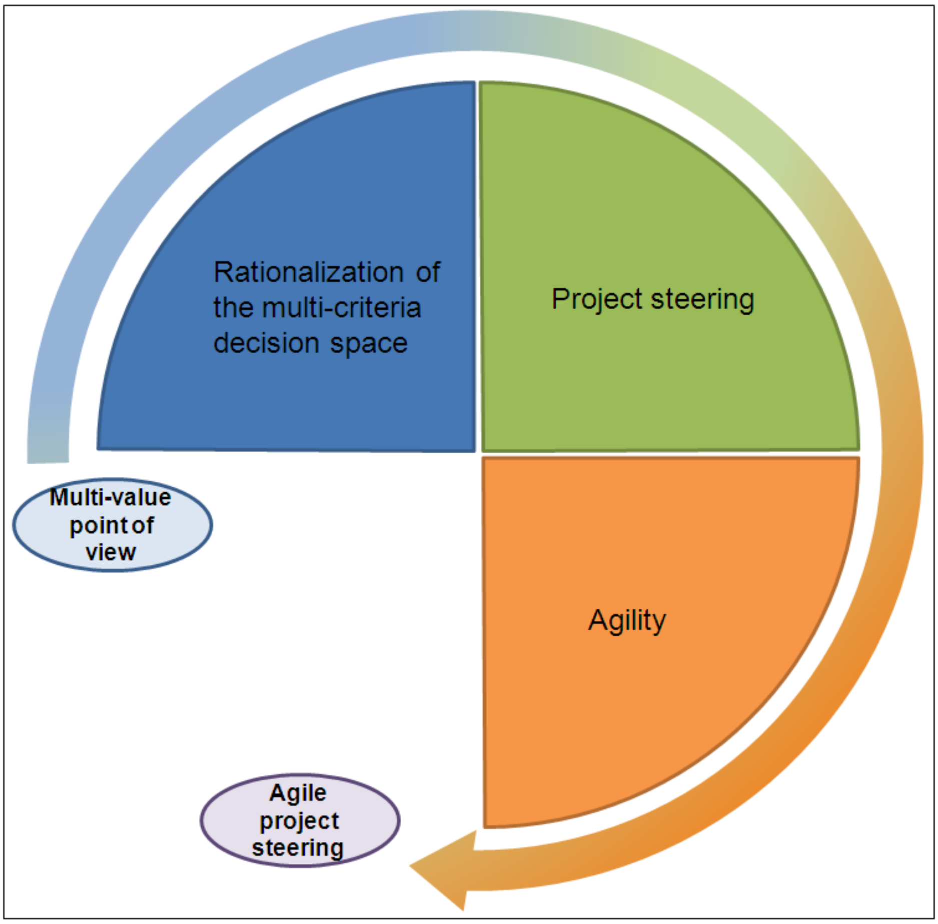

Figure 77. **Agile project steering through multi-value point of view**

The multi-value point of view adopted in this model enable a rationalization of the multi-criteria decision space. This increases the quality of the decision-making, while keeping the process agile. This model enable to pilot project toward the most adapted value creation according to the enterprise strategy.

VIII. Conclusion and discussion

1 Analysis of the contributions

This thesis was conducted in research action in the aeronautic subcontractor L'Hotellier. A study of our industrial context led to the identification of key characteristics that enable the definition of a research perimeter: the development of disruptive technological innovations in SMEs. Through an analysis of the specificities of this context we underlined that the main issues posed by such developments is the identification and the access to relevant knowledge (technology and market-related). We then conducted a review of innovation process models and came to the conclusion that this question is not enough tackled in the literature, especially when it come to the critical decision phases.

We were faced with the following problematic: *Given the fact that SMEs are not able to follow classical innovations processes models, what are the main aspects that should be the focus of disruptive technological innovation projects.* The study of this problematic led to the identification of value creations and risks as the key information in such projects. Based on this conclusion, we formulated our research question: *How can a SME manage a disruptive technological innovation project while taking into account a complex value creation, a point of view enclosing the whole value chain and the product it supports, this with a scope ranging from operational to strategic management levels?*

1.1 Contributions of our model

In order to answer this research question we elaborated a model that aims to help managers to pilot innovation projects through the control of critical decisions.

1.1.1 Model structuring characteristics

In innovation projects, we have identified the values created as a key piece of information for critical decisions. As such, we made of this question the heart of our research. We studied this notion and identified several types of values. In addition to this richness, we underlined the fact that the enterprise developing the innovation is not the only beneficiary of this value creation. They can be created for various internal and external stakeholders. This led us to define the notion of value creation as the creation of one type of value for one given stakeholder.

However, this value creation is very complex. Due to the heterogeneous nature of each value type and stakeholders, value creations are also very heterogeneous. As such, it is very difficult to perform a robust comparison between them. In addition to that, risks are associated to each value creations. This makes the comparison or the agglomeration of these value creation and risks very hard to robustly establish. Based on this conclusion, our model propose to increase the quality of the decisions of disruptive technological innovation projects a decision by identifying and presenting to decision-makers the value creations and risk of the project as totally independent decision criteria.

1.1.2 Model presentation

Our model aims to facilitate the steering of a project by formalizing and rationalizing a robust decision-making process. This model includes two steps. The first is the recognition of a key decision of a project. The second one is based on a rationalized decision-making model. Once a critical decision has been identified, our model proposes a phase of problem setting where the possible areas of value creations of the decisions are identified and the requirements recognized. This phase is followed by the construction of the possible alternatives of the decisions. The value creations generated by each of these alternatives are then identified and assessed. For each value creation, the risks associated are identified and their criticity assessed. This enables us to present decision-makers with an analysis of the value creations and risks associated to each alternative.

Based on these pieces of information, decision-makers can rationalize and enhance the quality of their choice, selecting the alternative that ensures the value creations the most adapted to the strategy of the enterprise. This model takes into account the product designed as well as the value chain of the innovation. It ensures that the decisions taken are based on the strategic tactic and operational aspects of the project. This high level of information presented enable decision-makers to guide the project in the most adapted direction. By repeating this operation on each of the critical decision, the decision-makers can pilot the project toward the value creations most adapted to the enterprise (see Figure 78).

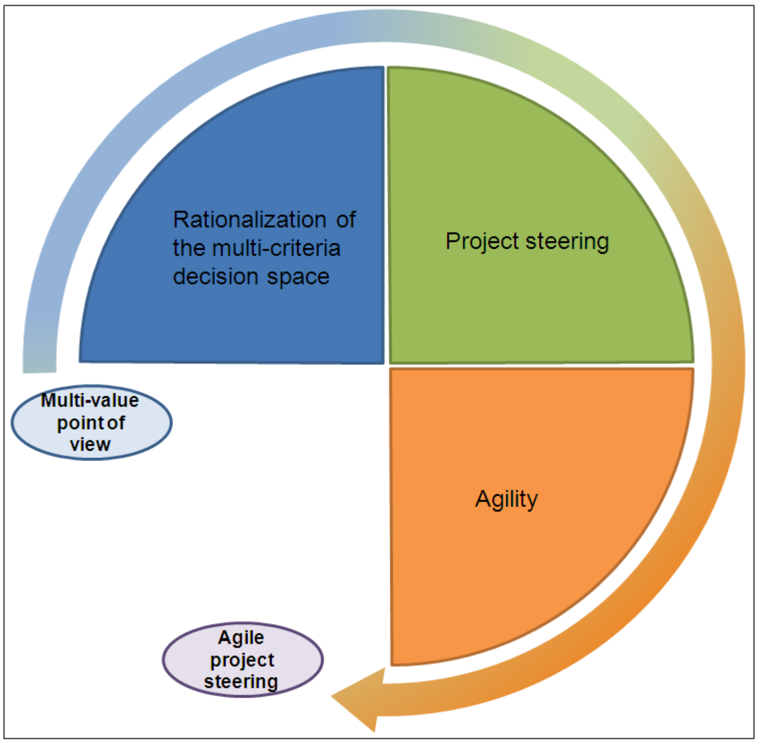

Figure 78. Agile project steering based on a multi value point of view

1.2 Positioning

We have seen in the first chapter detailing the context of our work that classical models of design and innovation process are not sufficient to tackle disruptive technological innovation in SMEs. This is due to the difficulties these structures have to identify and gain access to some specific key knowledge. The identification of this issue justifies the need for our contribution. However, what we propose here is not on the same level as the ones we cited. We did not design an innovation process that SMEs should follow in disruptive technological innovations. This model does not details how the innovation project should be conducted and which should be its main phases. For these aspects, we rely on the internal project management process of the enterprise (formalized or non-formalized).

Our model focuses on one specific activity of the innovation process: critical decision-making. What we propose is a method that helps managers to tackle this specific aspect. But our model goes beyond this sole purpose; we advocate that thanks to the richness of the information presented to decision-makers, it also constitute an efficient way of piloting these projects (see Figure 79). It gives managers enough information to reconcile the operational and tactical aspects of the project management and its strategic dimension.

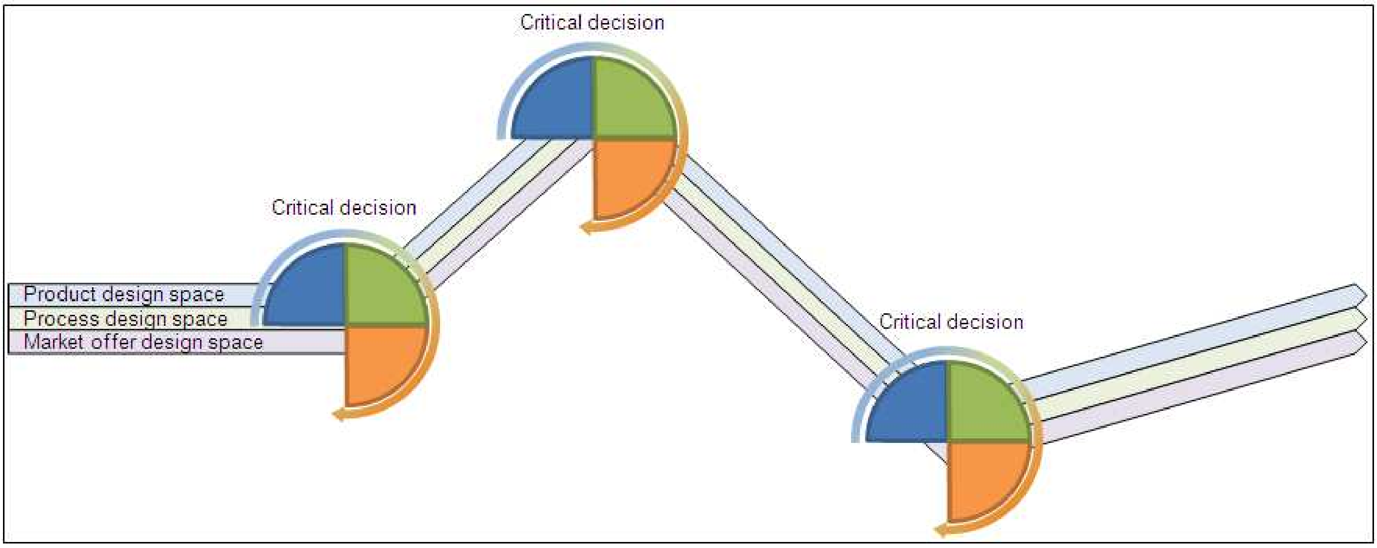

Figure 79. Project steering through the control of the critical decisions

1.3 Originality of the model

In the last parts, we have seen what our model do and what is its positioning. We now focus on what is the originality of this model. We identify several specific aspects that make the value of our model: its value chain focus, the link it enables between technical, tactical and strategic variable and the co-representation of multiple values and risks. The following paragraphs detail these three points.

1.3.1 Value chain focus

One of the main originality of our model is its area of focus. We have seen that our model treats only one specific activity of an innovation project: the critical decision process. However, paradoxically the impact is has on the project is very wide. We have demonstrated that our model takes into account the innovative product as well as the whole value chain. The information gathered comes from the inside of the enterprise as well as its suppliers and customers. Likewise, the outcome of our model also impacts an important number of various actors (see Figure 80). This large positioning is in our opinion very valuable. It is one of the aspects that enable this decision model to be used to pilot the innovation project.

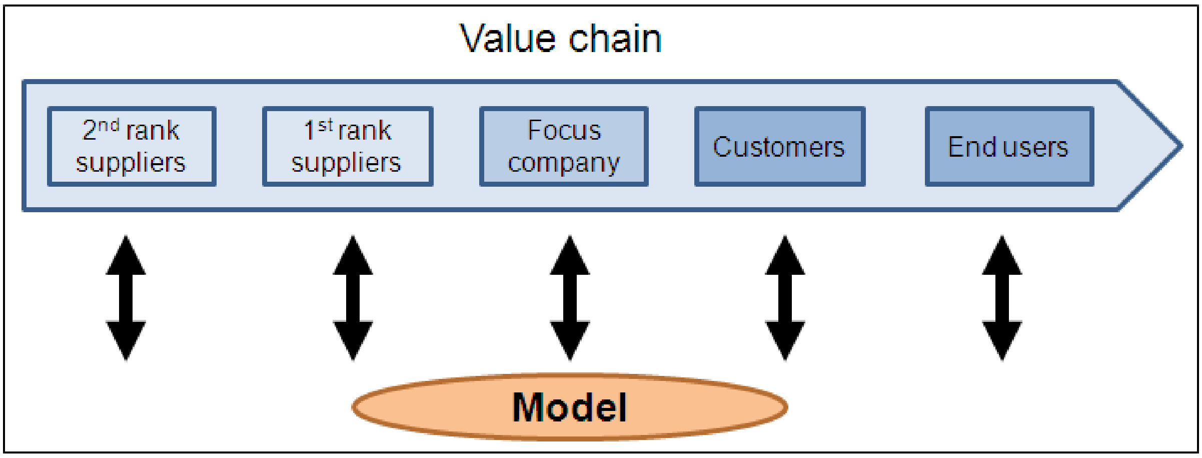

Figure 80. Value chain focus of the model

1.3.2 Link between technical, tactical and strategic variables

The second originality of our model is the fact that, in addition to its action perimeter throughout the whole value chain, our model also encloses the three management levels (see Figure 81). The inputs of our model can be of multiple natures. Some are very technical data (mechanical parameters in our experimentation for example) other are of a more abstract nature (relations between stakeholders for example). All these inputs can crucially impacts the decision criteria. It is thus critical to be able to take them into account in order to ensure the quality of the decision. Our model has this ability to make the link between these technical, tactical and strategic variables.

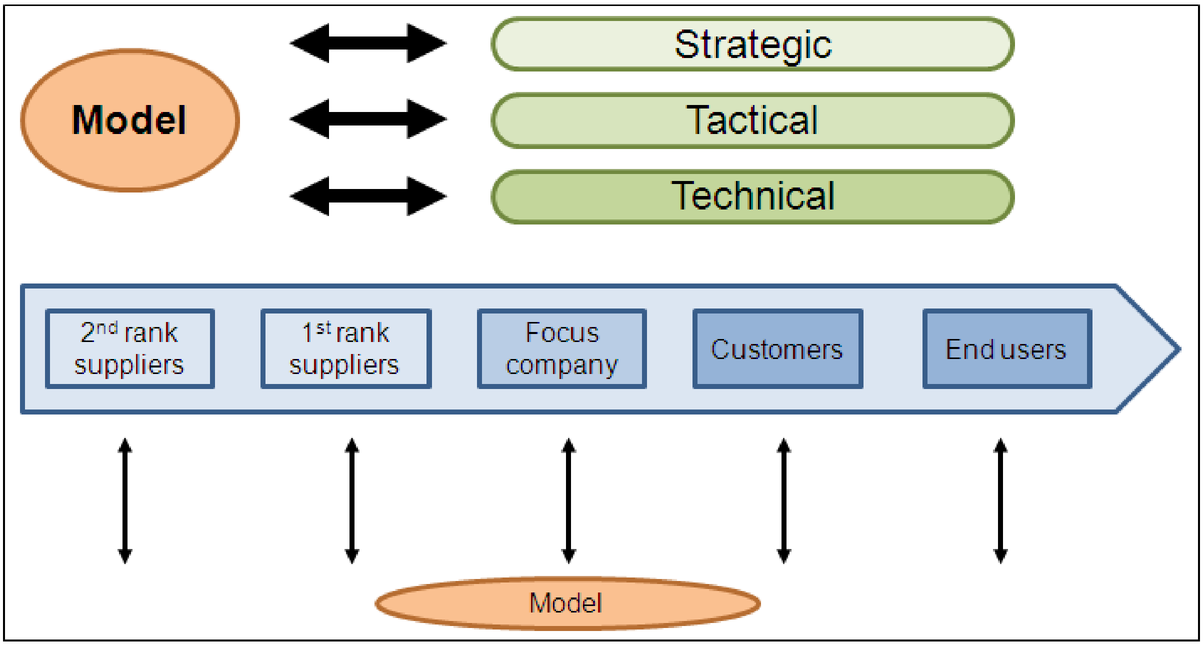

Figure 81. Relation between technical, tactical and strategic variables

1.3.3 Co-representation of multiple value creations and risks

Finally, the third particular contribution of our model is its mixed multi-values and risks approach. In today's industrial world, where the importance of non-financial values is increasing, it is essential to take into account other more complex benefits such as ethical or environmental contributions. Our model enables this rich point of view. We further increase its richness by also presenting information on the risks associated to each value creation. This multiple point of view – value creations and risks – is original in our approach. The benefits it gives to decision-makers can be very interesting.

2 Limitations

We have seen in the last paragraphs the main contribution of our model and the aspects that makes it original. In the following parts, we focus on its limitations. These are of two main categories: limitations that are due to our context and limitations of our model that were not treated due to lack of time.

2.1 Context-related limitations

2.1.1 Limits of the experimentation

One of the limitations of our work is related to our experimentation. The differences of timelines between our thesis work and the innovation project are very important. Interruptions in the projects as well as delays in the development process are the cause of divergences between these timelines. Applying our model after the first decision in order to compare the real decision with what it would have been if our model had been used is interesting. It facilitates the evaluation of the benefits of our model.

However, where the application of our model to the first decision was a bit late, its application on the second one was a bit premature. Or rather it would have been interesting to increase its duration since our thesis concluded before we were able to have access to all the information that were necessary for the decision. This hazard was treated in the best way we could by leaving instruction detailing how to use the tools we created (excel financial model and excel value creations model) in order to update the results of our model with the relevant pieces of information when they are available.

Finally, it would be interesting for the assessment of the quality of our model to be able to study the outcome of the project in a few year times. At this stage of development of the project, the feed-backs we have on the project are limited. An analysis of the contribution of our model on the level of success of the project performed once its outcome is known could bring to light other benefits or limitations it could have.

2.1.2 Representation and study of value destructions

Another limit of this work concerns the way we handle value representations. Our original purpose was to present to decision-makers not only a summary of the value created by the different alternatives of a decision, but also a summary of the value that is destroyed by the selection of each alternative. However, we were not able to implement this. The amount of information that can be put in one graph is limited. We were able to represent stakeholder (Y-axis), value types (X-axis), value creations (size of a bubble at the intersection of the value type and the stakeholder) and risk criticity (color of the bubble). However, this left no place to represent a destruction of value (or negative value creation) in a clear and readable way. As a consequence, we settled for the representation of a comparison of the value creation between the different alternatives.

2.2 Other limits in our work

By presenting an assessment of the values that can be created by the alternatives of a decision and the risks associated, our model aims to facilitate and increase the quality of the decision-making. However, one aspect is not well taken into account into this presentation: the level of certainty that is associated with each of these data. The assessment of the risks and value creations are based on hypotheses (in our experimentation sell volumes, manufacturing costs, mechanical properties, etc.) that are not exactly known since there is no certitude on these data. In some cases, the uncertainty is low enough so that the data is usable. In other cases, the uncertainty is too important to be neglected. When it was the case, we decreased the level of information (by using comparisons and qualitative assessment in place of quantitative ones) presented in order to reach a sufficient level of confidence in the information we presented.

Presenting more quantitative information could be possible and could only be benefic to decision-makers if this information is reliable. A solution would be to add to this quantitative information a confidence interval. This would enable decision-makers to access the quantitative values while knowing the extent to which they can trust these values. This solution could however damage the readability of the information presented. This solution was not explored due to time issues.

3 Perspectives

During our PhD work, we succeeded in the development of a model, designed for a specific industrial context. This work has limits that we exposed above. However, it could also be base for further work. It is these possible perspectives that we explore in this paragraph

3.1 Context extensions

Due to the environment of our research action, this work we produced was designed for a specific industrial context: disruptive technological innovations developed by SMEs in the aeronautical industries. However, providing changes, this model should be adaptable to other industrial contexts.

3.1.1 Size of the enterprise

In this work, we focused on small and medium enterprises. Their specificities (scarce resources, low formalization of process and knowledge) are the cause of limitations (but also advantages) in their capacity to innovate. As such, our model tackles problem specific to SMEs and is particularly useful for these kinds of structures. However, it could also benefit other types of enterprises. Because of its low prescribtivity, our model can be adapted to the specific development processes of bigger structures. In this context, it would accomplish its function of helping managers to pilot innovation projects. Having more formalized knowledge management processes could facilitate the use of our model. The access to more resources (experts, external studies, tests implementations) could also increase the quality of the information presented.

3.1.2 Industrial sector

In addition to the size of the firm studied, we also choose to focus on the aeronautical industrial sector. Once again, due to the specificities of this sector (high expectancies in terms of reliability, high strategic impact of innovations, business to business work relations), our model is particularly useful for this environment. However, some other sectors are characterized by similar characteristics, such as the transportations, defense and health industrial sectors. For these industries, our model would also be very useful. But its application would require an adaptation to the specificities of these sectors. The health and transportation sectors can address a bigger number of customers (mass-market in some cases) that can be sometimes very different. This would represent a significant change with the industrial context we focused on. On the other hand, in the defense industrial sector, the political aspects of the business can be game-changing. An adaptation of our model would have to focus on these aspects.

3.2 Other perspectives

3.2.1 Increased integration

We have stated in our work that our model could serve as a framework for the integration of value creation management tools (see II.5: Managing value creation:). In our work, we used some of these tools (Value Analysis, functional analysis, FMEA) to identify and assess certain value creations and risks, However our model does very little to incorporate other tools in a robust and valuable manner. An interesting research perspective could be to complete our model with a typology of possible problems and challenges that can be encountered in innovation development. Possible value creation management tools could be associated to each of these issues. Such a model would have a wider perimeter of application, focusing on more aspects of the innovation project management instead of helping to its piloting through the control of the critical decisions. Due to the increased complexity and prescribtivity, such an approach would be more adapted to a utilization in bigger industrial structures.

3.2.2 Computerization

Finally, a last proposition of potential perspective for our research work would be the development of a computerized version of our model. The excel model we have developed is not very user-friendly and not very robust. It does not represent a viable solution. However, based on our work, a proper decision support tool could be developed. Such a tool could guide a decision responsible into the different steps of our model as well as proposing an easy way of implementing the results and ease the phase of value creation and risks representation. However, due to the richness and complexity of innovation projects, one of the main challenges of such a development would be to be able to design a solution standard and robust enough so it could be useful in different cases without hindering the capacity of our model to present information adapted to the environment decision (vocabulary adapted to the various types of decisions for example).

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Annex I: Experimentation results

The following pages regroup the samples of the results of our experimentation. We regroup here some of the different pieces of information that were presented to the decision-makers. We begin by presenting the value creation and risk summary graphs for the first decision: selection of a manufacturing process for our ceramic. We then present the deeper level of information presentation associated to these graphs. For space reasons, the detailed results of the second decisions are not presented here

There are six different graphs, one for each alternative of the decision. On these graphs are presented the level of value creation and risks assessed for each of these alternatives. The Y-axis represents the different types of values that can be created and the X-axis represents the different stakeholders that can beneficiate from these value creations. Bubbles represent a value creation of a specific type (Y-axis) for a specific stakeholder (X-axis). The size of the bubble is an indicator of the level of value creation in comparison with the same type of value creation in other alternatives (see Table 10 represented below). The risk associated to each value creation is represented by a color code according to their criticity (probability x impact): green for criticity between one and seven, orange for criticity between eight and fourteen and red for higher criticity (see Table 13 reproduced below for the definition of the levels of probability and impact).

1st level	2nd level	3rd level	4th level	5th level
No value creation for the stakeholder	Small value creation for the stakeholder Significantly higher the 1st level	Medium value creation for the stakeholder Significantly higher than 2nd level Much higher the 1st level	High value creation for the stakeholder Significantly higher than 3rd level Much higher the 2nd level	Very high value creation for the stakeholder Significantly higher than the 4th level Much higher than 3rd level

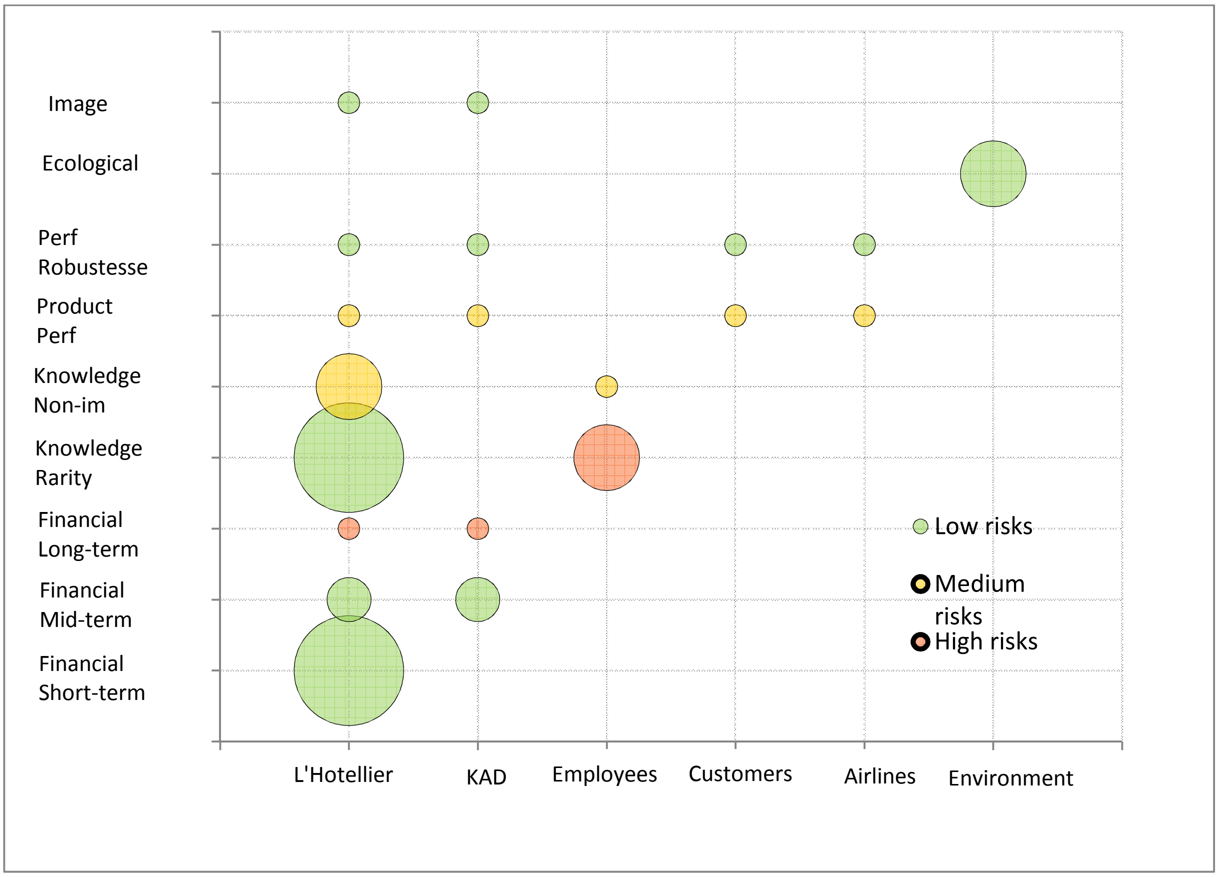
Five level qualifying value creations

Risk probability evaluation			Risk impact evaluation	
1	Rare		1	Insignificant
2	Unlikely		2	Minor
3	Possible		3	Moderate
4	Likely		4	Major
5	Almost certain		5	Catastrophic

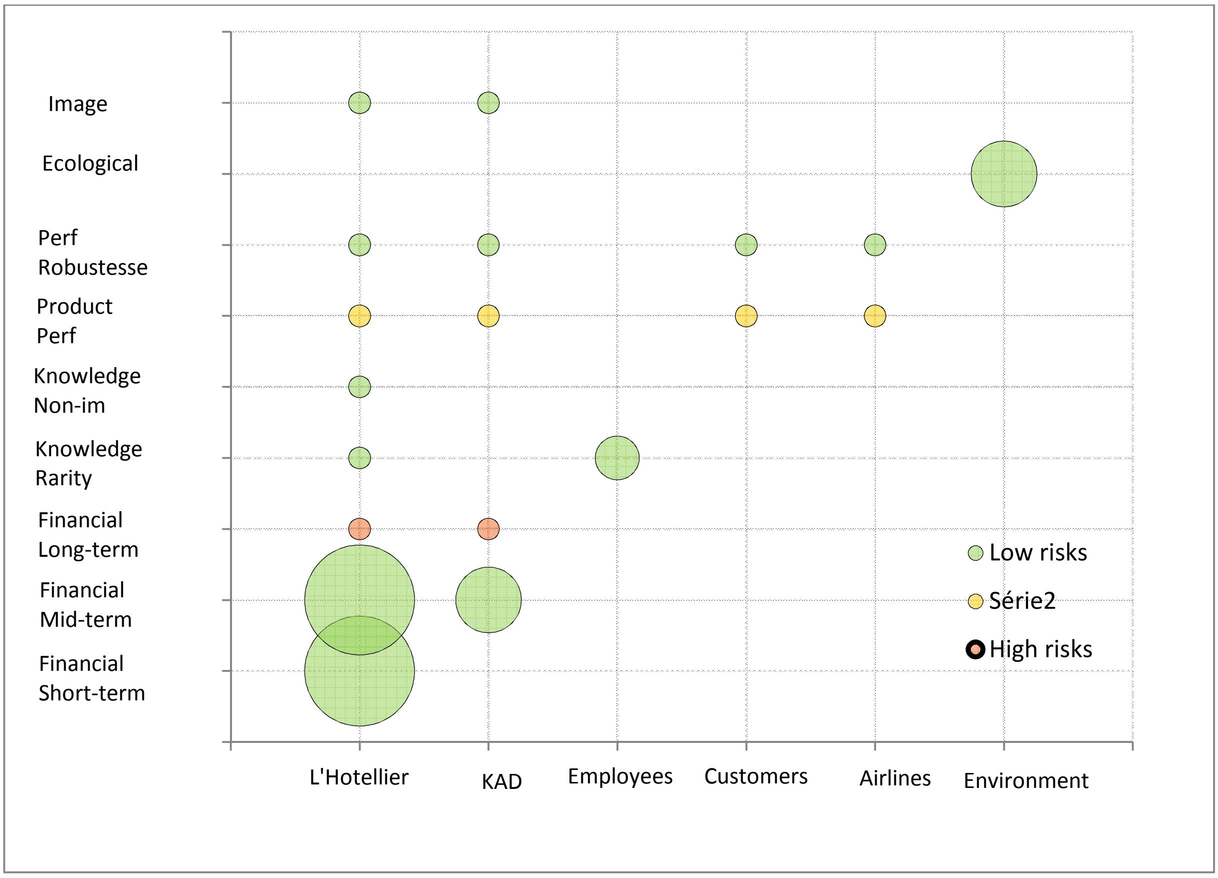
Risk probability and impact evaluation scales

1 Graphic summaries

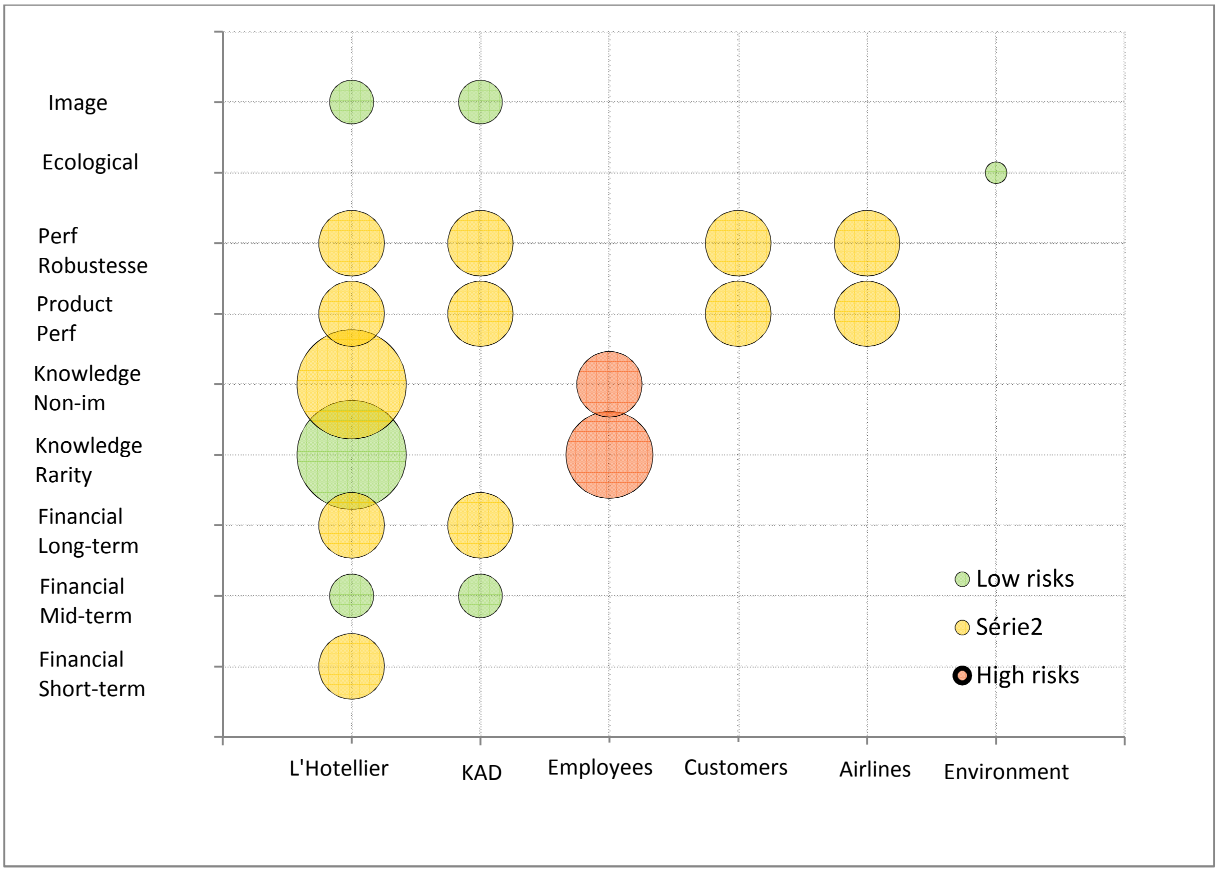
1.1 Uniaxial compression (internal)



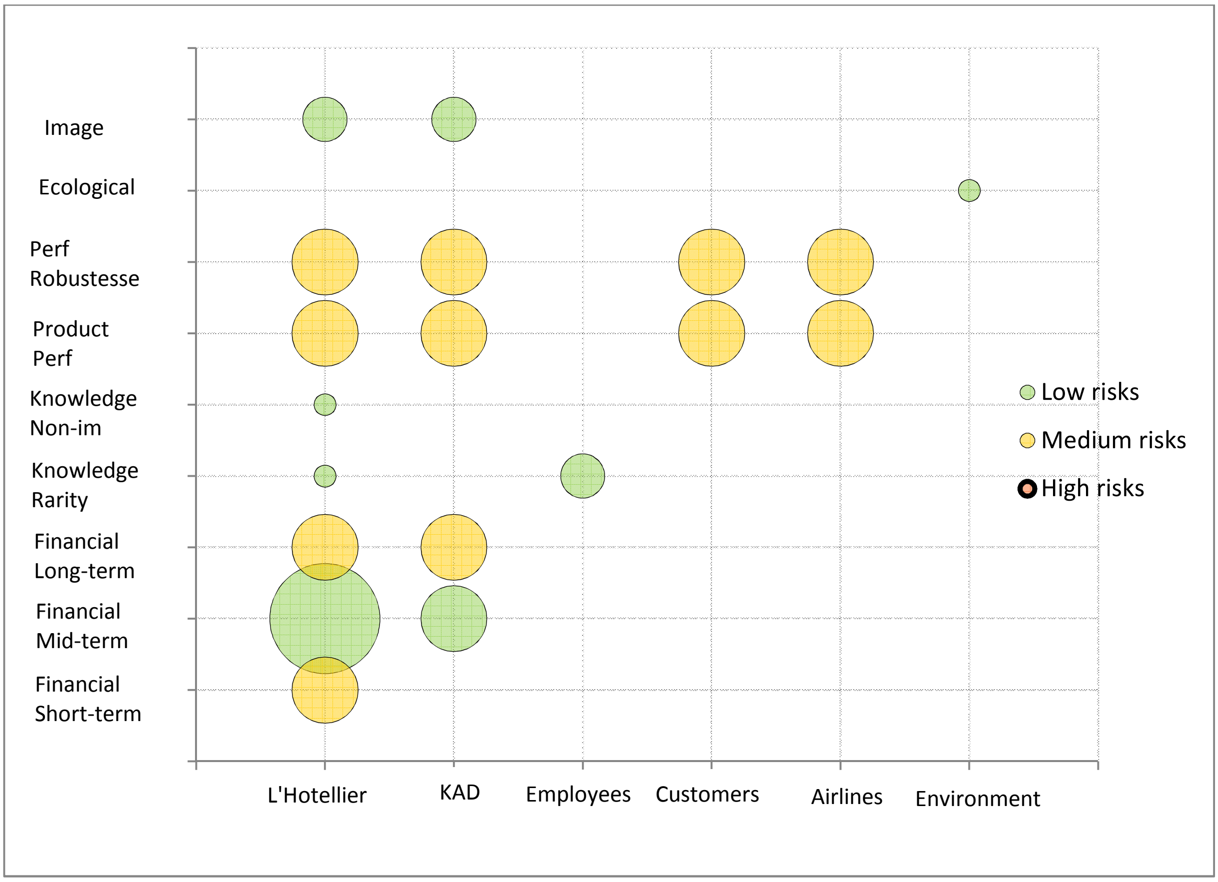
1.2 Uniaxial compression (external)



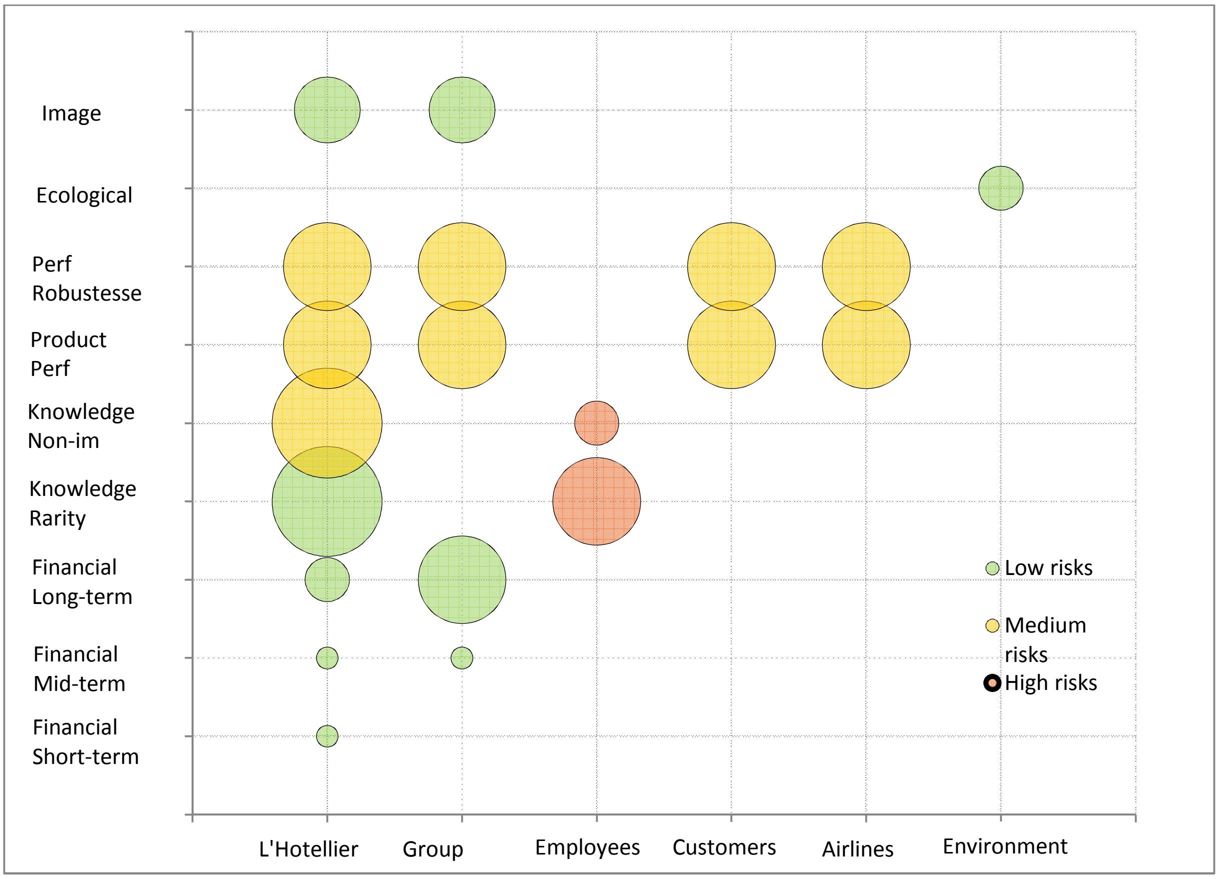
1.3 Slip casting (internal)



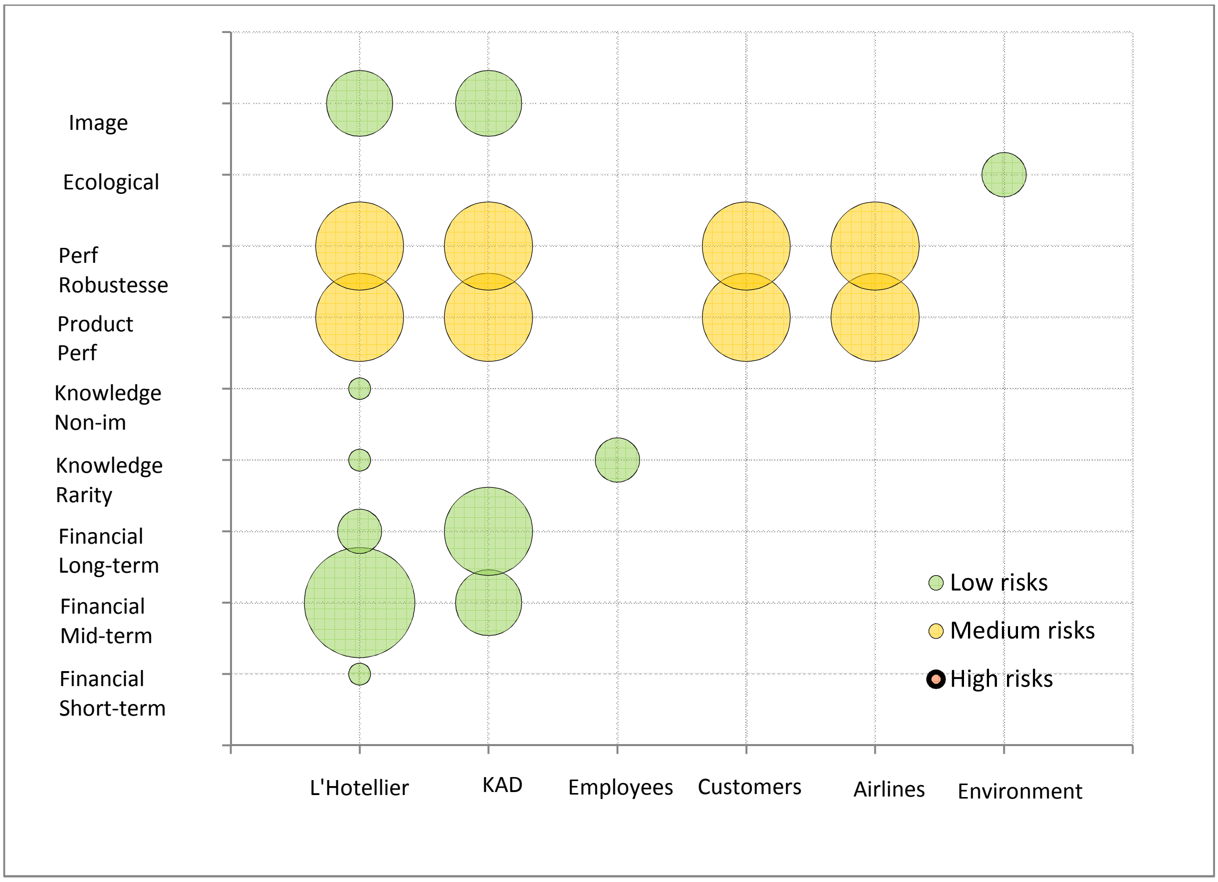
1.4 Slip casting (external)



1.5 Powder injection molding (internal)

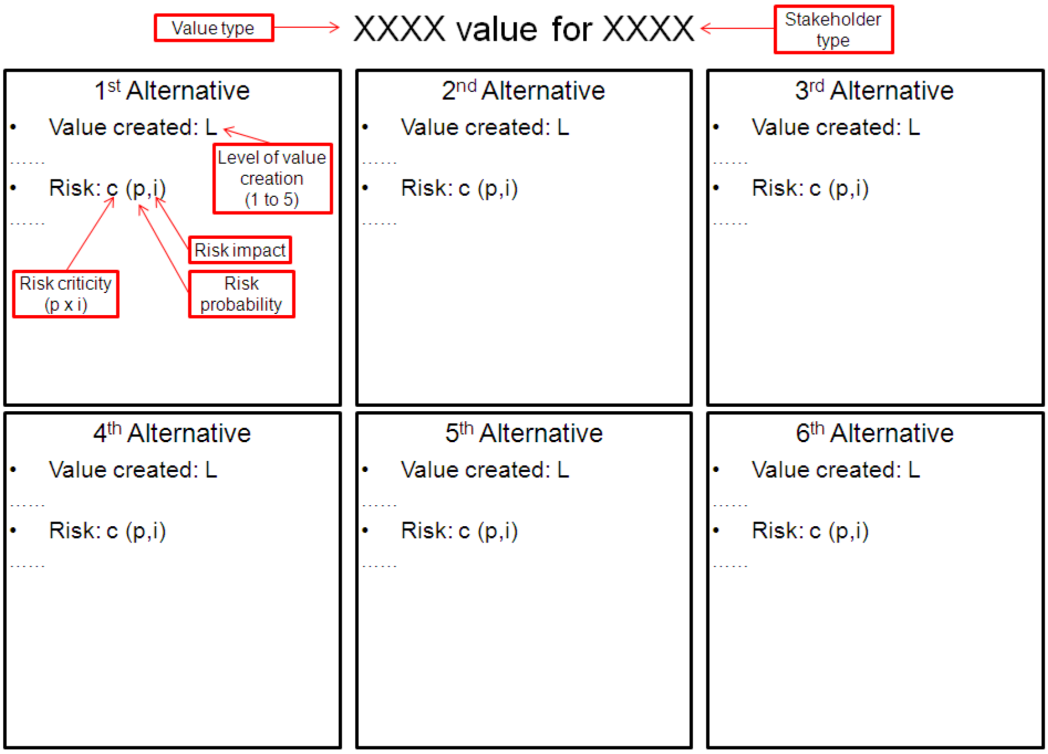


1.6 Powder injection molding (external)



2 Deeper level of information

The graphs presented above summarized the information on each of the alternatives of the decision. A deeper level of analysis is also presented to decision-makers. For each value creation, we built a page that details a comparison of each alternative according to this value creation. For each of these pages, a graph summarize this comparison, presenting the position of each alternative according the level of value creation considerate and the criticity of the risks associated to this value creation. These documents follow the template presented below:



Template presenting and summarizing the comparisons of the alternatives for a specific value creation

Each alternative on the graphs is represented by an acronym:

UC (int) represents the uniaxial compression alternative implemented in L'Hotellier

UC (ext) represents the uniaxial compression alternative done externally

SC (int) represents the slip casting alternative implemented in L'Hotellier

SC (ext) represents the slip casting alternative done externally

PIM (int) represents the powder injection molding implemented in L'Hotellier

PIM (ext) represents the powder injection molding done externally

2.1 Short-term financial value for L'Hotellier

Short-term financial value for L'Hotellier

Uniaxial compression (int)

- Value created: 4

Technology already developed, small investments required for its adaptation for the focus company (~20k€)

- Risks: 2 (1,2)

Low prob. of error: the technology is already developed.

Medium impact: The development costs of this technology are low compared to the other technologies

Slip casting (int)

- Value created: 2

Provisional development costs ~ 60k€

Adaptation of the technology for L'Hotellierto be added (~30k€)

- Risks: 9 (3,3)

Medium prob. of error: the technology exists but was never developed for this material

Medium impact: The development costs of this technology are low compared to PIM

PIM (int)

- Value created: 1

Provisional development costs ~120k€. Adaptation of the technology for L'Hotellierto be added (~40k€)

- Risks: 12 (3,4)

Medium prob. of error: the technology exists but was never developed for this material

High impact: The development costs of this technology are the highest of the 3 techno

Uniaxial compression (ext)

- Value created: 5

Technology already developed

- Risks: 2 (1,2)

Low probability of error: the technology is already developed.

Moderate impact: The development costs of this technology are low compared to the other technologies

Slip casting (ext)

- Value created: 3

Provisional development costs ~ 60k€

- Risks: 9 (3,3)

Medium prob. of error: the technology exists but was never developed for this material

Medium impact: The development costs of this technology are low compared to PIM

PIM (ext)

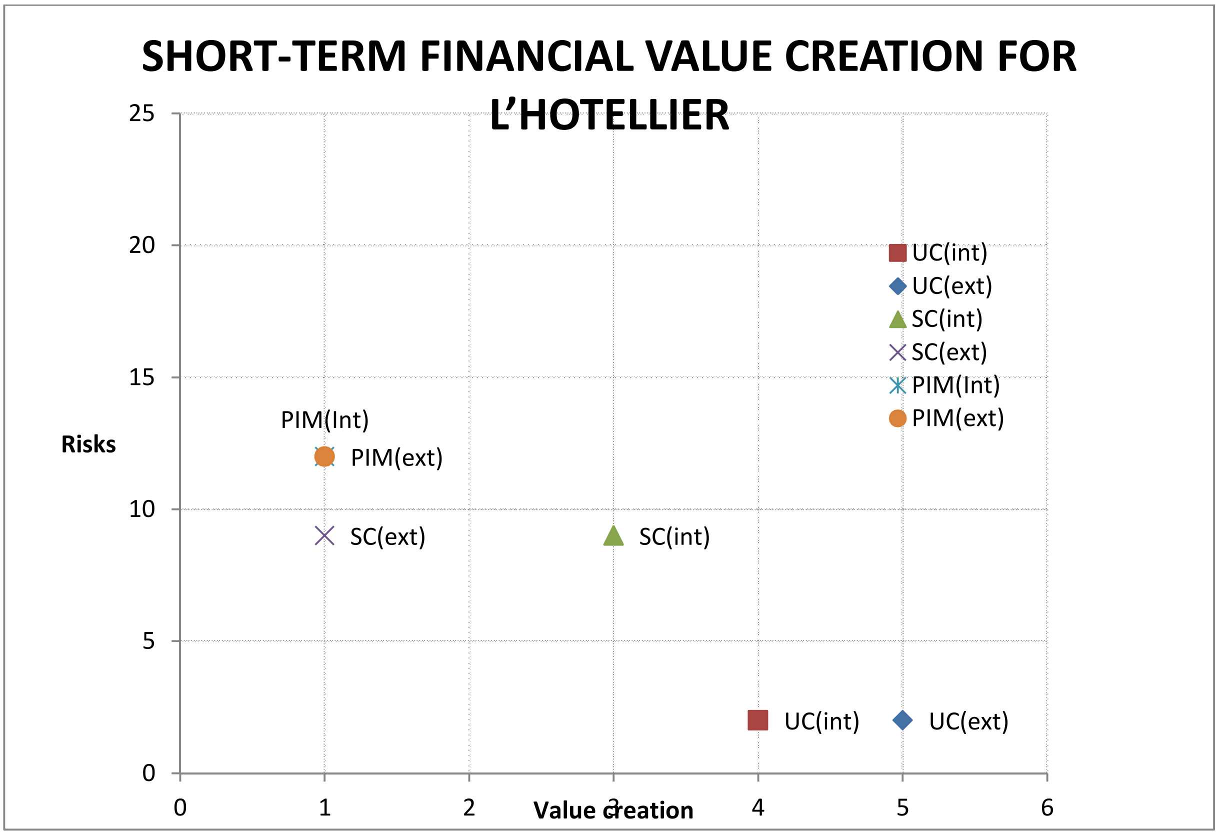
- Value created: 1

Provisional development costs ~120k€

- Risks: 9 (3,3)

Medium prob. of error: the technology exists but was never developed for this material

High impact: The development costs of this technology are the highest of the 3 technologies



2.2 Mid-term financial value for L'Hotellier

Mid-term financial value for L'HOTELLIER (L'HOTELLIER)

Uniaxial compression (int)

- Value created: 2

High investment costs (sintering furnaces)

- Risks: 1 (1,1)

Underestimation of production tools costs: unlikely since the y are well known and usual

Slip casting (int)

- Value created: 2

High investment costs (sintering furnaces)

- Risks: 2 (1,2)

Underestimation of production tools costs: unlikely since the y are well known and usual

PIM (int)

- Value created: 1

High investment costs (sintering furnaces and injection press)

- Risks: 2 (1,2)

Underestimation of production tools costs: unlikely since the y are well known and usual

Uniaxial compression (ext)

- Value created: 5

No investment required

- Risks:

No risk

Slip casting (ext)

- Value created: 5

No investment required

- Risks:

No risk

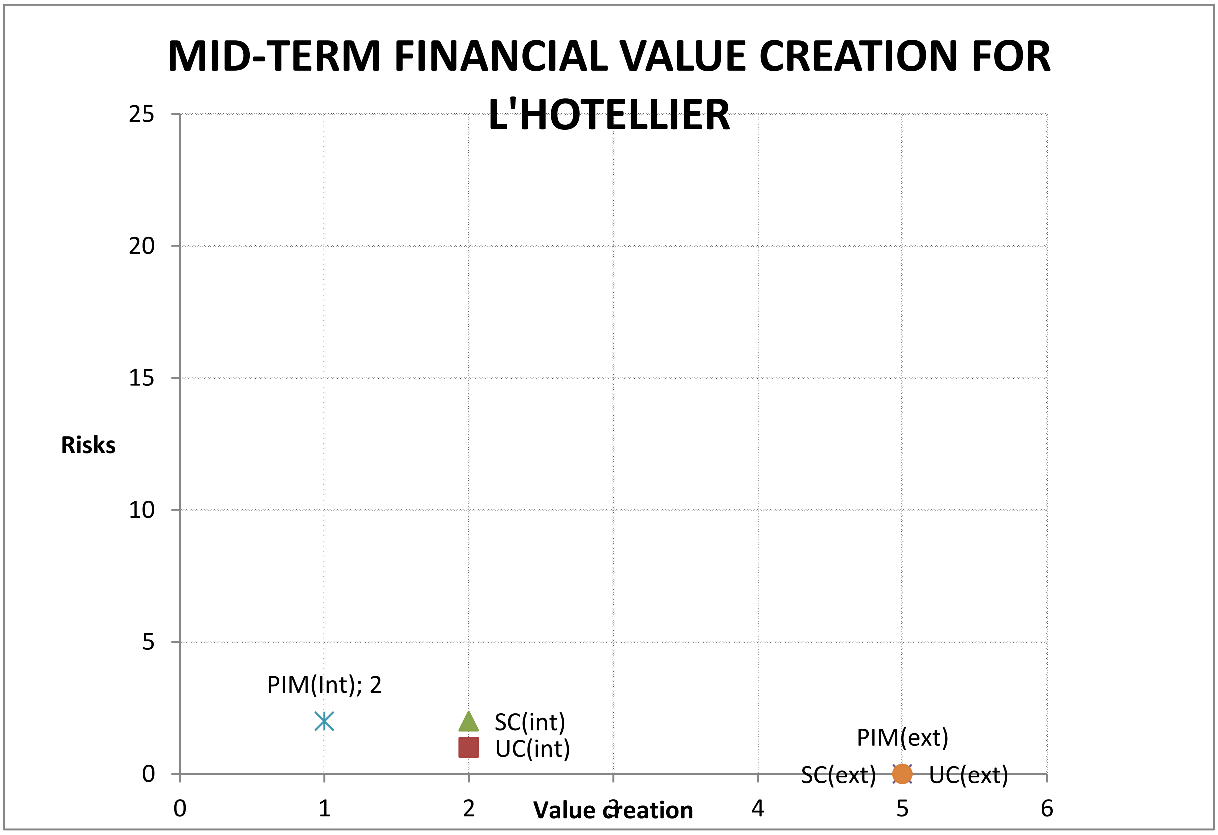
PIM (ext)

- Value created: 5

No investment required

- Risks:

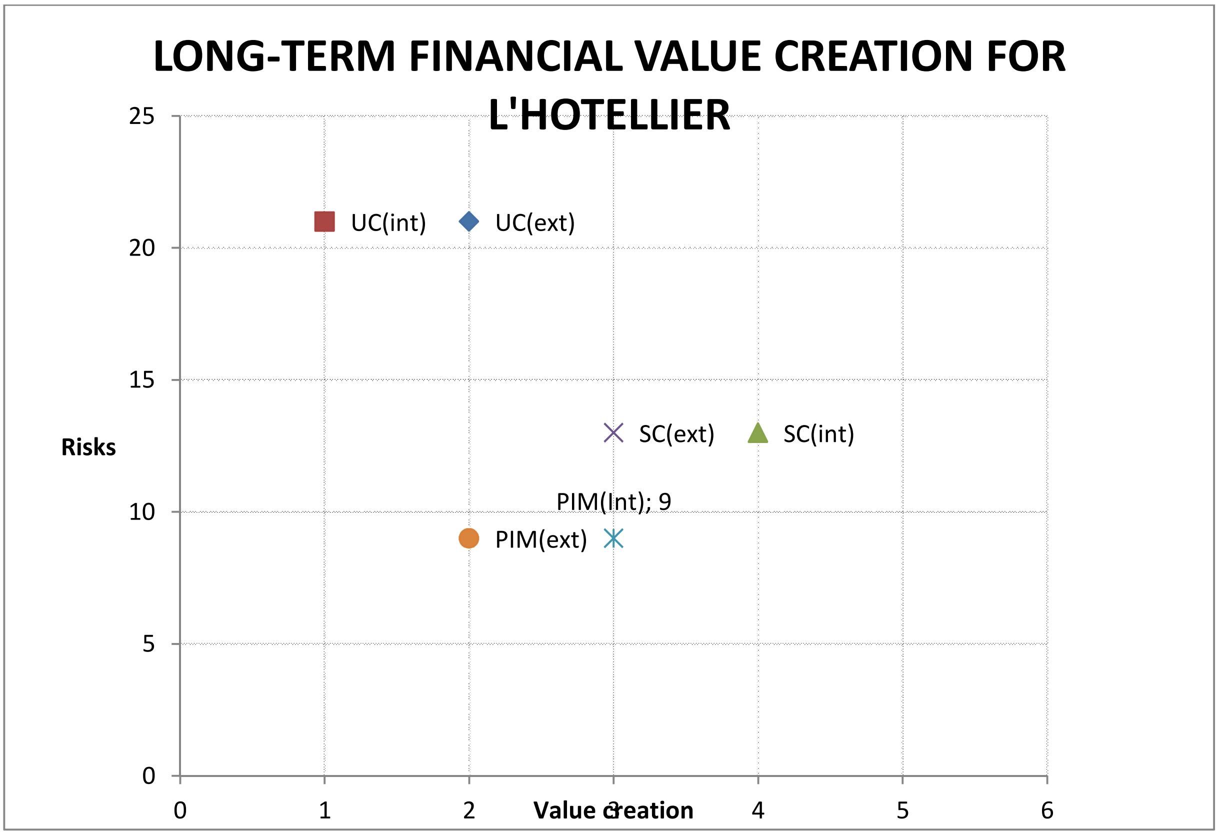
No risk



2.3 Long-term financial value for L'Hotellier

Long-term financial value for L'HOTELLIER

Uniaxial compression (int) • Value created: 1 High discard rate • Risks: 21 (4,4) low quality of final product implies higher number of discarded products (1, 5): defection of the powder supplier	**Slip casting (int)** • Value created: 4 Provisional size of series adapted to slip casting (1000-5000 pcs) • Risks: 13 (2,4) low quality of final product implies higher number of discarded products (1, 5): defection of the powder supplier	**PIM (int)** • Value created: 3 Provisional size of series not adapted to slip casting (>10000 pcs) • Risks: 9 (1,4) low quality of final product implies higher number of discarded products (1, 5): defection of the powder supplier
Uniaxial compression (ext) • Value created: 2 High discard rate • Risks: 25 (4,5) (4,5) low quality of final product implies higher number of discarded products (1, 5): defection of the powder supplier	**Slip casting (ext)** • Value created: 3 • Risks: 13 (3,2) (2,4) low quality of final product implies higher number of discarded products (1, 5): defection of the powder supplier	**PIM (ext)** • Value created: 2 No investment required • Risks: 9 (1,4) low quality of final product implies higher number of discarded products (1, 5): defection of the powder supplier



2.4 Mid-term financial value for KAD

Mid-term financial value for KAD

Uniaxial compression (int)

- Value created: 2

High investment costs (sintering furnaces)

- Risks: 1 (1,1)

Underestimation of production tools costs: unlikely since the y are well known and usual

Slip casting (int)

- Value created: 2

High investment costs (sintering furnaces)

- Risks: 2 (1,2)

Underestimation of production tools costs: unlikely since the y are well known and usual

PIM (int)

- Value created: 1

High investment costs (sintering furnaces and injection press)

- Risks: 2 (1,2)

Underestimation of production tools costs: unlikely since the y are well known and usual

Uniaxial compression (ext)

- Value created: 5

No investment required

- Risks:

No risk

Slip casting (ext)

- Value created: 5

No investment required

- Risks:

No risk

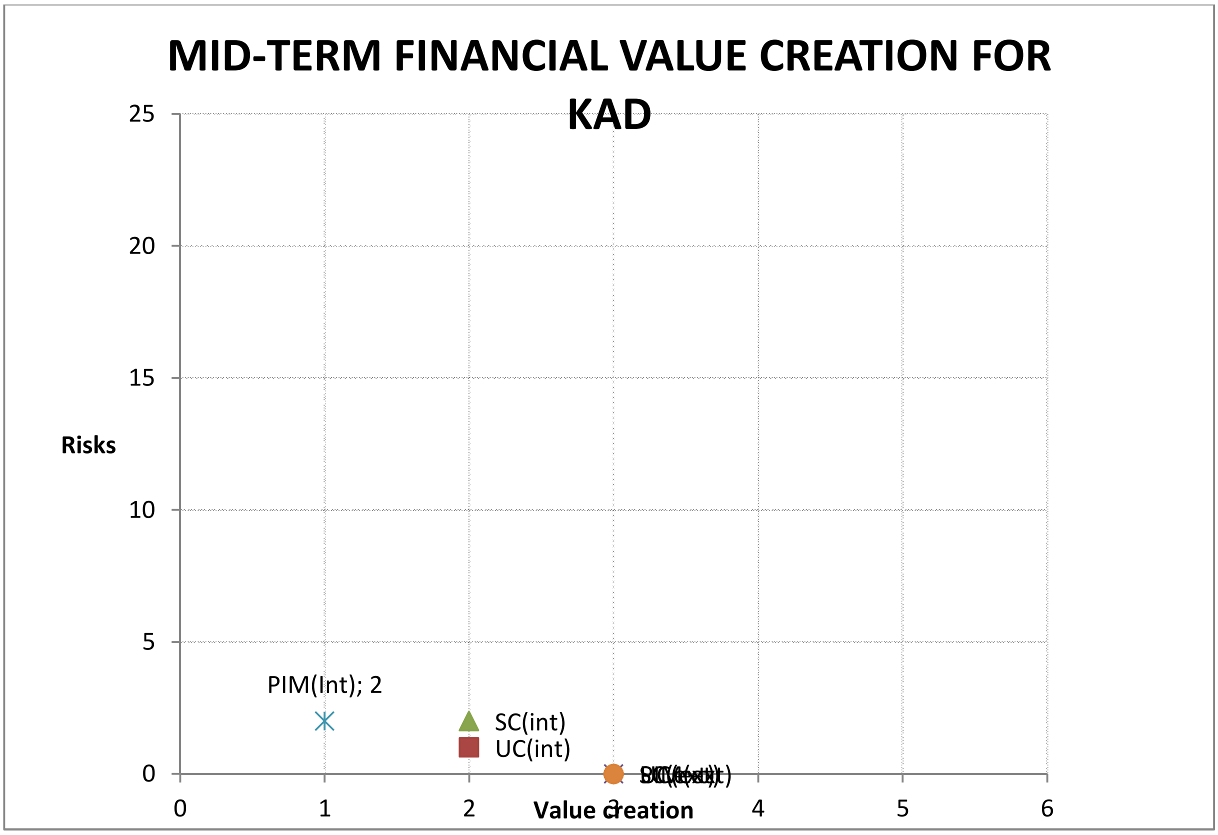
PIM (ext)

- Value created: 5

No investment required

- Risks:

No risk



2.5 Long-term financial value for KAD

Long-term financial value for KAD

Uniaxial compression (int)

- Value created: 1

High discard rate

- Risks: 21

(4,4) low quality of final product implies higher number of discarded products

(1, 5): defection of the powder supplier

Slip casting (int)

- Value created: 4
- Risks: 13 (3,2)

(2,4) low quality of final product implies higher number of discarded products

(1, 5): defection of the powder supplier

PIM (int)

- Value created: 3

High investment costs (sintering furnaces and injection press)

- Risks: 9

(1,4) low quality of final product implies higher number of discarded products

(1, 5): defection of the powder supplier

Uniaxial compression (ext)

- Value created: 2

High discard rate

- Risks: 25 (4,5)

(4,5) low quality of final product implies higher number of discarded products

(1, 5): defection of the powder supplier

Slip casting (ext)

- Value created: 3
- Risks: 13 (3,2)

(2,4) low quality of final product implies higher number of discarded products

(1, 5): defection of the powder supplier

PIM (ext)

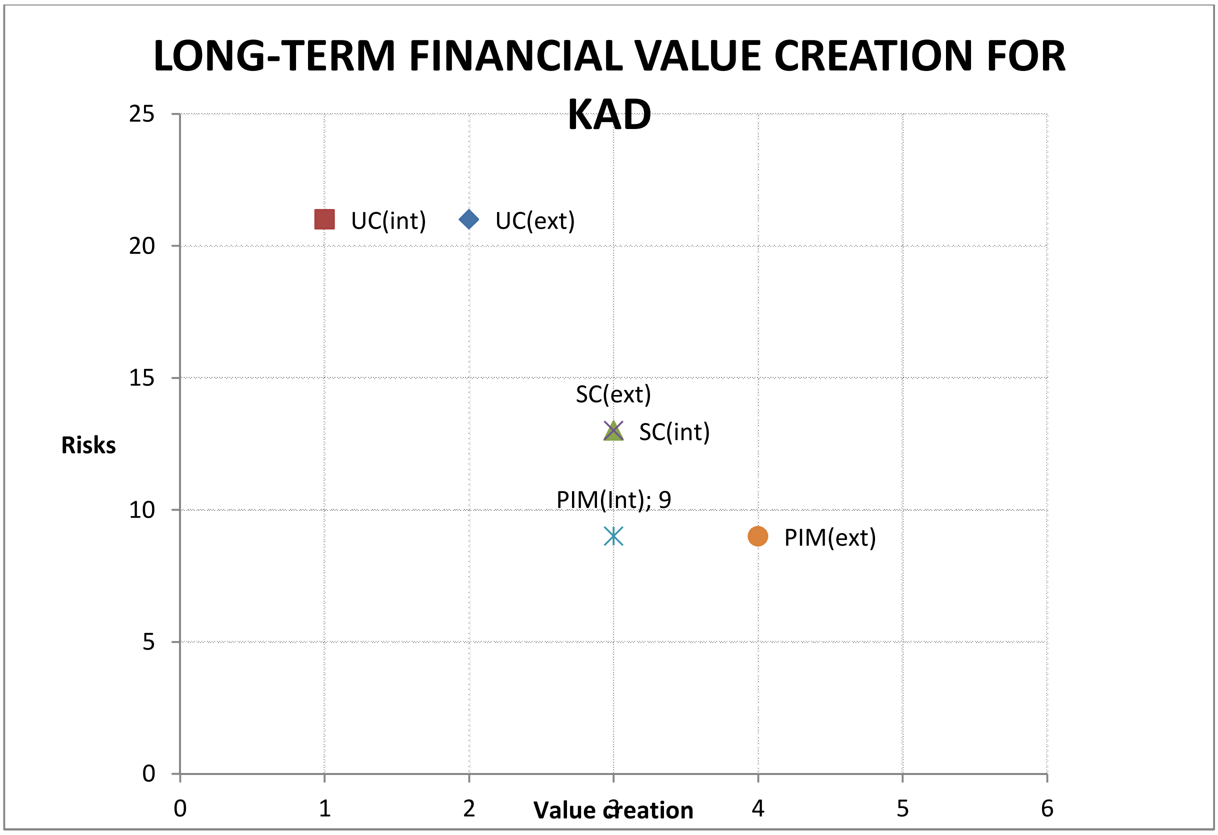
- Value created: 2

No investment required

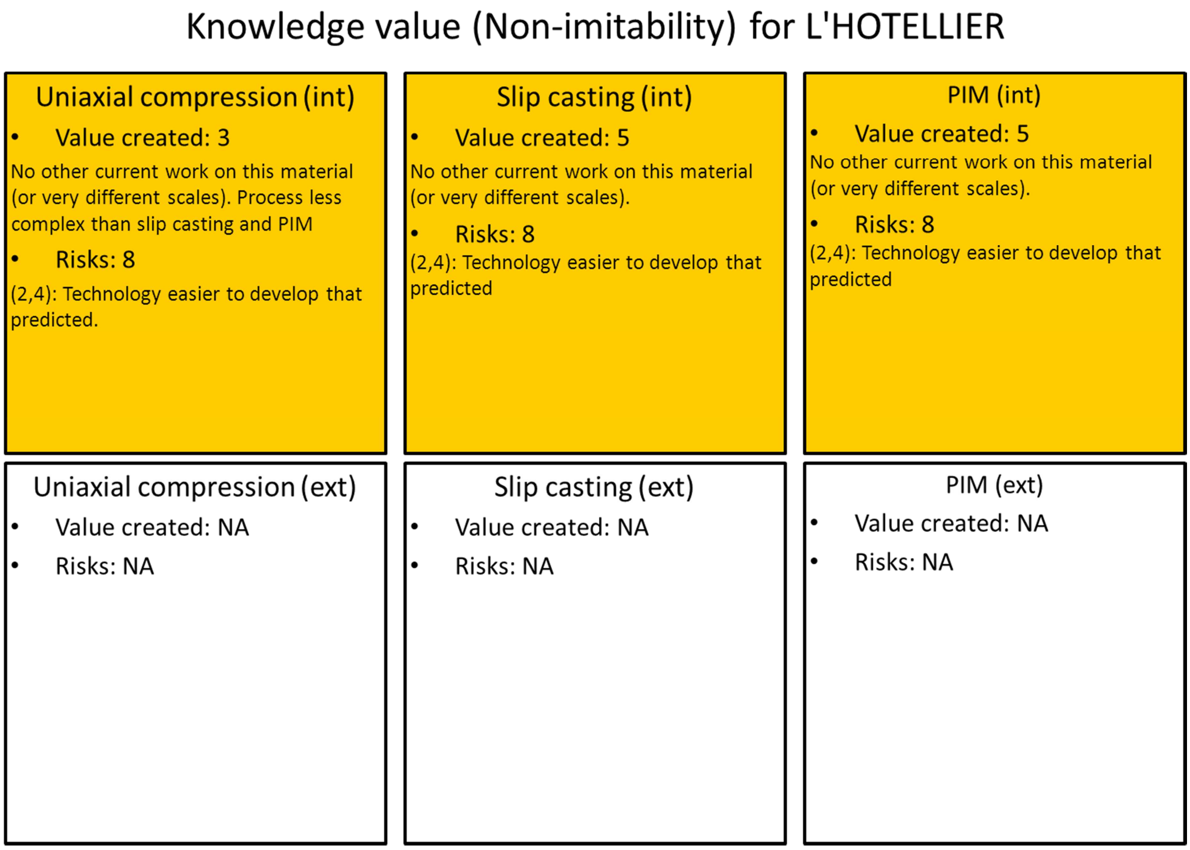
- Risks: 9

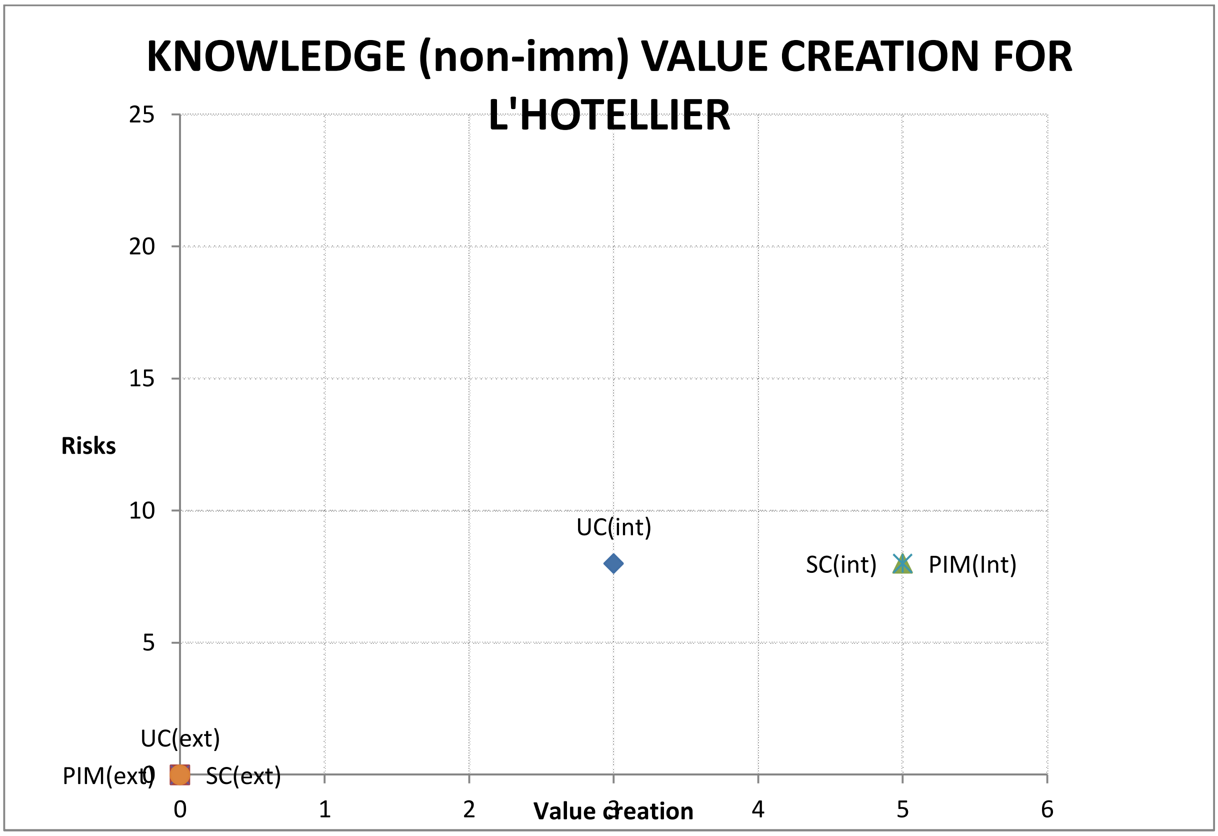
(1,4) low quality of final product implies higher number of discarded products

(1, 5): defection of the powder supplier



2.6 Knowledge value for L'Hotellier





2.7 Knowledge value for the employees

Knowledge value (Rarity) for the employees

Uniaxial compression (int)

- Value created: 3

Control of the sintering process

- Risks: 16

(4,4): Hiring of new resources; very probable since the control of the sintering phase is highly complex

Slip casting (int)

- Value created: 4

Control of the sintering and slip casting process

- Risks: 20

(5,4): Hiring of new resources; very probable since the control of the sintering phase and slip casting process is highly complex

PIM (int)

- Value created: 4

Control of the sintering and PIM process

- Risks: 20

(5,4): Hiring of new resources; very probable since the control of the sintering phase and injection process is highly complex

Uniaxial compression (ext)

- Value created: 2

Ceramic-related expertise (quality, engineering, …)

- Risks: 4

(1,4): Hiring of new resources.

Unlikely, current resources competent

Slip casting (ext)

- Value created: 2

Ceramic-related expertise (quality, engineering, …)

- Risks: 4

(1,4): Hiring of new resources.

Unlikely, current resources competent

PIM (ext)

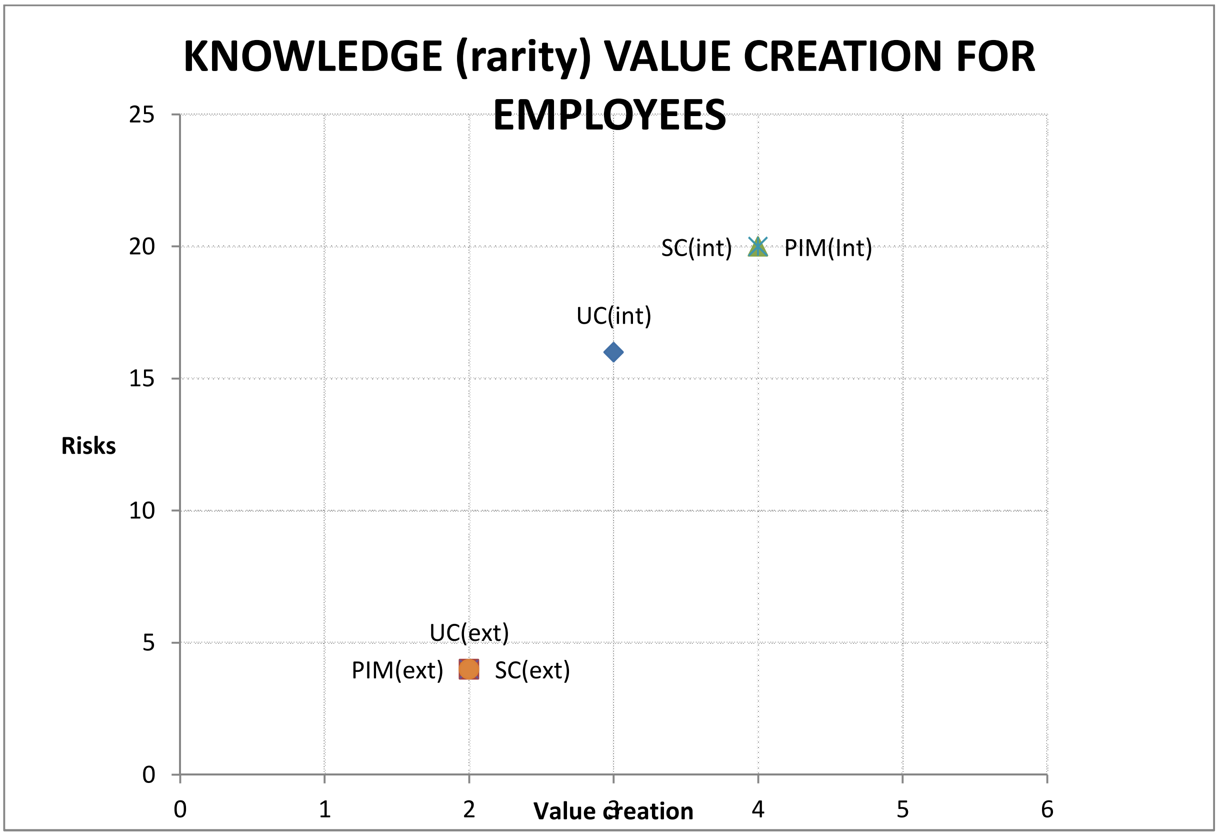
- Value created: 2

Ceramic-related expertise (quality, engineering, …)

- Risks: 4

(1,4): Hiring of new resources.

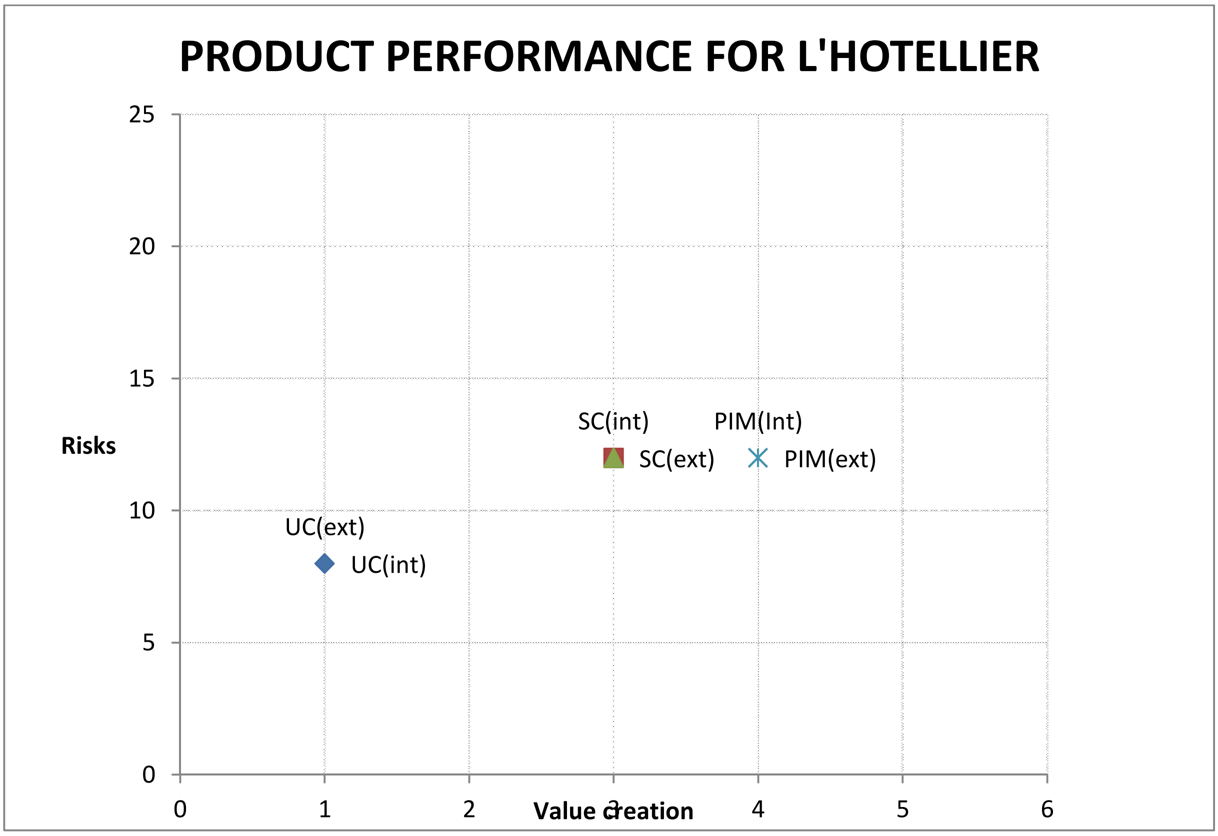
Unlikely, current resources competent



2.8 Product performance for L'Hotellier

Product performance for L'HOTELLIER

Uniaxial compression (int)	Slip casting (int)	PIM (int)
• Value created: 1 Anisotropic material characteristics very high probability of critical cracks • Risks: 8 (2,4): Tests conducted, material strength known. Very high impact in case of significantly low mechanical strength	• Value created: 3 Better properties than uniaxial compression according to experts • Risks: 12 (3,4): No tests, only experts advices. Very high impact in case of significantly low mechanical strength	• Value created: 4 Better properties than uniaxial compression and slip casting according to experts • Risks: 12 (3,4): No tests, only experts advices. Very high impact in case of significantly low mechanical strength
Uniaxial compression (ext)	**Slip casting (ext)**	**PIM (ext)**
• Value created: 1 Anisotropic material characteristics very high probability of critical cracks • Risks: 8 (2,4): Tests conducted, material strength known. Very high impact in case of significantly low mechanical strength	• Value created: 3 Better properties than uniaxial compression according to experts • Risks: 12 (3,4): No tests, only experts advices. Very high impact in case of significantly low mechanical strength	• Value created: 4 Better properties than uniaxial compression and slip casting according to experts • Risks: 12 (3,4): No tests, only experts advices. Very high impact in case of significantly low mechanical strength



2.9 Product performance for KAD

Product performance for KAD

Uniaxial compression (int)

- Value created: 1

Anisotropic material characteristics very high probability of critical cracks

- Risks: 8

(2,4): Tests conducted, material strength known. Very high impact in case of significantly low mechanical strength

Slip casting (int)

- Value created: 3

Better properties than uniaxial compression according to experts

- Risks: 12

(3,4): No tests, only experts advices. Very high impact in case of significantly low mechanical strength

PIM (int)

- Value created: 4

Better properties than uniaxial compression and slip casting according to experts

- Risks: 12

(3,4): No tests, only experts advices. Very high impact in case of significantly low mechanical strength

Uniaxial compression (ext)

- Value created: 1

Anisotropic material characteristics very high probability of critical cracks

- Risks: 8

(2,4): Tests conducted, material strength known. Very high impact in case of significantly low mechanical strength

Slip casting (ext)

- Value created: 3

Better properties than uniaxial compression according to experts

- Risks: 12

(3,4): No tests, only experts advices. Very high impact in case of significantly low mechanical strength

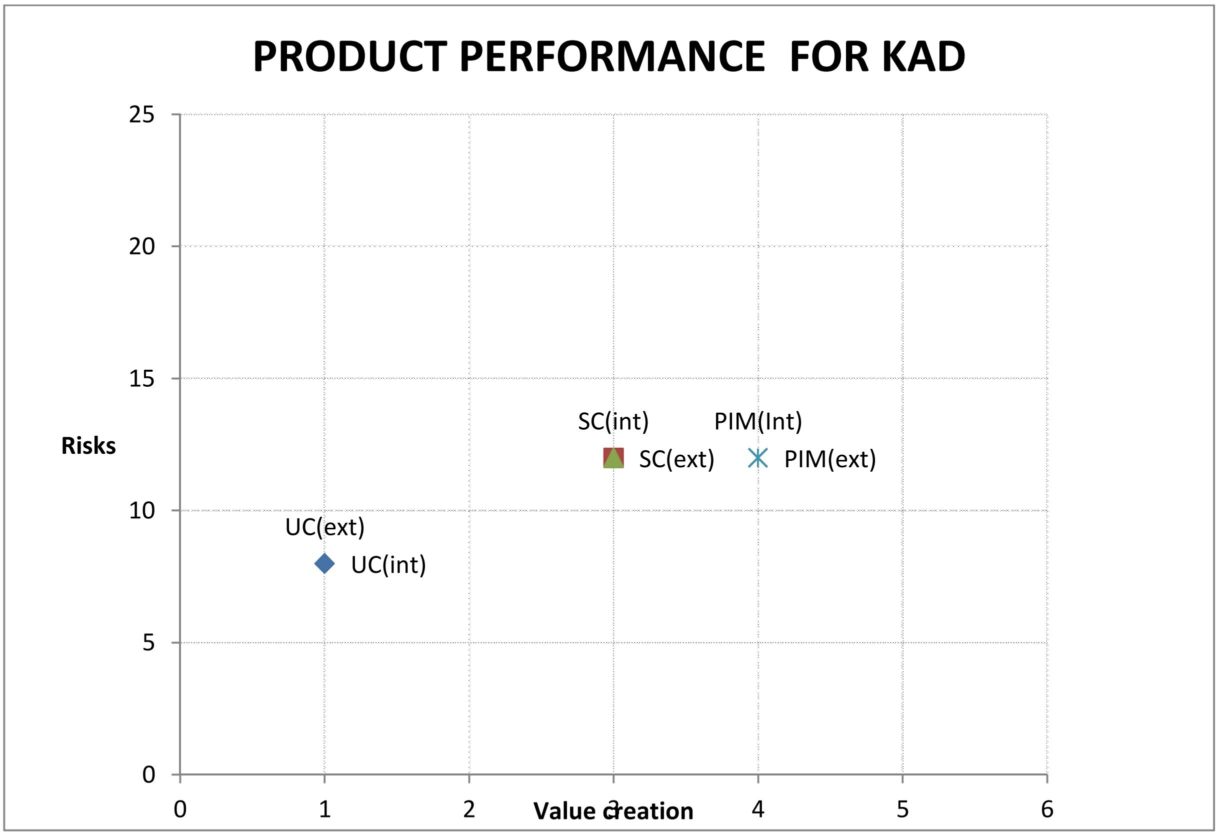
PIM (ext)

- Value created: 4

Better properties than uniaxial compression and slip casting according to experts

- Risks: 12

(3,4): No tests, only experts advices. Very high impact in case of significantly low mechanical strength



2.10 Product performance for the customers

Product performance for the customer

Uniaxial compression (int)
- Value created: 1

Anisotropic material characteristics very high probability of critical cracks
- Risks: 8

(2,4): Tests conducted, material strength known. Very high impact in case of significantly low mechanical strength

Slip casting (int)
- Value created: 3

Better properties than uniaxial compression according to experts
- Risks: 12

(3,4): No tests, only experts advices. Very high impact in case of significantly low mechanical strength

PIM (int)
- Value created: 4

Better properties than uniaxial compression and slip casting according to experts
- Risks: 12

(3,4): No tests, only experts advices. Very high impact in case of significantly low mechanical strength

Uniaxial compression (ext)
- Value created: 1

Anisotropic material characteristics very high probability of critical cracks
- Risks: 8

(2,4): Tests conducted, material strength known. Very high impact in case of significantly low mechanical strength

Slip casting (ext)
- Value created: 3

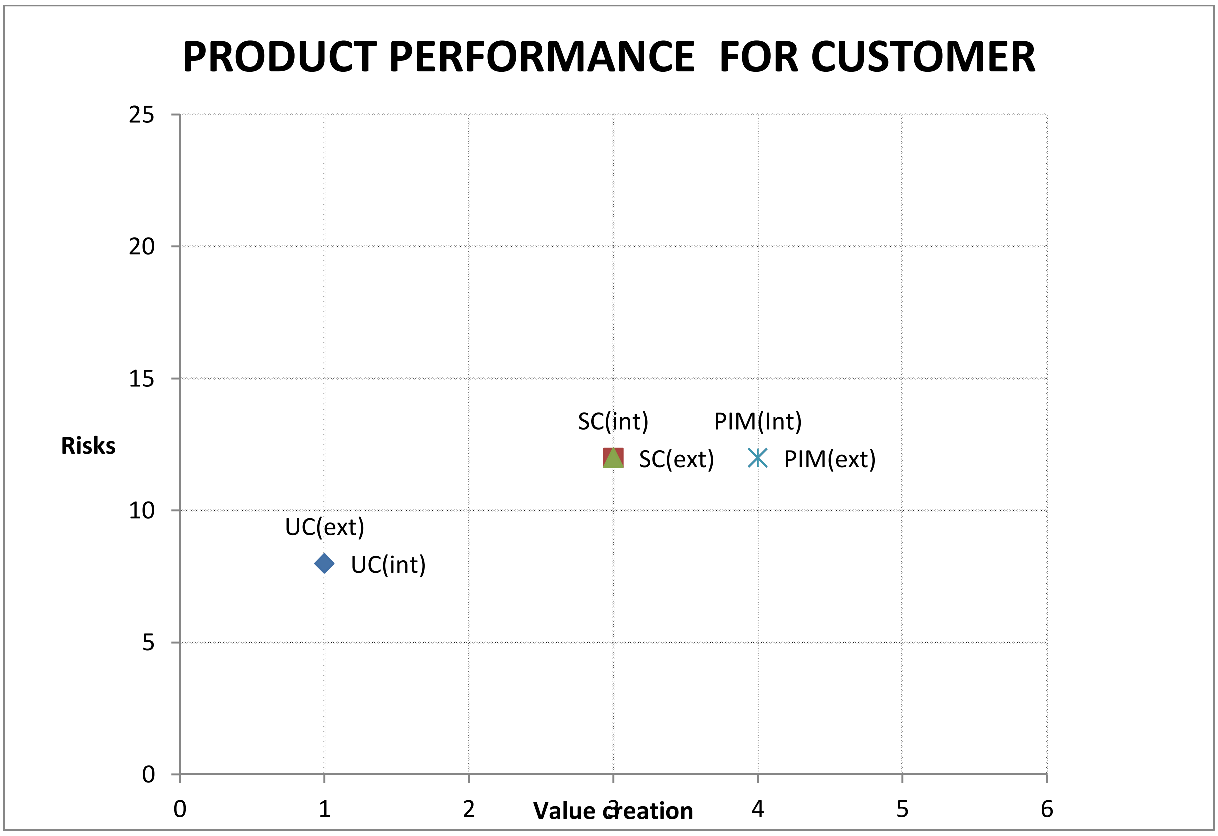
Better properties than uniaxial compression according to experts
- Risks: 12

(3,4): No tests, only experts advices. Very high impact in case of significantly low mechanical strength

PIM (ext)
- Value created: 4

Better properties than uniaxial compression and slip casting according to experts
- Risks: 12

(3,4): No tests, only experts advices. Very high impact in case of significantly low mechanical strength



2.11 Product performance for the airlines

Product performance for the airlines

Uniaxial compression (int)

- Value created: 1

Anisotropic material characteristics very high probability of critical cracks

- Risks: 8

(2,4): Tests conducted, material strength known. Very high impact in case of significantly low mechanical strength

Slip casting (int)

- Value created: 3

Better properties than uniaxial compression according to experts

- Risks: 12

(3,4): No tests, only experts advices. Very high impact in case of significantly low mechanical strength

PIM (int)

- Value created: 4

Better properties than uniaxial compression and slip casting according to experts

- Risks: 12

(3,4): No tests, only experts advices. Very high impact in case of significantly low mechanical strength

Uniaxial compression (ext)

- Value created: 1

Anisotropic material characteristics very high probability of critical cracks

- Risks: 8

(2,4): Tests conducted, material strength known. Very high impact in case of significantly low mechanical strength

Slip casting (ext)

- Value created: 3

Better properties than uniaxial compression according to experts

- Risks: 12

(3,4): No tests, only experts advices. Very high impact in case of significantly low mechanical strength

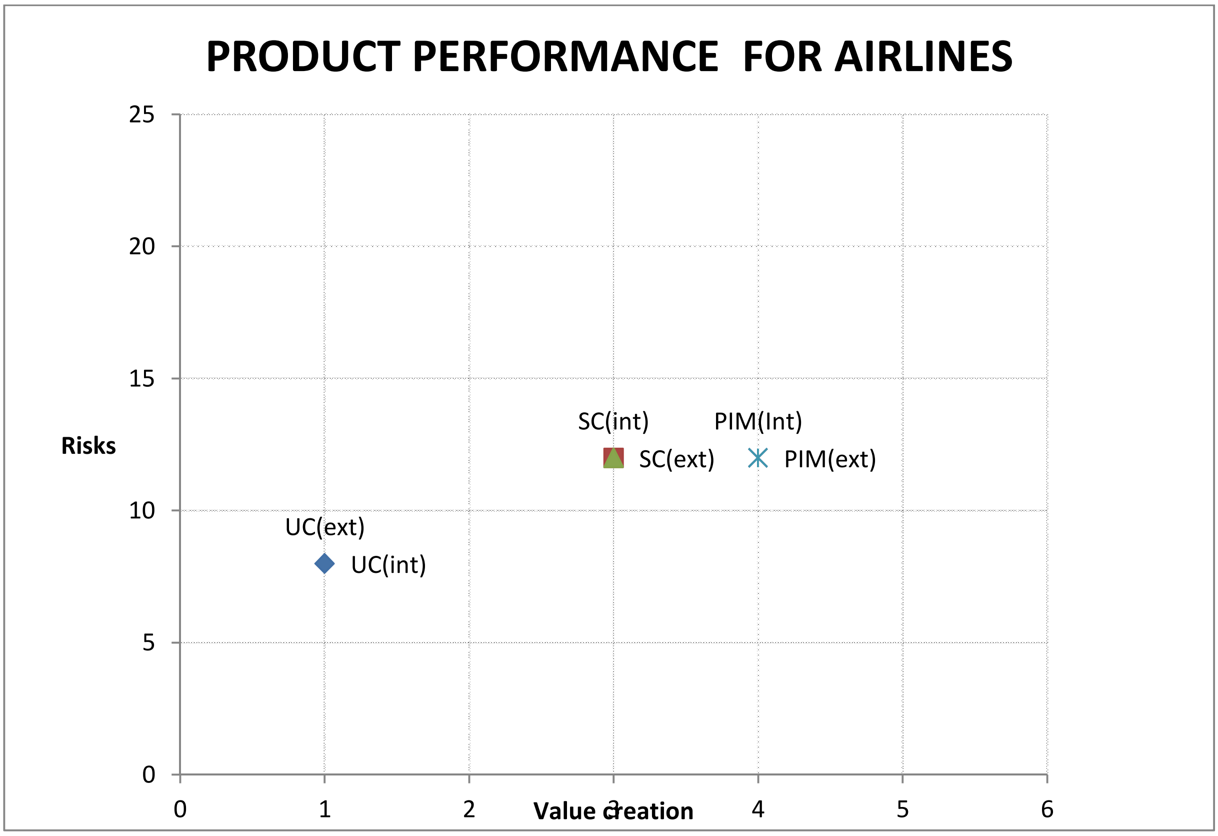
PIM (ext)

- Value created: 4

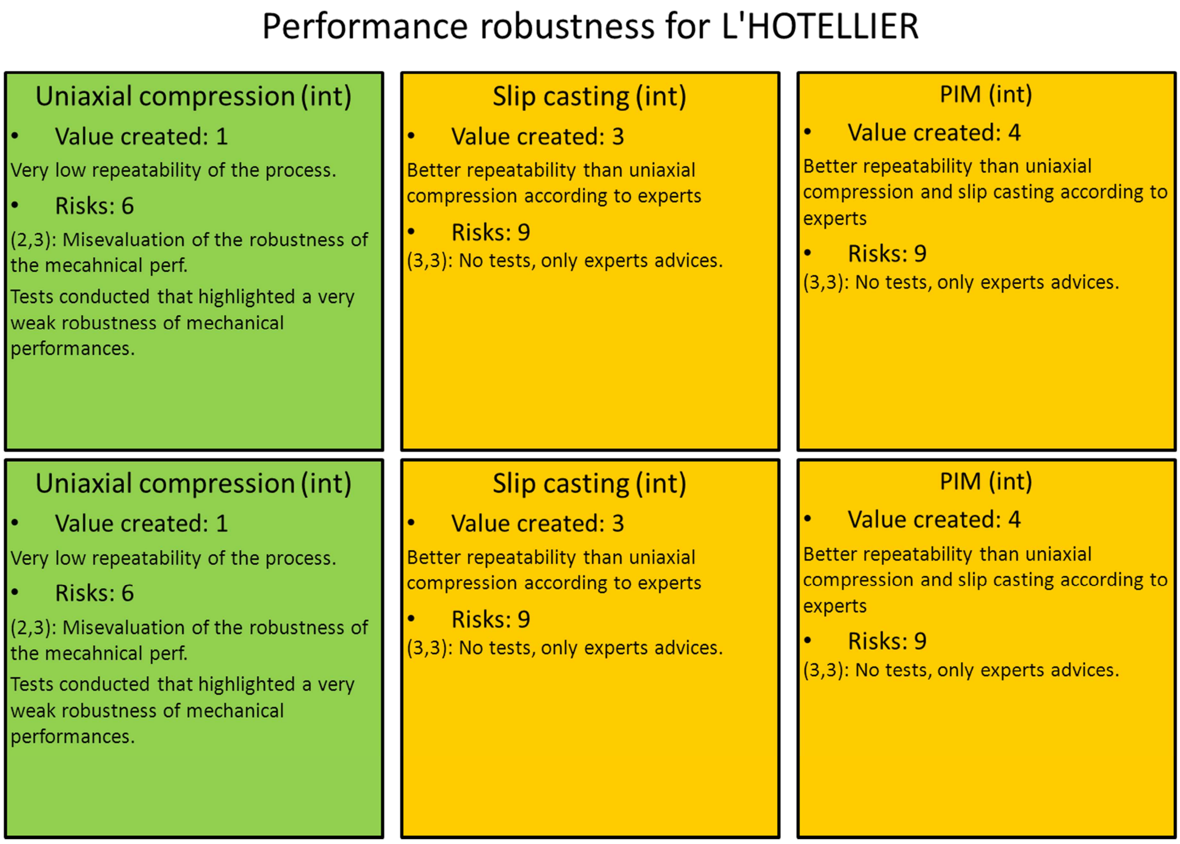
Better properties than uniaxial compression and slip casting according to experts

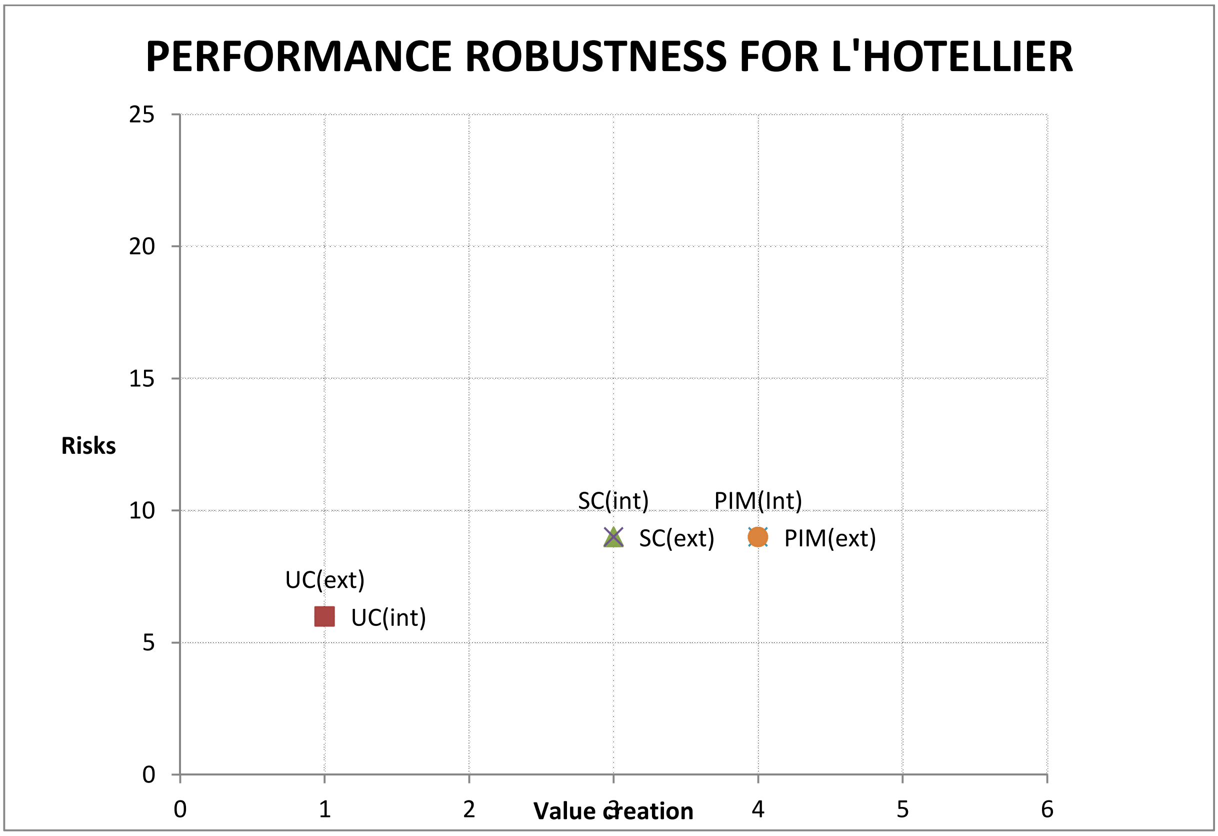
- Risks: 12

(3,4): No tests, only experts advices. Very high impact in case of significantly low mechanical strength



2.12 Performance robustness for L'Hotellier





2.13 Performance robustness for KAD

Performance robustness for KAD

Uniaxial compression (int)

- Value created: 1

Very low repeatability of the process.

- Risks: 6

(2,3): Misevaluation of the robustness of the mecahnical perf.

Tests conducted that highlighted a very weak robustness of mechanical performances.

Slip casting (int)

- Value created: 3

Better repeatability than uniaxial compression according to experts

- Risks: 9

(3,3): No tests, only experts advices.

PIM (int)

- Value created: 4

Better repeatability than uniaxial compression and slip casting according to experts

- Risks: 9

(3,3): No tests, only experts advices.

Uniaxial compression (int)

- Value created: 1

Very low repeatability of the process.

- Risks: 6

(2,3): Misevaluation of the robustness of the mecahnical perf.

Tests conducted that highlighted a very weak robustness of mechanical performances.

Slip casting (int)

- Value created: 3

Better repeatability than uniaxial compression according to experts

- Risks: 9

(3,3): No tests, only experts advices.

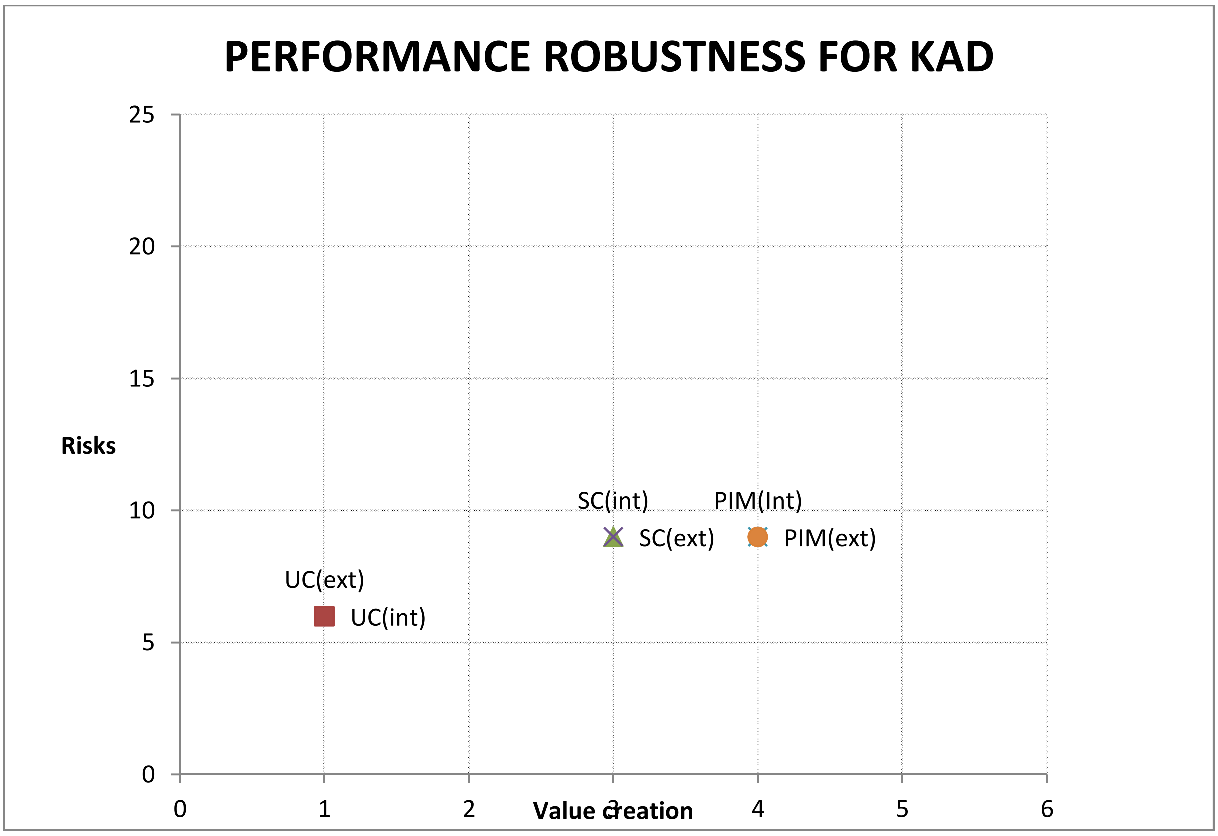
PIM (int)

- Value created: 4

Better repeatability than uniaxial compression and slip casting according to experts

- Risks: 9

(3,3): No tests, only experts advices.



2.14 Performance robustness for the customer

Performance robustness for the customer

Uniaxial compression (int)

- Value created: 1

Very low repeatability of the process.

- Risks: 6

(2,3): Misevaluation of the robustness of the mecahnical perf.

Tests conducted that highlighted a very weak robustness of mechanical performances.

Slip casting (int)

- Value created: 3

Better repeatability than uniaxial compression according to experts

- Risks: 9

(3,3): No tests, only experts advices.

PIM (int)

- Value created: 4

Better repeatability than uniaxial compression and slip casting according to experts

- Risks: 9

(3,3): No tests, only experts advices.

Uniaxial compression (int)

- Value created: 1

Very low repeatability of the process.

- Risks: 6

(2,3): Misevaluation of the robustness of the mecahnical perf.

Tests conducted that highlighted a very weak robustness of mechanical performances.

Slip casting (int)

- Value created: 3

Better repeatability than uniaxial compression according to experts

- Risks: 9

(3,3): No tests, only experts advices.

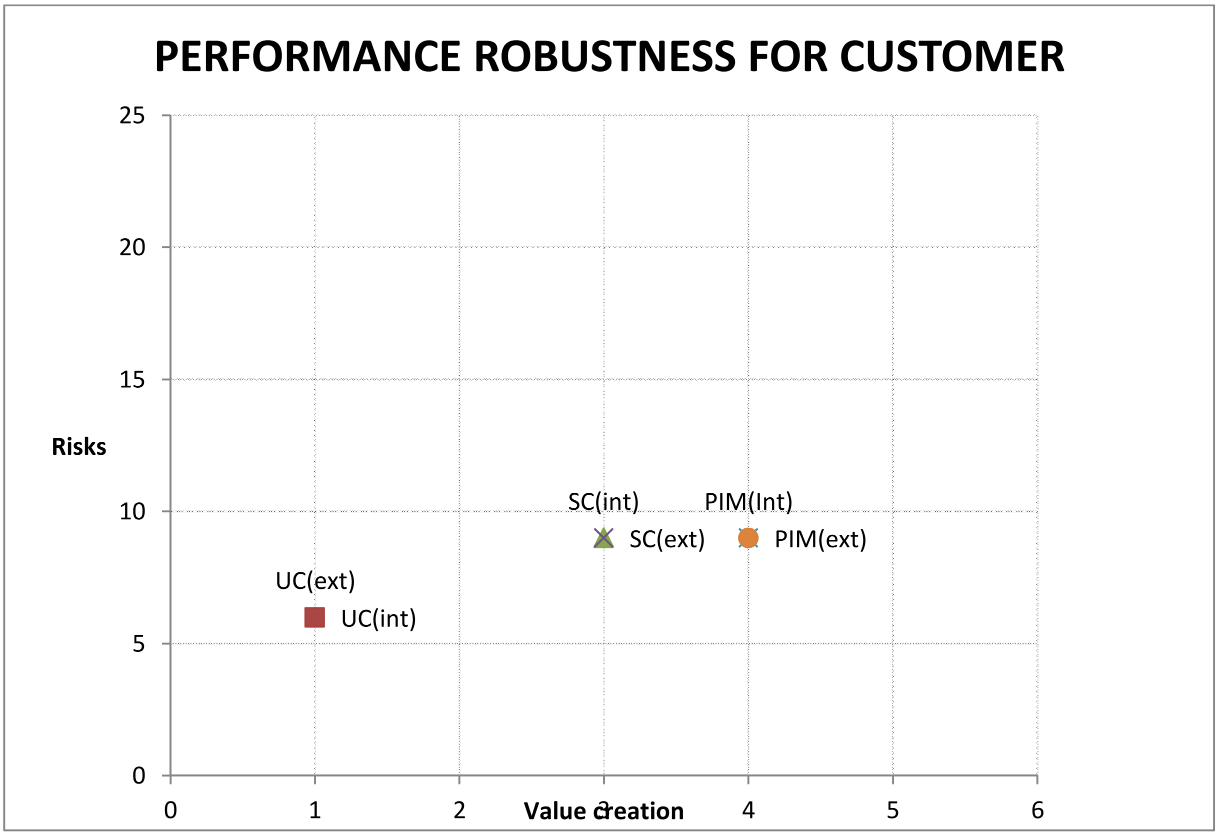
PIM (int)

- Value created: 4

Better repeatability than uniaxial compression and slip casting according to experts

- Risks: 9

(3,3): No tests, only experts advices.



2.15 Performance robustness for the airlines

Performance robustness for the airlines

Uniaxial compression (int)

- Value created: 1

Very low repeatability of the process.

- Risks: 6

(2,3): Misevaluation of the robustness of the mecahnical perf.

Tests conducted that highlighted a very weak robustness of mechanical performances.

Slip casting (int)

- Value created: 3

Better repeatability than uniaxial compression according to experts

- Risks: 9

(3,3): No tests, only experts advices.

PIM (int)

- Value created: 4

Better repeatability than uniaxial compression and slip casting according to experts

- Risks: 9

(3,3): No tests, only experts advices.

Uniaxial compression (int)

- Value created: 1

Very low repeatability of the process.

- Risks: 6

(2,3): Misevaluation of the robustness of the mecahnical perf.

Tests conducted that highlighted a very weak robustness of mechanical performances.

Slip casting (int)

- Value created: 3

Better repeatability than uniaxial compression according to experts

- Risks: 9

(3,3): No tests, only experts advices.

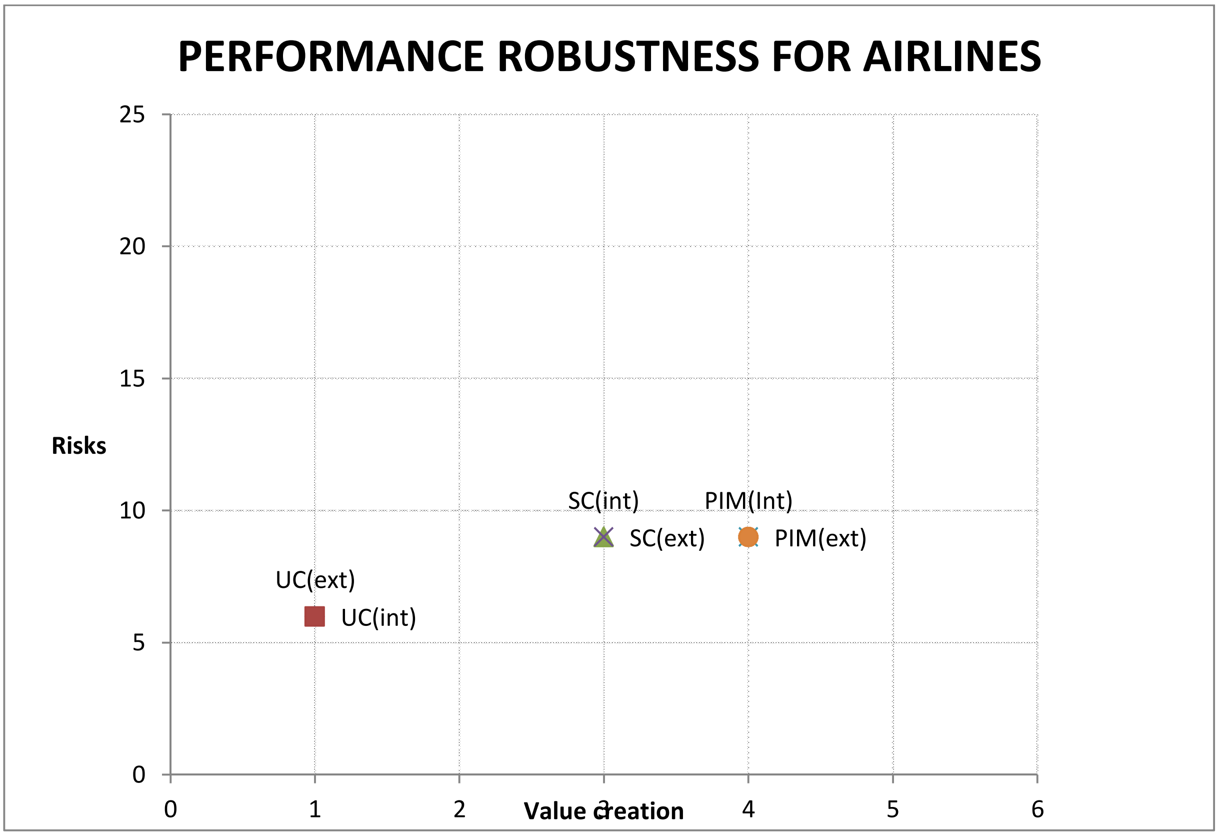
PIM (int)

- Value created: 4

Better repeatability than uniaxial compression and slip casting according to experts

- Risks: 9

(3,3): No tests, only experts advices.



2.16 Ecological value for the environment

Ecological value for the environment

Uniaxial compression (int)

- Value created: 3

Less environmental impact than other processes (moderate quantity of by -products, compression done manually).

- Risks: 10

(2,5): Misevaluation of by-products

Low proba: Usual products in moderate quantity

High impact: a single product can have an important effect

Slip casting (int)

- Value created: 1

High quantity of by-products, use of non-reusable molds

- Risks: 15

(3,5): Misevaluation of by-products
Moderate probability: Usual products, high quantity
High impact: a single product can have an important effect

PIM (int)

- Value created: 1

moderate quantity of by –products, use of heavy industrial tools

- Risks: 9

(2,5): Misevaluation of by-products
Low proba: small amount of usual products; High impact: a single product can have an important effect
(2,2) Misevaluation of environmental impact of the injection press

Uniaxial compression (ext)

- Value created: 3

Less environmental impact than other processes (low quantity of by -roducts, compression done manually).

- Risks: 10

(2,3): Misevaluation of by-products

Low probability: Usual products

High impact: a single product can have an important effect

Slip casting (ext)

- Value created: 1

High quantity of by-products, use of non-reusable molds

- Risks: 15

(3,5): Misevaluation of by-products
Low probability: Usual products high quantity
High impact: a single product can have an important effect

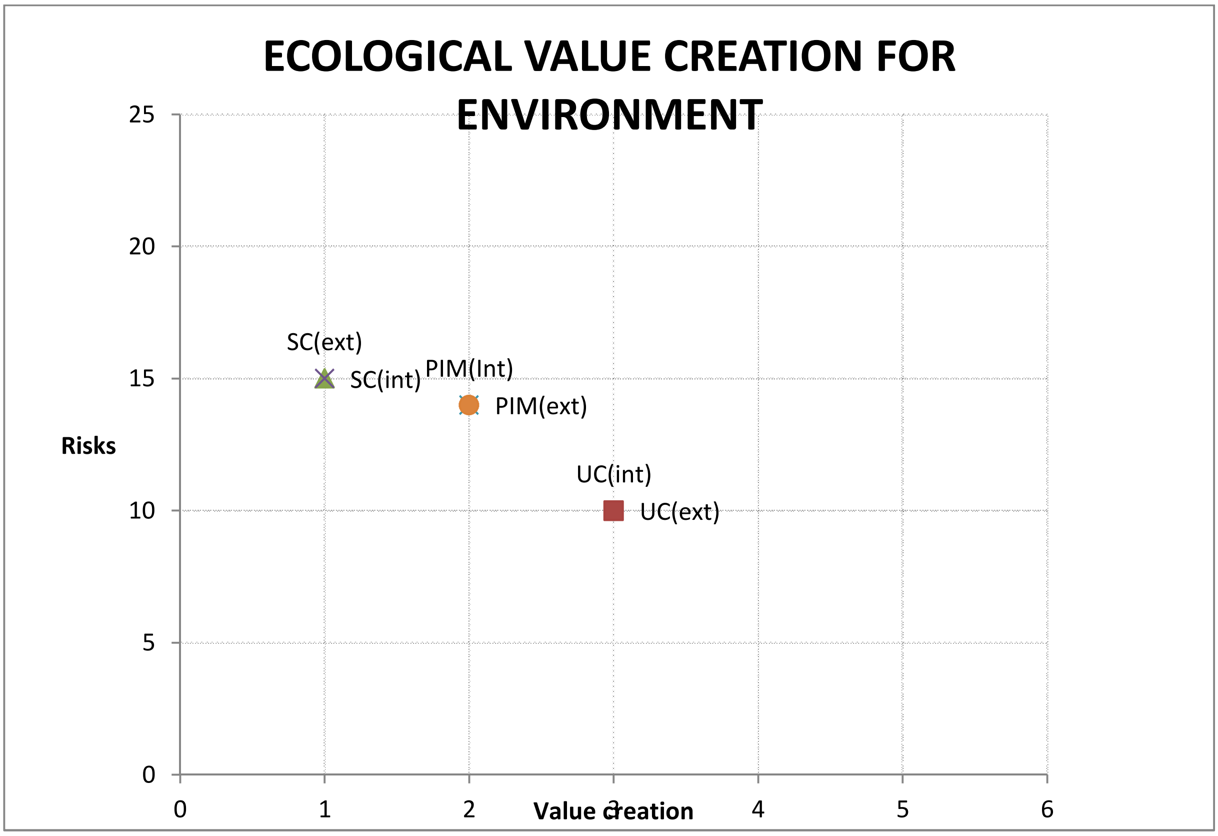
PIM (int)

- Value created: 1

moderate quantity of by –products, use of heavy industrial tools

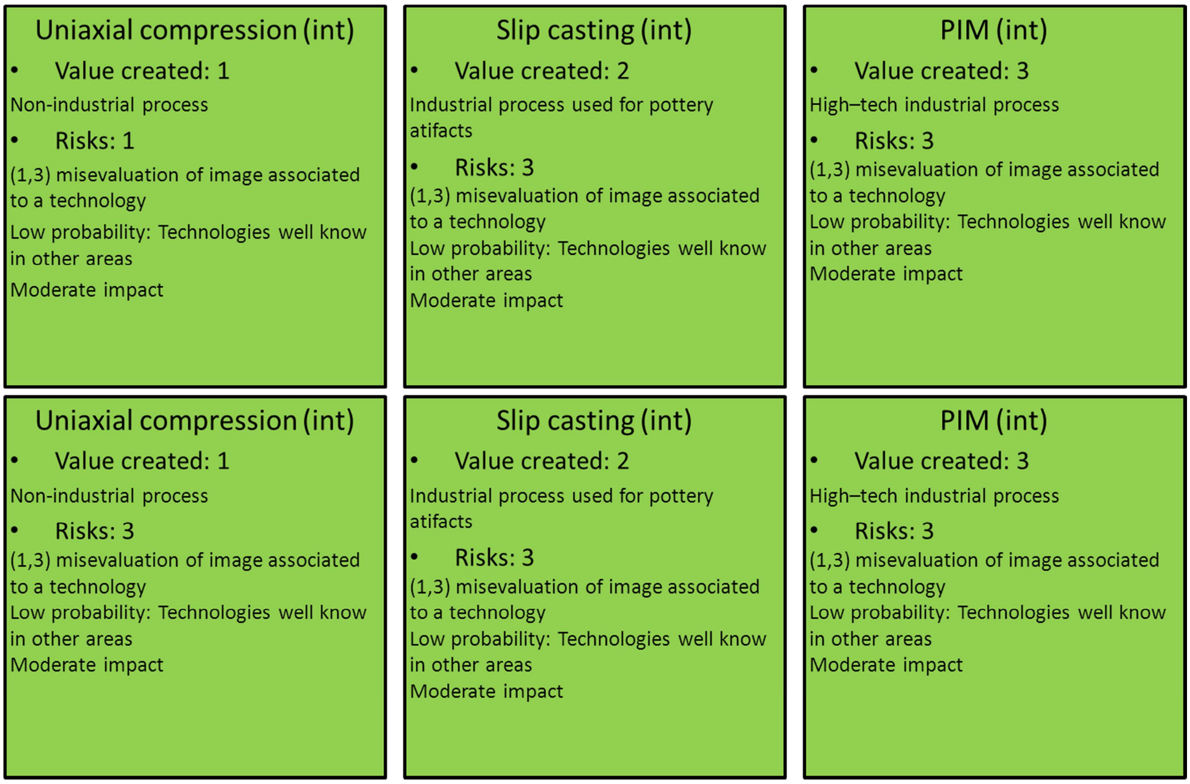
- Risks: 9

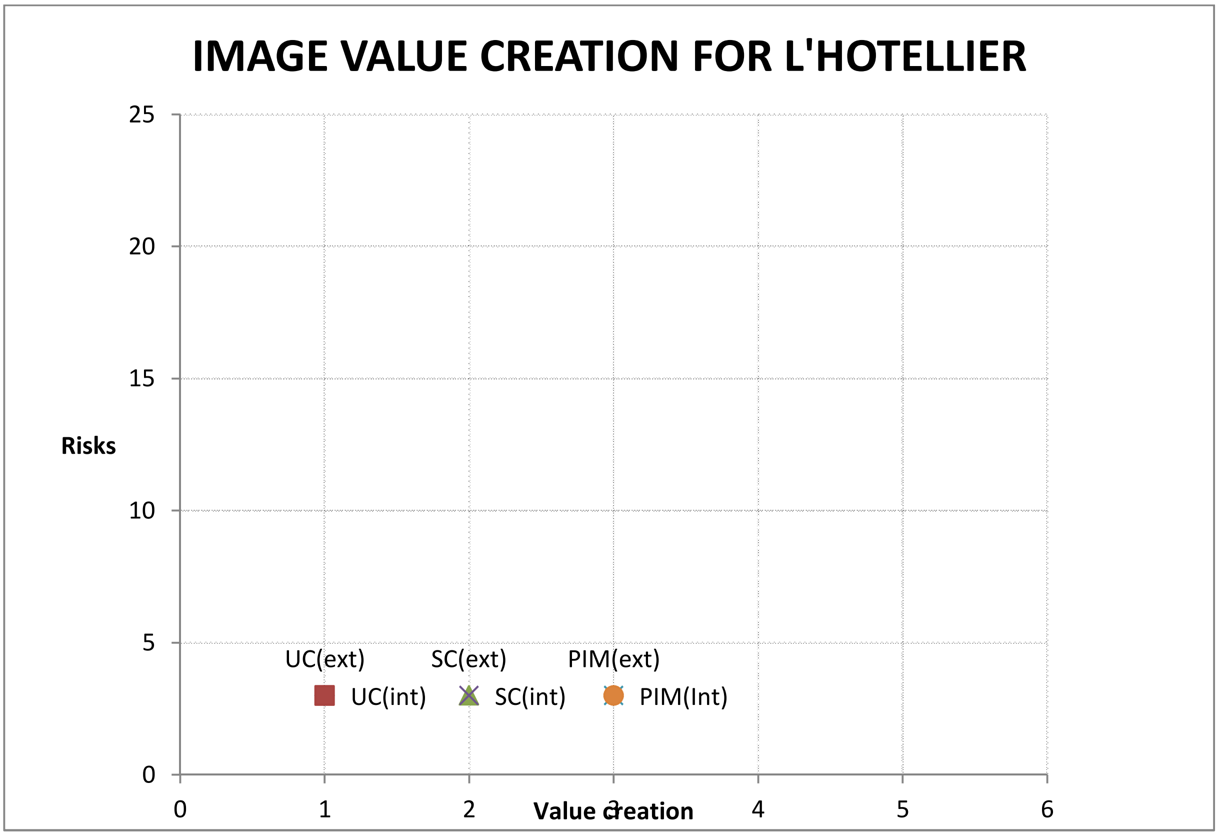
(2,5): Misevaluation of by-products
Low proba: small amount of usual products; High impact: a single product can have an important effect
(2,2) Misevaluation of environmental impact of the injection press



2.17 Image value for L'Hotellier

Image value for L'HOTELLIER (low/high tech)





2.18 Image value for KAD

Image value for KAD(low/high tech)

Uniaxial compression (int)
- Value created: 1

Non-industrial process
- Risks: 1

(1,3) misevaluation of image associated to a technology
Low probability: Technologies well know in other areas
Moderate impact

Slip casting (int)
- Value created: 2

Industrial process used for pottery atifacts
- Risks: 3

(1,3) misevaluation of image associated to a technology
Low probability: Technologies well know in other areas
Moderate impact

PIM (int)
- Value created: 3

High–tech industrial process
- Risks: 3

(1,3) misevaluation of image associated to a technology
Low probability: Technologies well know in other areas
Moderate impact

Uniaxial compression (int)
- Value created: 1

Non-industrial process
- Risks: 3

(1,3) misevaluation of image associated to a technology
Low probability: Technologies well know in other areas
Moderate impact

Slip casting (int)
- Value created: 2

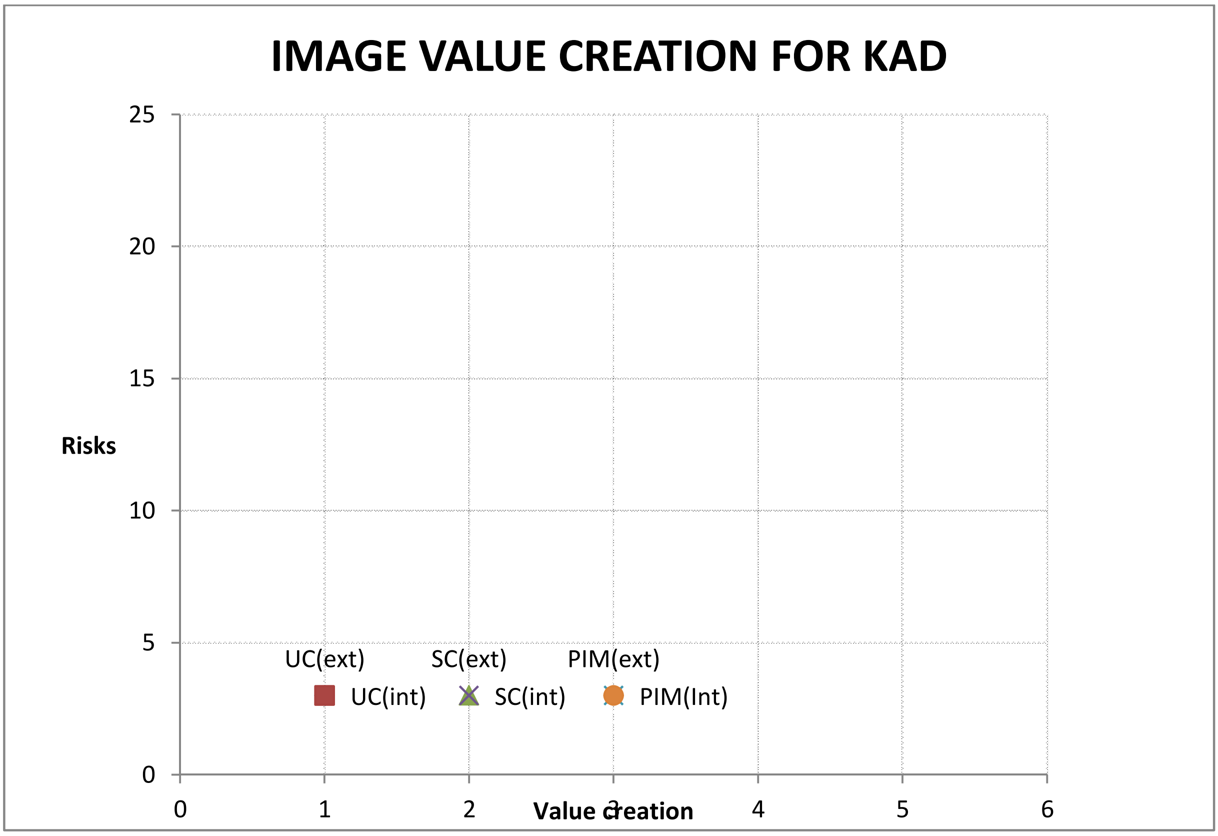
Industrial process used for pottery atifacts
- Risks: 3

(1,3) misevaluation of image associated to a technology
Low probability: Technologies well know in other areas
Moderate impact

PIM (int)
- Value created: 3

High–tech industrial process
- Risks: 3

(1,3) misevaluation of image associated to a technology
Low probability: Technologies well know in other areas
Moderate impact



IX.Annex II: Economic model

In order to assess the creation of financial value, we constructed economic models that aim to calculate the costs and benefits associated to the introduction of the ceramic disk. Four different models exist: two for helicopters related extinguishers (short maintenance cycle and long maintenance cycle) and two for business jets extinguishers (short maintenance cycle and long maintenance cycle). Each model takes into account three different stakeholders: L'Hotellier, its customer for the OEM market (helicopter or business jet manufacturer) and the maintenance customers (purchaser of helicopter and business jets). For each of these stakeholders, an analysis was performed of the cost (manufacturing, purchasing, etc.) and benefits in order to enable a comparison between three different scenarios: pyrotechnical device, ceramic disk with short life duration, ceramic disk with long life duration. These models study the costs and benefits associated to all the products that will be sold in year 2014, taking into account the maintenance cost for a duration of 20 years (mean life duration of an extinguisher).

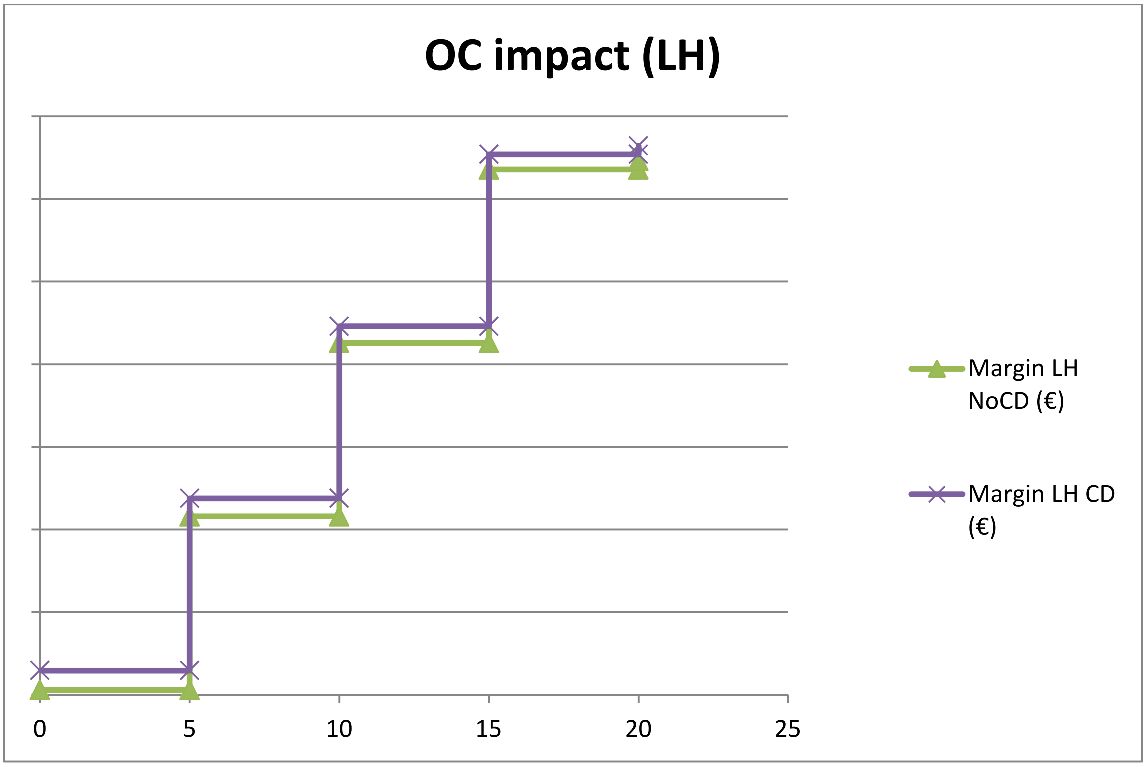
These models take as input data:

- The selling price of the ceramic disk for the original
- The selling price of spare ceramic disk (maintenance market)
- The invoiced price of end of life cost of the ceramic disk
- The manufacturing cost of the ceramic disk
- The end of life cost of the ceramic disk

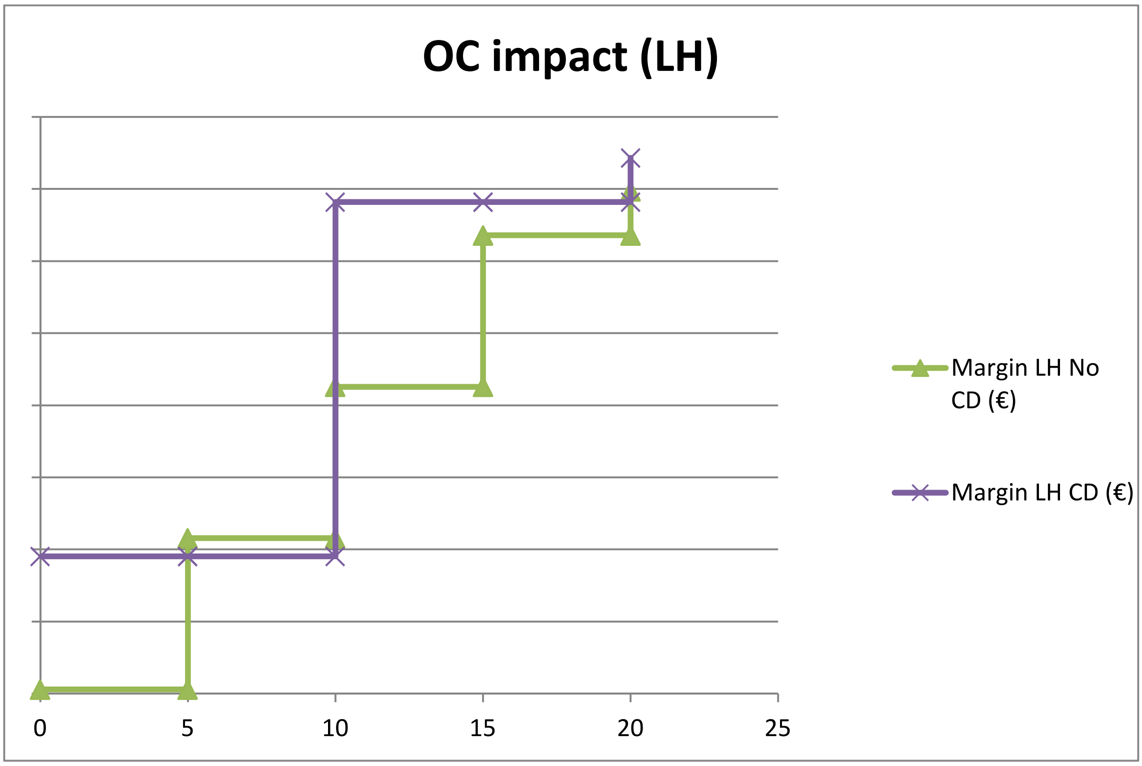
This parameter can be modified in order to assess their impacts.

The graphs below presented the cumulated cost for the customers (original mount and maintenance customers) and the margin for L'Hotellier. The X axis represent the years (2014+0, +5, +10, +15, +20), the Y axis represent the cumulated financial value (margin for L'Hotellier (LH), cost for the other stakeholders) For confidentiality reasons, the data presented in the graphs below have been changed and no financial value is given. We only present here the graphs related to the helicopter market.

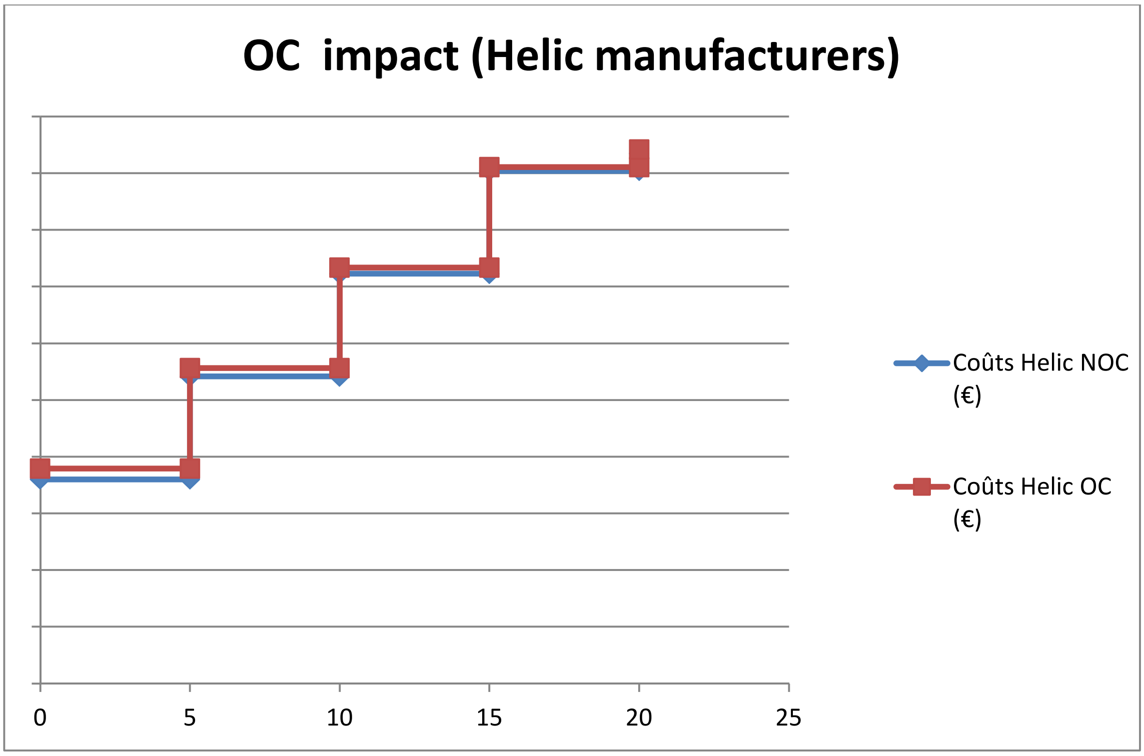
1 L'Hotellier's margin with and without a ceramic disk with short life duration



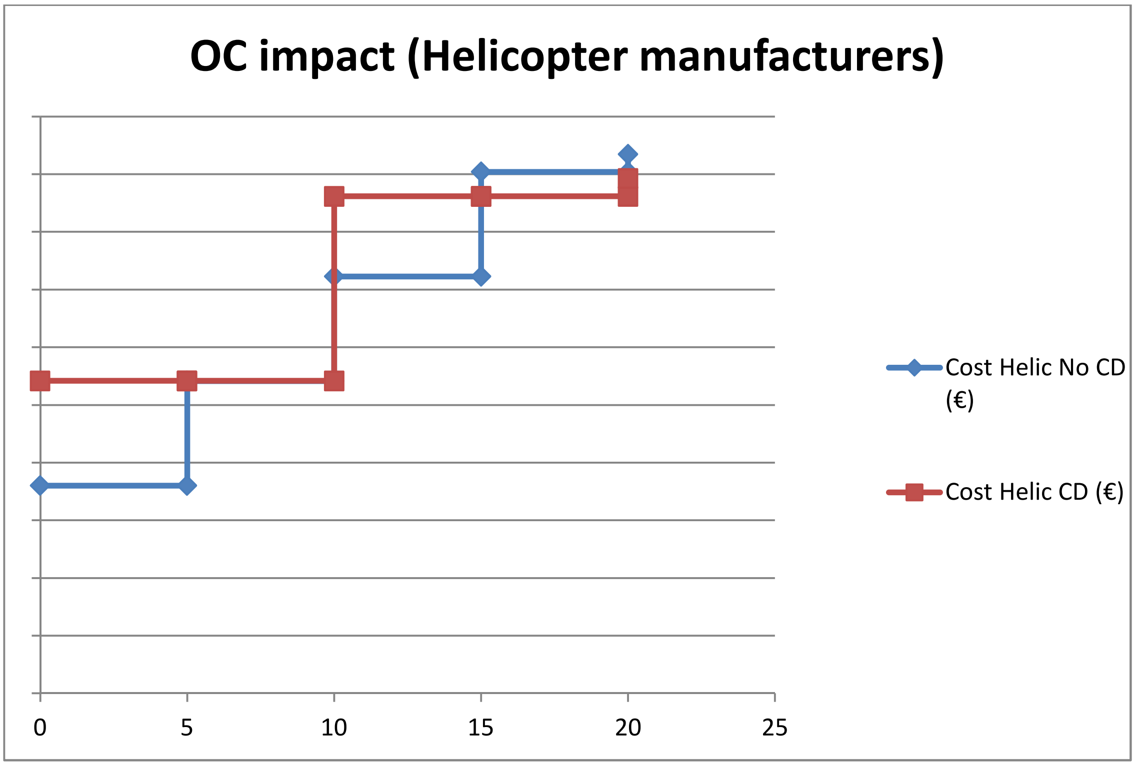
2 L'Hotellier's margin with and without a ceramic disk with long life duration



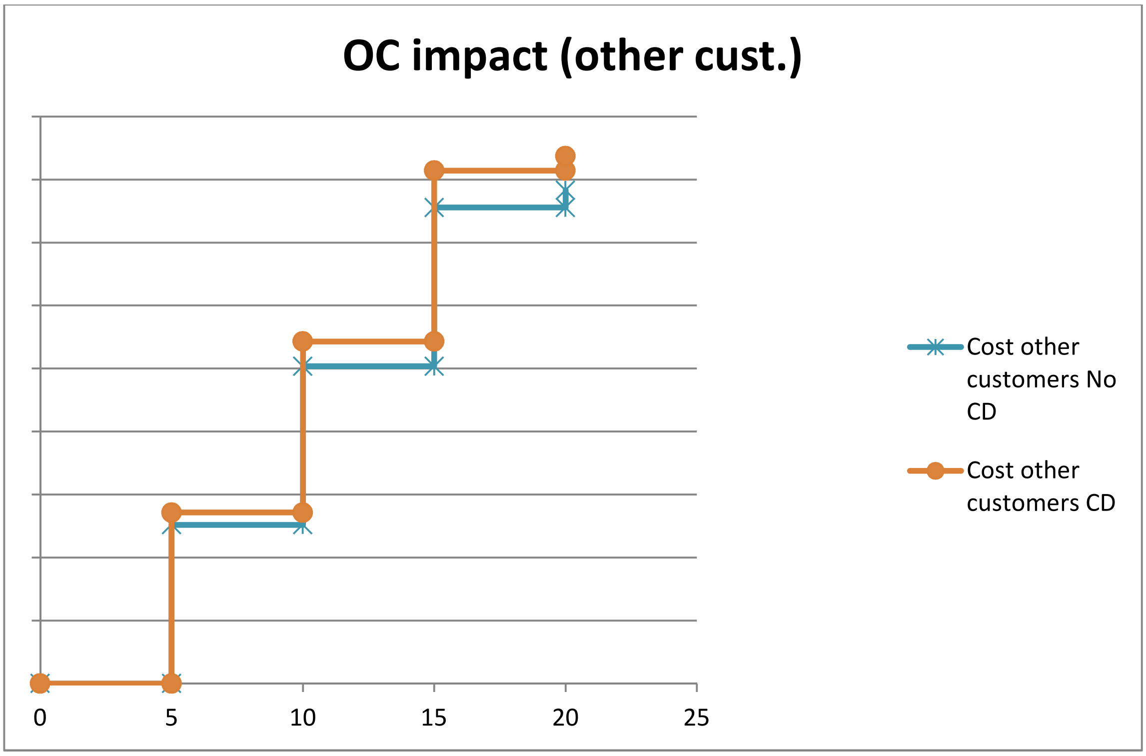
3 Helicopter manufacturers' costs with and without a ceramic disk with short life duration



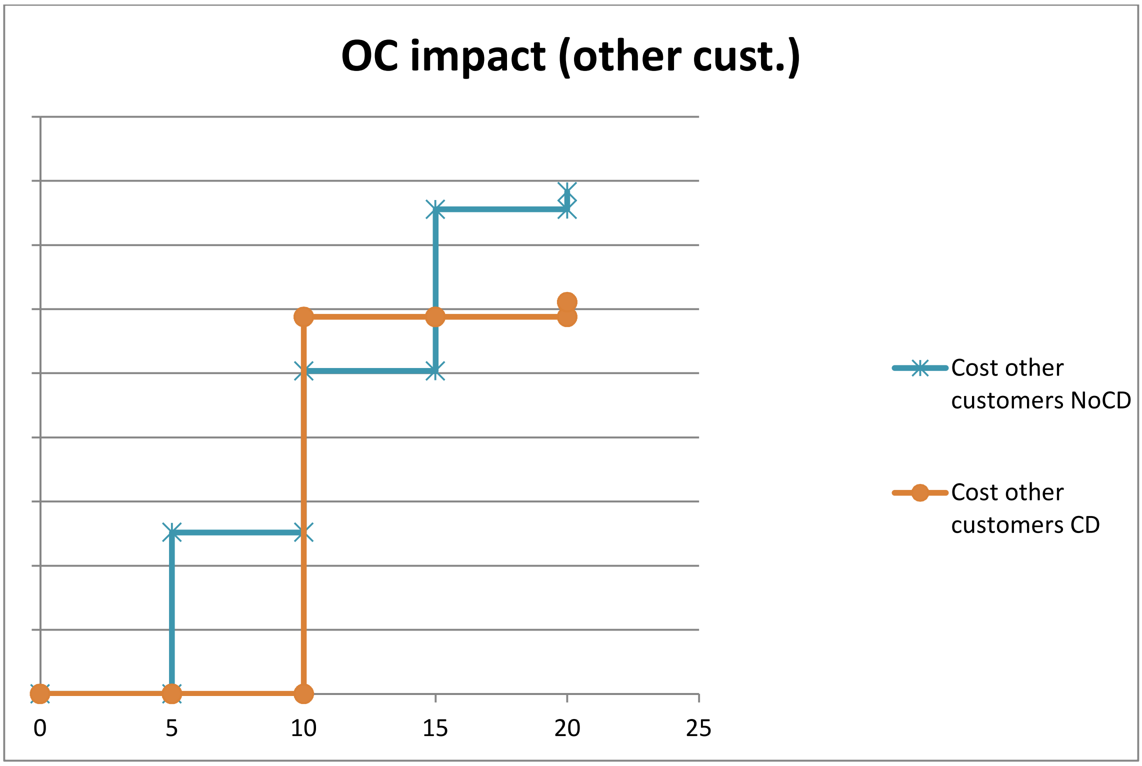
4 Helicopter manufacturers' cost with and without a ceramic disk with long life duration



5 Maintenance costs with and without a ceramic disk with short life duration



6 Maintenance costs with and without a ceramic disk with long life duration



X. Annex III: Interviews summary

As said in the description of our experimentation, nine persons were interviewed in order to gather information related to the problem setting phase of our model: the chief executive director, the technical director, the chief financial director, the operations director, the commercial director and two people of his team, the quality manager and the purchasing manager. We had the objective of accessing knowledge in all the areas of the enterprise in order to have a view as complete as possible of the impact of the innovation. A discussion as free as possible was established with the interviewees. The discussion was centered on a few selected fields:

- The current cash cow product, its characteristics, benefits and drawbacks,
- The market that the firm addresses currently with this product and its position,
- The innovation developed, its characteristics, benefits and drawbacks,
- The internal and external stakeholders of the innovation, their characteristics and the reasons of their interests.

A summary of the results of these interviews are presented in the following table. Each line of this table is dedicated to an interviewee. The columns are dedicated to the fields covered in the interviews (see list above). For confidentiality reasons, some pieces of information gathered in these interviews are not included here. There were however taken into account in our work.

	Current cash cow product	Market addressed by L'Hotellier	Innovation	Internal and external stakeholders
Executive director	There is only on suppliers for the different pyrotechnical devices (three different ones). This is because qualifying a new one would represent significant costs and efforts. L'Hotellier is only a small customer of this supplier (<2% of the supplier's turnover).	Three main markets: OEM, reparation and spares. Changes in the choice of suppliers are quite rare in the OEM market since it would require qualification of the new supplier and the building of a new relation. KAD (and L'Hotellier) are the only ones to sell a whole fire protection system. The reparation market is characterized by high margins. L'Hotellier is proposing two approaches: stock management or one shot reparations. Two types of competitors exist for L'Hotellier's reparation market: agreed and non-agreed operators. Two areas of progress could justify an increase in the maintenance costs: introduction of a service in addition to the reparation and technical improvement.	The ceramic disk would represent a good opportunity to increase L'Hotellier's market shares. For the OEM, the competitive advantages would be the technological advance and the advantage that the product offers to the customer. For the reparation and the spares market, it would help to decrease the number of L'Hotellier's product that are copied. Introducing the ceramic disk could also save L'Hotellier some heavy investments required by the presence of pyrotechnical devices (formations, materials, authorizations). The general hope is that the ceramic disk would enable L'Hotellier to increase its market share. It would ensure its growth and increase its profitability. It would also give an innovative image of L'Hotellier and show to the American group that their R&D team is capable of innovative developments.	Civil authorities are to be added to the classical stakeholders. L'Hotellier has to keep them informed on the quantity of explosives they stock on site. They could also provide grants to help to the development of the innovation. Another possible stakeholder would be the aeronautical cluster that L'Hotellier is a part of.
Financial director	The product is characterized by very high margins that compensate the lower margins on other products.	There are two main markets, OEM and reparation. L'Hotellier aims to increase its activity in both markets	The introduction of the innovation would be a good way of increasing the market share of L'Hotellier for new products. It would also make more difficult the copy of L'Hotellier's product and thus secure the maintenance market.	The main external stakeholders are the suppliers and customers.

	Current cash cow product	Market addressed by L'Hotellier	Innovation	Internal and external stakeholders
Technical director	There is only one supplier for the pyrotechnical devices. This is done in order to limit the purchase cost. Diversifying the sources for the pyrotechnical component would require a redesign of the product. This technology is in use since 40 years. Another technology tried without much success is the "metron", a small blade propelled by a spring and triggered by a very small pyrotechnical device. However its is not very reliable and quite heavy.	L'Hotellier addresses two different markets: OEM and reparation. The competitors on the OEM market are well known. One has almost 60% of the market and can thus propose low prices. The other (10% market shares) proposes incremental innovation to differentiate from the others. L'Hotellier and KAD (30% market shares) are the only ones that have the possibility to propose the whole fire protection system to customers. It is a significant advantage. The two main competitors of L'Hotellier put a high pressure on costs. All extinguishers are technically alike. The organization of the reparation market is defined with the customer. Part of the reparation is done by L'Hotellier, another part is performed by agreed stations that purchase their spare parts to L'Hotellier. Finally, some 40% of the reparation market is done by non-agreed stations that copy L'Hotellier's parts.	One of the main advantages of the ceramic disk would be to prevent during a limited time the copy of L'Hotellier's products by non-agreed maintenance operators. Furthermore, integrating the opening device in the extinguisher could represent a significant simplification of the logistic process. Replacing the pyrotechnical device would also present an interest in terms of security (no explosive) and would decrease the quantity of lead azide released in the environment. This sustainable view corresponds to a major expectation of L'Hotellier's customers for the OEM market. Even if the ceramic disk is not launched for economical reasons, it could represent a good response to other innovations launched by competitors or to a strengthened regulation on lead. It is also a good opportunity to valorize the know-how of L'Hotellier in terms of R&D. OEM customers expect from the ceramic disk a system without weight increase. It should simplify the logistics of the maintenance process. They would not be ready for a significant price increase.	In addition to customers and suppliers, certification authorities should also be taken into consideration. These organizations are neutral and have requirements rather than expectations. They focus on the reliability, robustness, security, quality of the product.

	Current cash cow product	Market addressed by L'Hotellier	Innovation	Internal and external stakeholders
Operations director	The main critical component of the pyrotechnical cartridge is the detonator. There is only one supplier for this component since it is a very sensitive component. The volume ordered is the only lever that can be used in the negotiations with the supplier. The cartridge is manufactured inside L'Hotellier. The qualification of this component is very heavy since the expectations in terms of reliability are extremely high.	L'Hotellier as a status of subcontractor for these markets since it proposes a system (detection + extinction). L'Hotellier has two main activities: new products and reparations. The reparation market requires a particular qualification. The turnover related to this activity is increasing. L'Hotellier is studying the possibility to adopt a general service offer (management of the availability of the fire systems of a fleet instead of one-shot reparations)	A better reliability is expected and could solve quality problems had on the main metallic disk. It would increase the innovative image of L'Hotellier (expectation from the customers). The ceramic disk should generate at least the same margin than the classical product. Developing this system would be a good occasion to reach a solution that simplifies the maintainability of the extinguishers.	The main external stakeholders are the suppliers and customers. A distinction can be made between aeronautic and military customers.. The relevant internal stakeholders are the employees working on the cartridge a potentially dangerous activity.
Quality manager	The pyrotechnical technology is characterized by a very high reliability. The qualification of suppliers for this component is a heavy process.	L'Hotellier has to main activities: design and production of products for the OEM market and reparation of these products. Those activities require certifications given b y independent institutions.	L'Hotellier has to be certain of the reliability of the ceramic disk. A heavy quality process needs to be implemented in order to ensure that the ceramic disks produced are 100% reliable.	The customer, suppliers, certification authorities should be taken into account in the study of the stakeholders.

	Current cash cow product	Market addressed by L'Hotellier	Innovation	Internal and external stakeholders
Purchasing manager	There is only one supplier for the pyrotechnical device. A diminution in the volume of pyrotechnical devices ordered would probably be the cause of an increase in the prices.	There are two main markets: OEM and reparations.	Introducing the ceramic disk could be a good way to increase the market shares of L'Hotellier. This could lead to a better profitability.	Possible new suppliers should be taken into account as stakeholders of the innovation as well as the current pyrotechnical supplier.
Commercial director	One of the main characteristics of the current products is its revision cycles. The extinguishers and cartridges require revisions every 5 or 10 years depending on the models and the stress they are submitted to in their lifecycles. This is a cause of complexity in the logistic process.	Three markets: OEM, reparation and spares. On the OEM L'Hotellier has the advantage of supplying the whole fire protection system.	Introducing the ceramic disk would simplify the maintenance operations (estimation: ½ hour gained for the whole lifecycle), some mounting and de-mounting operation been suppressed. The logistic would also be simplified (the special transports required for the pyrotechnical devices would no longer be needed). A diminution of the weight of the system could also be interesting (from 50g for helicopters and 200g for airplanes) The ceramic disk being harder to copy would also help to secure the reparation and spares markets. It could give a competitive advantage to L'Hotellier for new programs and could represent an opportunity to be qualified as a secondary source for older programs.	Second rank customers (airlines for example) should be taken into account as stakeholders. They could exercise pressure on the aircraft manufacturers for the adoption of the ceramic disk. The innovation would be interesting for them if it induce maintenance costs reductions.

	Current cash cow product	Market addressed by L'Hotellier	Innovation	Internal and external stakeholders
Commercial	Pyrotechnical devices are characterized by heavy regulations (storage and transportation). They require revisions that are not always synchronized with the extinguishers.	Three markets: OEM, reparation and spares.	The ceramic disk represent an interesting opportunity however, the customers would have difficulties to accept significant increases in the price or weight of the system. In addition to a competitive advantage for new programs, the ceramic disk is also beneficial since it helps to secure the aftermarket.	The main external stakeholders are the suppliers and customers.
Commercial	Pyrotechnical devices are characterized by heavy regulations (storage and transportation). They require revisions that are not always synchronized with the extinguishers.	Three markets: OEM, reparation and spares. Different types of customers: civilians and military	The ceramic disk would be all the more interesting if it is adapted to current extinguishers. This would enable to retrofit current products with ceramic disks.	The main external stakeholders are the suppliers and customers. A distinction can be made between aeronautic and military customers.