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SUPPORTING DECISIONS in SMEs projects of disruptive technological innovation by BALANCING VALUES AND RISKS related to stakeholders

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ABSTRACT

Innovation, which is acknowledged as a key factor for the development of companies, may be too delicate to become a success for companies. Uncertainty related to value creation is often an important dissuasive reason. This is particularly the case for high-tech small and medium enterprises (SMEs). Indeed, they often have scarce human and financial resources which handicap them in accessing new knowledge. This weakness can be crucial at a given stage of the innovation development because SMEs loosely represent processes and knowledge. The second aspect we consider here is the type of innovation developed: a disruptive technological innovation. It presents a high technological uncertainty and involves a market discontinuity. As a result, it is inherently characterized by a lack of knowledge regarding the technology and the market. This context leads to establish that one of the most important challenges in technological disruptive innovation projects in SMEs is the identification and access to critical knowledge.The literature review describes innovation processes as a more or less complex succession of activities and decisions. But the decision-making micro-stages, whose quality depends on the ability of identifying and accessing specific and critical knowledge, is one weak point of high-tech SMEs. We propose here a model to increase efficiency of critical decisions in disruptive innovation projects under the following hypothesis: critical decision-making in a disruptive technological innovation project in a SME is easier, more rational and robust when decision-makers know its impacts in term of value creation and risks associated to all decision alternatives. This model is tested within a project on two decisions assessed as critical; one of them is detailed here. The results of these two experimentations validate our hypothesis. We realized interviews on feedbacks from our case study that demonstrate that the use of this method was very helpful to inform and facilitate the work of decision makers. Our implementation of a formalized decision process enables robust decision-making without hindering the flexibility of the innovation process of the SME.

INTRODUCTION

In order to help companies implement innovation, numerous studies have been made describing innovation processes well fitted to the company organization. In chapter 1, a literature review analyzes the innovation models and their advantages and limits in our context of disruptive innovation in SMEs. It also emphasizes the issues of value creation and of its links with the identification and prioritization of the stakeholders' requirements by the innovator. A diversity of risks threats this value creation and methods have been developed to limit their occurrence and impacts. We propose in chapter 2 a model for eliciting these value creation opportunities for innovation stakeholders and risks associated. The model is presented along the case study of a practical project of disruptive innovation development. The nature of the innovation and its technological context are presented and details are provided for the experimentation and the model validation. Chapter 3 concludes on to the practical ability of our method to provide help to decision makers.

1. Literature review

Innovation processes and knowledge management in innovation

Early theories about innovation focus on the inputs and outputs of innovation. For 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 inevitably causes the renunciation of previous technological fields, products or organizations. New technologies result in inventions that are industrialized by R&D services and sold to the customer, thus becoming innovations.

In reaction to this technology push approach, Schmookler *(1953)* proved by analyzing patent statistics that the pull of demand could also be a significant cause of innovation *(Kleinknecht and Verspagen, 1989; Scherer, 1982)*. Kline and Rosenberg *(1986)* later developed a nonlinear model that aims to join three different components. The first component is the development process with its classical stages *(perception of a potential market, invention or analytic design, detail design and test, redesign and production, distribution and marketing)*. The second and third components are the research activity and the knowledge produced. The so-called chain-linked model proposes several paths to innovation establishing connections inside these three spaces and it also considers possible feedbacks from one activity to another one.

In between the management and engineering approaches are the works of Cooper. According to its developer, the stage-gate systems "simply apply process management methodologies to this innovation process" *(Cooper, 1990)*. The objective of these theories is not to explain the process of innovation. The stage-gate and the chain-link models 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 stage to the other. The second group of models focuses on the design engineering process. The Pahl and Beitz model *(1996)* is one of the most predominant approaches in this regard. It proposes a rationalization of the different steps of a new product development process. This method is very useful and adapted to the re-design of complex systems but characterized by a low level of innovation. Furthermore, even if the model is prescriptive about the nature of the different steps of the innovation process, it lacks of information on tools and guidelines needed to perform these steps.

The C-K theory *(Hatchuel and Weil, 2002)* is a design theory that describes the design activity as a series of knowledge production and design refinement concepts. This model is especially relevant for companies that want to innovate on a regular basis and want to foster their creativity along with a knowledge management system for capitalizing the knowledge developed during an innovation project to reuse it in another. First, this is not the case in SMEs and CK-theory does neither propose a typical innovation process nor risk-oriented tools to identify critical knowledge and make appropriate decisions on design alternatives.

Motte, Bjarnemo and Yannou *(2011a)* showed the generic aspects of New Product Development methods as well as the complementary aspects of methods from design engineering discipline and from management discipline *(including strategic and organizational dimensions)*. Motte, Bjarnemo and Yannou *(2011b)* also showed that shortcomings and limitations exist for these NPD approaches: a lack of consideration for business issues in design engineering discipline and of technological and design alternative issues in management discipline. They finally identified *(Motte, Yannou, Bjärnemo, 2011c)* a series of requirements an NPD method should possess to satisfactorily tackle radical innovations, notably in addressing concurrently issues of organizational changes, development process and strategy formulation.

The necessary documentation and knowledge management *(including the competences of the design team members)* and the constant evaluation of the probability of coming up with a conceptually useful and innovative design has been addressed with several approaches. The design documentation can be supported by a question-based information system like the Dred platform developed by Bracewell, Aurisicchio and Wallace *(Aurisicchio and Bracewell, 2009; Aurisicchio et al., 2008; Bracewell et al., 2009)*. The notion of Intermediary Design Objects *(IDO)* has also been proposed by Jeantet *(1998)* and Boujut and Blanco *(2003)* to enable the designers to make design decisions continuously along the conceptual design process *(IDOs may be physical or virtual prototypes, sketches, questionnaires, etc)*. The quality and pertinence of these IDOs determine the quality of the design outcome*(s)*. As stated earlier, CK-theory *(Hatchuel and Weil, 2003)* also proposes strategic views of managing design knowledge and competences. Finally, Thompson and Paredis *(2010)* propose a relevant Rational Design Theory *(RDT)* which consists in maximizing the expected value of utility of a design concept. But very few theories or frameworks exist that propose performance indicators to guide the idea generation, evaluation and selection.

Radical Innovation Design *(RID)* *(Yannou, 2013; Yannou et al., 2013)* is one of them. Design is seen as an investigation process partially structured in a stage-and-gate process organized in a two macro-stages of problem setting and problem solving. Its main objectives are to constitute multi-disciplinary teams which develop this investigation spirit with the constant building and reinforcement of proofs. Three types of proofs are defined:

- The proofs of Value for bringing evidence that "it is differentiating from the existing solutions in terms of service utility as well as new satisfied needs, on large and creditworthy market segments",
- The proofs of Innovation for bringing evidence that "the invention may be protected and the innovation may be communicated, perceived, understood and valorized, i.e., it corresponds to a certain willingness-to-pay.
- The proofs of Concept for bringing evidence that "it works or it is likely to work in situations the solution is expected to be delivered"

This VIC proofs model is used to monitor the radical innovation process to increase the likelihood of the innovation project to be successful in the technology market as well as business perspectives. This RID methodology is certainly 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.

The models exposed in this chapter have all interesting characteristics in different situations. However no precise methodological way is provided to deal with value assessment and risks in the case of disruptive innovation in SMEs.

Innovation performance for enterprises

Value creation for the firm developing the innovation

According to Van Horne *(2006)*, the purpose of innovation is value creation. The most obvious beneficiary of this value creation is the firm developing the innovation. Schumpeter *(1939)* presents it as one of the main causes of economic activity and growth. In his work about the stage-gate system, 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". For Garcia and Calantone *(2002)*, "an innovation differs from an invention in that it provides economic value". Hitt et al. *(2000)* in their 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 for competitiveness since it enables to offer valuable, rare, inimitable and differentiated products to the market *(Conner, 1991)*. According to Boly *(2008)* the value of an innovation is the result of eight different aspects: economic, strategic, intellectual, commercial, functional, degree of novelty, reputation, hedonistic.

Astebro *(2004)* explores the impact of 36 innovation, technology and market characteristics on the probability of success in the early design stages. He suggests a forecast to be used as a screening tool of early design reviews in which the key success factors aim at examining the likelihood of projects reaching the market. In his study, three criteria address potential "technological improvement of the invention," five address "technological opportunity," three address "potential external constraints," seven address "measures of demand," five address "innovation characteristics," one concerns the price, three address "cost measures," and the balance addresses appropriate conditions and various investment criteria.

Millier *(1999)* addresses the issue of necessary conditions or key factors that lead to successful innovation projects. These key factors, based on the consideration of different risks linked to failure, are defined as 1) technical, 2) economic or commercial, and 3) internal/organizational conditions. Technical factors consist of product unicity, intellectual property issues, scientific or technological "momentum" and industrial scalability. Economic factors concern the existence of a market and the identification of market segments and clients which have already made the need explicit, and foresight on regulations, law or other obstacles. Internal or organizational conditions concern ensuring the internal promotion of the project, project organization and planning, development of the alliances and the distribution networks, and identification of different resources within the company. Millier *(1999)* suggests this model can also be applied as a managerial model for project evaluation.

However the company is not the only beneficiary of these value creations, innovation also benefits numerous stakeholders. In a project management context, it is essential to take into account these key stakeholders in order to ensure its success *(Achterkamp and Vos, 2008; Fowler and Walsh, 1999; Wateridge, 1998)*.

Taking the expectations of stakeholders into account

The notion of stakeholder is close to the notion of value and the concept of multiple value creations. It extends the perimeter of the parties concerned by a product, a decision... The financial value is not anymore the only one taken into account, and as a consequence the focus is not placed 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 1***)*. It includes other groups that may have interest in the firm such as political groups and associations. This approach underlies that enterprises that consider their relations with other actors must be bi-lateral, thus having stakeholder support requires a balanced relationship.

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 are taken into account. For Freeman *(1984)*, ". . .a stakeholder in an organization is any group or individual who can affect or is affected by the achievement of the organization's objectives." Stakeholders can thus represent a potential help or danger for the firm. It is thus very important to be sure to include all the relevant stakeholders in an innovation project.

The first very classic decomposition is the one proposed by Carol and Näsi *(1997)* that differentiates internal and external stakeholders. Another distinction can be made between primary stakeholders, linked to the organization through a contract such as employees, suppliers, and customers, and secondary stakeholders such as competitors, local authorities and lobbying groups *(Carroll and Buchholtz, 2000)*. Lepineux *(2003)* 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. Mitchell 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.

Studying the performance of an innovation project means studying the value created by this project and this value creation must be adapted to the expectations of the stakeholders of the project. Values expected are very different and, as a consequence, cannot be aggregated. Furthermore, determining which stakeholders should benefit from this value creation is also difficult, as they are very different and they can have antagonistic goals.

Risk threatening value creation in innovation projects

Overview of the concept of risk

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)*. According to this definition, risks are characterized by two main pieces of information: their likelihood of occurrence and impacts. The standard risk model *(Smith and Merritt, 2002)* is based on these premises *(see Figure 2)*.

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 et al., 2009)*. 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 Management Institute, 2004)*, risk management consist in the treatment of the project uncertainties through a structured four-step generic approach: risk identification, analysis, treatment and control. 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 *(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.

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 *(2006)*, the more radical the innovation, the higher the uncertainty regarding technical and economic feasibility. The lack of experience can be the cause of major lapses in the risk identification phase that can have dra-

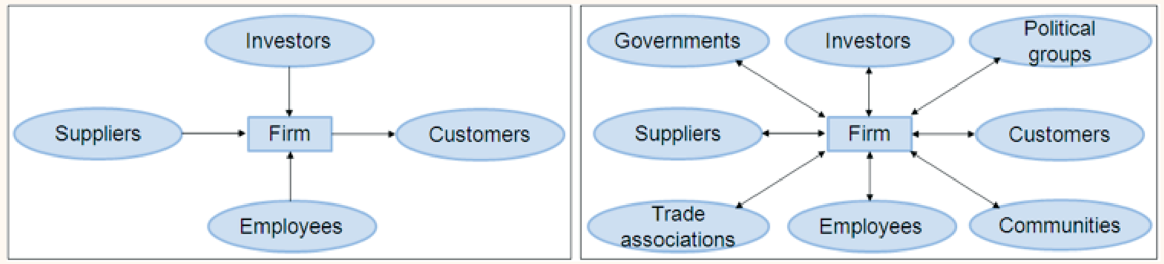


FIGURE 1. *Input-output and stakeholders models*

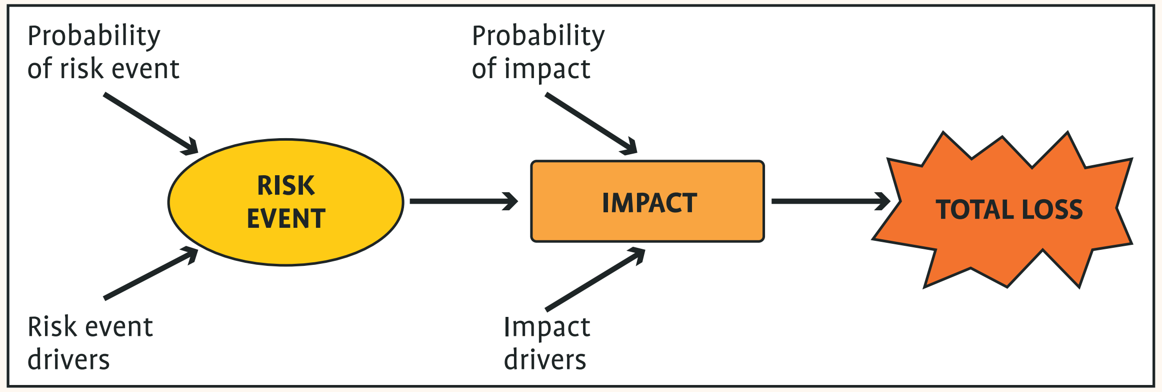


FIGURE 2. *Standard risk model [39]*

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

TABLE 1. *Specific problems of risk management in innovation projects identified in this analysis*

matic impact. The risk 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 mastery phase of risks may also be less efficient. With no applicable lessons from similar projects, it may be harder to devise mastery solutions of risks and their outcome may be less certain. **Table 1** summarizes the problems that arise specifically in a context of innovation.

These risks are the inevitable counterparts of the possible value creation expected from innovations. Kastensson et al. *(2010)* notes that for innovation managers, "risk taking is a success factor to achieve innovation". 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 et al., 2002; Mu et al., 2009; Wang et al., 2010)*, the two most important domains in which risks appear for innovation projects are: technology and market.

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 technology and the market.

The presence of risks should not put companies off innovation, as this is crucial for their survival. According to Midler *(1998)*, in product development, the biggest risk is to choose not to take any. 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. For EMS it seems clear that identification of these risks and their treatment when it comes to disruptive innovation is particularly difficult because of the frequent lack of resources in these types of businesses.

Conclusion

The above literature review shows the importance of taking into account value creations and risks in a model of project management in disruptive technological innovation. It highlights that this model should tackle problems of an operational, tactical and strategic nature. Secondly, the model should be able to deal with problems related to the innovative product or the organization supporting its lifecycle. This leads us to formulate the following hypothesis: In a context of disruptive technological innovation projects in SMEs, it is beneficial for the decision-making process to present information about the diverse value creations *(different types of value and different stakeholders)* and the risks related to them.

The next section presents the proposed model for supporting the decision-making process for disruptive innovation process in SMEs.

2. Experimentation

Context of the experimentation

This work was conducted as a research action inside a small aeronautics integrator. The company designs, manufactures and sells airplane extinguishers. The objective of the innovation was to develop a disruptive technological solution for the opening of the extinguisher in case of emergency. This technology should replace the old one in some of their products, to be determined.

The company is a medium sized company with a very good technological know-how. In this company, as in this industry in general, innovations are usually incremental and this technology refinement and ramp-up is not trivial.

Technical Innovation

The idea was to use ceramics to replace the current device used to trigger the opening of aeronautic extinguishers: pyrotechnical cartridge. These ceramic components break while submitted to an electric current. 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 a PhD candidate assigned with the responsibility of completing the product design and providing the executive committee with information to enable a decision regarding the market offer to implement.

Project main phases

The two main functions of the device controlling the opening of the extinguisher are:

- 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.

A first preliminary development phase had been completed before the start of our study. However, the results of these tests were not exploitable. No sufficient repeatability in the rupture energy of ceramics was found, leading to a non robust design principle. This phenomenon was traced to the high dispersion of the mechanical properties of the ceramic and the poor quality of the joint between the ceramic and the metallic conductors.

Experimentation protocol

Selection of critical decisions open to experimentation

During the project, several situations seemed appropriate to experiment our method; we thus identified critical decisions to be made *(see* **Figure 3**). 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 was available as to how this had been achieved. Two other critical decisions were selected afterwards: the choice of an industrial ceramic manufacturing process and the selection of the most adapted market offer.

In this article we illustrate our method with the first of these decisions. However, the following limitations must be mentioned: the decision had already been taken at the time our model was developed. We applied "a posteriori" in order to validate that decision and compare the outcome of the traditional decision-making process with that of a formalized process.

Protocol

The project steering committee is constituted of six persons. Three of them are researchers involved in this work, a PHD student, two members of the company, the CEO and the chief technical officer. Each decision was followed by an evaluation phase to facilitate the quality analysis of our result and help validate our method.

The interviews of the various innovation stakeholders were a key step enabling much information to be collected. For reasons of confidentiality, in our case we could only interview internal stakeholders. We tried to make up for this shortfall by interviewing members of the enterprise who had the most knowledge about 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.

The validation of the model was very challenging for us in this study. No two innovation projects are alike. It is thus not possible to validate the performance by comparing our results with that of others 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. In order to assess our model, we asked different users how they felt about its performance. Since the main customer of our method was the project steering committee, interviews of its members were conducted. All results were then analyzed to assess the quality of the method. The interviews focused on following subjects:

- The method itself and its use: ease of implementation and costs;
- The results presented at the end of each experimentation;
- Adequacy and usefulness of the information presented;
- Quality of the results presented: are there any inexactitudes 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 in the committee on which alternative to choose?;
- General impression: what is the committee's general impression on the method experimented?

Identifying critical decisions

Impact assessment

Our model proposes an assessment of the impact of a decision on a project based on the traditional triptych quality, cost and on-time-delivery. This impact can be considered "weak" or "significant". The three relevant aspects were assessed by the project steering committee with the following results.

- From the quality point of view, the selection of a manufacturing process obviously has a significant impact. Since this selection concerns the process used to manufacture the final product, the capability and robustness of this process will impact the quality of the products brought to market. The final manufacturing cost of the product (an element of the project's quality) is also impacted by the choice of the manufacturing process.;
- From a cost perspective, the impact is not decisive. The price differences for developing manufacturing technologies for this ceramic is not that high compared to the total cost of the project.;
- From a time perspective, this decision has an impact on the project. Continuing the development requires knowing how the ceramic behaves, and this cannot be obtained without performing tests. The time required to develop the technology and the speed of the manufacturing process impact how quickly these tests can be performed.

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

Uncertainty assessment

In this case, the only pieces of information available on the possible alternatives were based on previous propositions made by the ceramic suppliers. However, the implications of the selection of a given industrial process on the final outcome of the project were not known by the

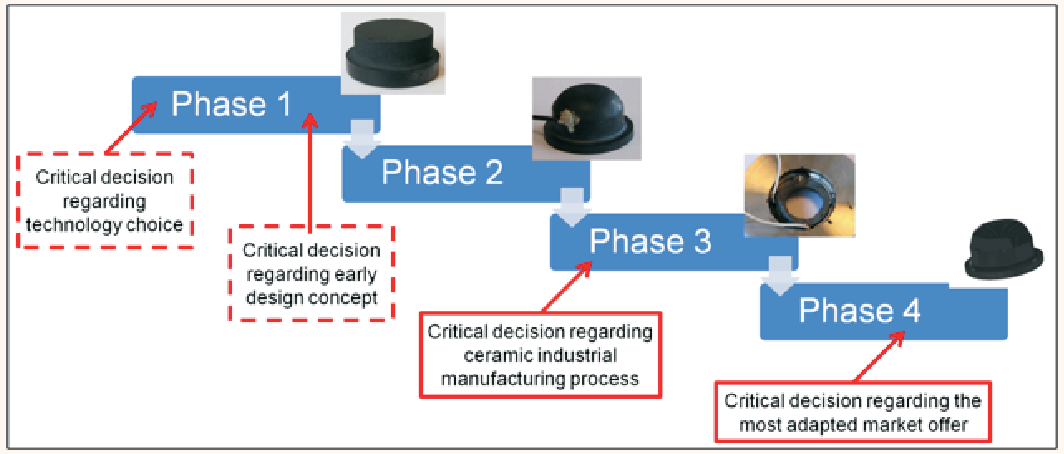


FIGURE 3. *Areas of critical decisions*

decision-makers. This uncertainty is significant regarding the project alternatives. Consequently, based on our criteria, this decision was identified as critical *(see* **Figure 4***)*. The importance of its outcome and the small amount of knowledge available makes it sufficiently complex to require a specific focus.

Problem setting

At this stage we must analyze the values potentially created by the innovation and its requirements. We present the setting of this problem in two steps. In the first, we present a preliminary analysis of possible values created by the innovation with an analysis of the stakeholders. We combine these analyses to identify possible value creations for our innovation. In the second step, we adapt this preliminary study to the decision in hand. We detail the values and stakeholders under consideration.

Interviews with the stakeholders

We define value creation as the creation of one type of particular value for a given stakeholder. The identification of value creation requires the study both of the values potentially created by the innovation and of its stakeholders. Identifying value creation is carried out in three steps. Firstly, possible types of values and stakeholders are identified through a literature review. Then the interview of identified stakeholders results in a more precise formulation of the value creations.

A literature review is completed in order to identify different stakeholders and types of values. The literature shows that an innovation can create multiple values. We can list the following: economic values, quality, on-time delivery, knowledge, quality of internal communication, ethical values and environmental values. A similar analysis focusing on an organization's possible stakeholders enabled us to identify the following: the organization itself, suppliers, customers, final users, the market, competitors, shareholders, employees and finally a generic stakeholder named humanity. We conducted interviews to gain more details about these stakeholders and their expectations in terms of value creations. For reasons of confidentiality, it was not possible to discuss the innovation extensively outside the enterprise. As a consequence, we only interviewed internal stakeholders. However, in order to access maximum knowledge on the expectations of external stakeholders, we took care to interview people inside the company who are used to working with these stakeholders. Thanks to their specific knowledge they are able to well depict 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 of his team members, the quality manager and the purchasing manager. Our objective was to access knowledge in all the areas of the company in order to have as much as possible a complete view of the innovation's impacts. Discussion with the interviewees was as free as possible and centered on a few selected areas:

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

In the following section, we present a summary of the results of these interviews. We first present our analysis of the verbatim of the interview regarding the innovation, the cash-cow product it aims to replace and the markets addressed. Based on this, we propose different types of values that the innovation can create. We then present an updated list of stakeholders identified and analyze their relationship with the innovation.

- Current product: The current product relies on a technology that is several decades old. It is characterized by very high reliability, which is identified as one of the most important values 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 for the firm). The latter brings high margins that balance a certain lack of profitability in other products and increases volume to

amortize development and qualification costs. However the company faces competitors which copy its products at a lower cost and gain significant market shares. Since the new product would be much harder to copy, it would enable an important economic value creation for the company;

- 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 with a safe advance on its competitors.

Crossing this analysis with the values found in the literature, we detailed the list of potential values initially identified. The notion of image value was added. The ethical value was replaced by well-being, a term that is better suited to the type of ethical values that our innovation may create. Finally, we eliminated the on-time delivery value, and the quality of communication because our innovation does not provide additional creations of these values. Having specified the value that the innovation can create, we then focused on the stakeholders that benefit from these value creations. The interview enabled us to reformulate the previous list of stakeholders. New stakeholders were identified, such as certification authorities and public authorities. Based on the results of the interviews, we analyzed the relationships of these stakeholders with the innovation *(see* **Figure 5***)*.

Expectations of stakeholders

- Company employees: The innovation would bring safer work conditions for a small number 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;
- Company: 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 this. 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 some investments related to employee safety. Finally, the company would gain expertise in this product that would show evidence of the value they add to the group;
- Customers: Innovative products would ensure a better impact on the environment in a context of strengthening regulations. It would save them some logistics costs, increase their employees' safety and diminish the related costs. It could also decrease the weight of airplane equipments;
- Corporate: The corporation could also use the innovation on their products with the same advantages as their branches;
- Public authorities: It would decrease some safety related risks in the area of the company's premises;
- Former product suppliers: The innovation being launched would result in our firm doing less business with them. If the (former) technology is still used on other products, this could lead to an increase of their prices. However, the company only represents a small part of their total business;
- New Product suppliers: They would gain a new business and possible access to a new technology;
- Environment: replacing the pyrotechnical cartridge by a ceramic compound would reduce the amount of lead released into the environment. It would also decrease the quantity of explosives stocked by the company and thus the risks of accidents or criminal use;
- Certification authorities: They are responsible for the aircraft certification. As such, authorization for new components is based on their recommendations. They have particular interest in the innovation being introduced.

By crossing these expectations with identified values, we are able to represent a first map of the innovation's potential value creations *(see* **Figure 6***)*. This first list of stakeholders and value creations is validated by the steering committee of the project that comprises actors from all business areas in the company.

Selecting a manufacturing process for the ceramic

This preliminary analysis gives a relatively good understanding of the innovation's different actors and their motivations. It served as a basis for specifying the problem related to our specific decision. By crossing this analysis with the particularities of the decision made, we are able to identify the value creations concerned by the decision and analyze its requirements.

Alternatives identification and selection

Once this problem setting phase had been completed, possible alternatives for the decision were sought. Of the six tactics proposed by Nutt *(2001)* for revealing the alternatives of a decision *(idea, benchmarking, integrated benchmarking, search, cyclical search and design)*, in this case, only the search tactic was used. As the decision focus was to select a manufacturing process for a technical ceramic, expert knowledge was required. In addition, since no process suited to ceramics currently exists, the involvement of an external actor able to adapt this technology was required. It was decided to ask the current ceramic producer to propose solutions.

Based on the provisional 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 to make this ceramic: uniaxial pressure *(the technology currently used)*, slip casting and powder injection modeling. For each alternative, two solutions were studied: the production is carried out by the company or by an external supplier. We present the three technologies in the following paragraphs. This presentation is based on the books Engineering Materials Science by Ohring *(1995)* and Physical Metallurgy and Advanced Materials Engineering by Smallman and Ngan *(2007)* .

Uniaxial compression or die pressing

Uniaxial compression is the manufacturing process currently used for the first testing step. It is very simple but can be very efficient depending on the type of ceramic used and the usage of the product required. In this process, ceramic powder, usually with a relatively high particle size *(around a few micrometers)* is mixed with a small quantity of binding agent. The mix is then pressed into a simple shape. The result is a crude sample called "green body" whose cohesion is ensured by the binding agent. In some cases *(depending on the type of material)*, the ceramic compound is then hard enough to allow small modifications in its shape. The next phase is a two-step thermal treatment. The first step eliminates the binding agent. The second step, sintering, is a high-temperature treatment. During this step, the ceramic shrinks and hardens to reach its final density. Finally, machining is required to give the component its final shape *(see* **Figure 7***)*.

This process is very often used in industry; the shaping material required is quite simple which makes this technique generally less expensive than others. However, from a quality point of view, the large amount of post-sintering machining required can make the ceramic crack. In addition, because the ceramic is only compressed in one direction, its mechanical properties are not homogenous. During the sintering phase, this can lead to a non-homogeneous shrinkage of the ceramic. The combination of these two parameters makes this process difficult to replicate well; such a process is well suited to the manufacture of small series *(a few thousand pieces per year)*. Finally, it is to be noted that the sintering process is very complex. It is highly complicated to ensure good control of both the shrinkage and the density of the ceramic during the sintering process.

Slip casting

Slip casting is a technique used in the industry to make thin ceramic shell-shaped objects. A ceramic slurry or slip consists of 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 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 mold. The component is then sintered at a high temperature *(see* **Figure 8***)*.

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

Powder injection molding

The powder injection molding process requires heavier machinery. An organic binder is added to the ceramic powder in order to obtain a low viscosity mix. This mix is then filled inside an injecting screw. Inside this screw, the mix is heated and injected into pre-heated molds. The components once ejected go through a thermal or chemical debinding process. Due to the high temperature or the chemical solvent, the entire binding agent is removed from the ceramic part which can then go through the sintering process *(see* **Figure 9***)*.

The materiel required for the injection molding process is the heaviest of the three processes considered. The shaping process *(injecting of the mixture into the mold)* is fully automatic which leads to a good repeatability of the process. It also ensures good homogeneity in the distribution of mechanical properties. Similarly to the other processes, sintering is a very complex step. Furthermore, the injection molding process can sustain very high production rates. Powder injection molding is suitable for large series *(over ten thousand pieces per year)*.

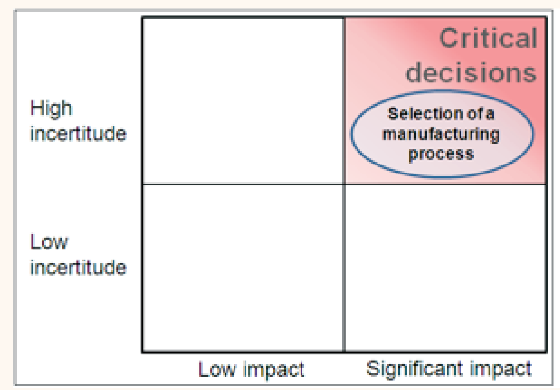


FIGURE 4. *Criticality of the first decision*

Criteria identification of alternatives assessment

Based on the previous analysis of the alternatives, we have to establish which value creations must absolutely be protected. 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 should not 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: the former, new potential suppliers and civil authorities. Effectively, for the current supplier of pyrotechnical components, the selection of any of the manufacturing process for the ceramic has the same impact. Moreover, for the possible value creations for future suppliers and civil authorities, with the information we currently have, the choice of an alternative will not make an important difference.

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.

Expressing value creation, 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 can help decision-makers.

In order to help the decision-makers in critical decisions for 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, and then based on the evaluation of the characteristic factors, the value creations are assessed. Finally, for each value creation, the risks associated are studied.

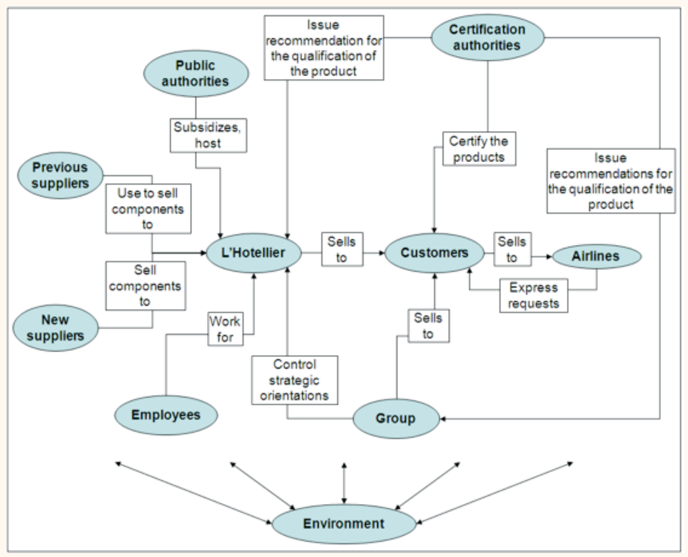


FIGURE 5. *Relations between the stakeholders of the innovation*

Expressing Value creation

We identify quantitative factors to characterized possible value creations. However, in some cases, it was not possible and we had to settle for quantitative evaluations *(see* **Table 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 3***)*. The short term financial value only concerns one stakeholder: the enterprise. It is characterized by the cost of adapting 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 costs 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 thousands Euros. The same estimation performed for the powder injection molding was one hundred and twenty thousand Euros.

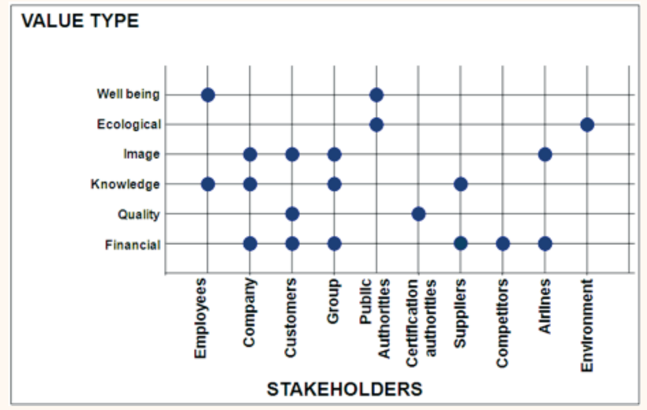


FIGURE 6. *Possible value creations by the innovation.*

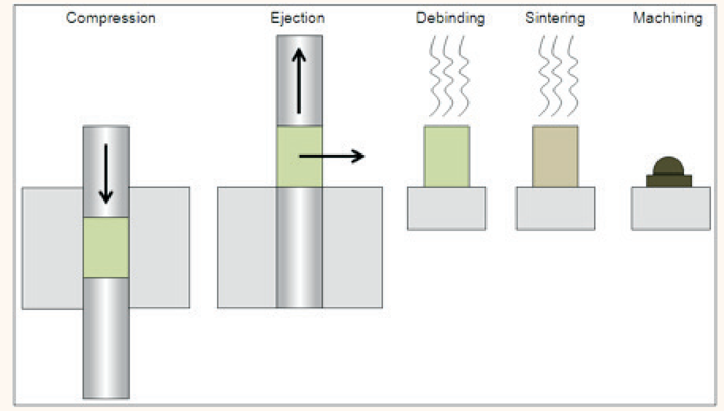


FIGURE 7. *Uniaxial compression process main steps.*

Mid-term financial value is created for the enterprise and its 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 prices, 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 the enterprise 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 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 estimate future unit costs precisely. However, comparisons can be made between these costs, based on provisional production volumes for the enterprise *(around six thousand pieces per year)* and its group *(around fifty thousand pieces per year)* and on the capacities of each process. In addition, based on previous experience, the uniaxial process is likely to be characterized by a high extra cost of poor quality. Based on this criterion for the enterprise the most expensive solution is uniaxial compression *(adapted for a medium series of around a few thousand pieces)* followed by injection *(adapted for series above ten thousand pieces)* then slip casting *(adapted for a medium series of around a few thousand pieces).*

Risks identification and analysis

For each of the value creations, we then performed a risk analysis. We 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 impact *(see* **Table 4***)*. We adopt this quite simple scale adapted from the FMEA 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.

For each industrial process we identified one major risk: underestimating the cost of adapting the process to our ceramic. For 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 such a risk would also be quite low. For slip casting and powder injection molding, the probability of underestimating the development costs is higher since there is no example of these technologies used 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 that is characterized by high development cost.

Value creation and representation of risks

Once the task of value creations and risk assessment are completed, the results must be presented to the decision-makers. This information must be presented in a form that is easy to read and understand, for its main objective is to facilitate the comparison between the alternatives. Information presenting a high level of detail on the different value creations and risks would result in information overload, and thus hinder decision-making. Consequently, we decided to present the information in two levels. The first presents a summary for each alternative of the value creations and risks. The second details each value/stakeholder pair, the value created by each of the alternatives and the associated risks.

Value creations and risks summary for each alternative

The low level of information acceptable to present the overview of each alternative means that this information must be qualitative in nature. The summary requires that the different types of value creations be represented on a similar scale. This is to avoid cognitive bias caused by too great a difference between the representations of the different values that could lead to irrelevant comparisons. We choose to establish five levels of value creation to facilitate their comparison in the different scenarios. *(see* **Table 5***)*.

Based on our assessment, we provided each value creation with a score ranging from one to five. The representation of the risks associated with each value creation is based on their previously assessed impact. 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 impact of each value creation *(see* **Figure 10** *and* **Figure 11***)*.

Deeper focus on risk and value creations

This first information presentation is essential in order to give decision-makers an overview of the value creations and risks associated with each alternative. However, this does not suffice for decision making. A deeper analysis of each alternative based on more detailed information is necessary. The purpose of presenting this second level of information 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 combines and synthesizes the information that led to the construction of the initial graphs for one value creation *(see* **Figure 12***)*.

It is essential to be able to make connections between the two levels of information; for this reason, we chose to link the two media. The final document is a series of graphs presenting value creations and risks for each alternative, where each circle representing value creation contains a hypertext link to the document synthesizing the information on this value creation for all the alternatives.

Analysis

By comparing the situations before and after the application of our model we can see that our approach significantly increases the level of information available to decision-makers. In one case the only information available is limited to the costs of developing each solution and to an estimate of the quality level of the outcome. After the application of our model however, we have a broader estimate. The economic aspect is divided into short, mid and long-term financial value creation. 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 customers but include the employees, airlines, the group Kidde and the environment.

A discussion with decision-makers based on the presentation of this information led to the a posteriori justification of the selection of the injection process. The product performance and performance robustness values and the non-inimitability of the knowledge involved represent the key criteria of this decision. Even if the decision might have been the same without our model, the supplementary information presented is helpful and could have changed the decision. As such, we can justify that our model is useful to decision-makers by providing them with an increased level of information.

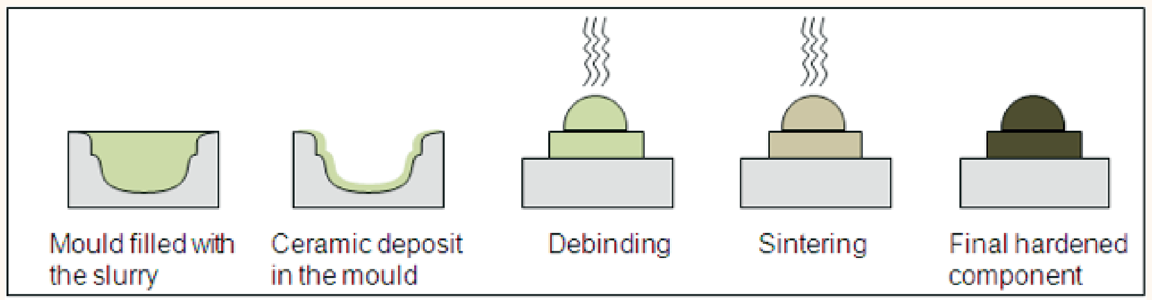


FIGURE 8. *Slip casting process main steps*

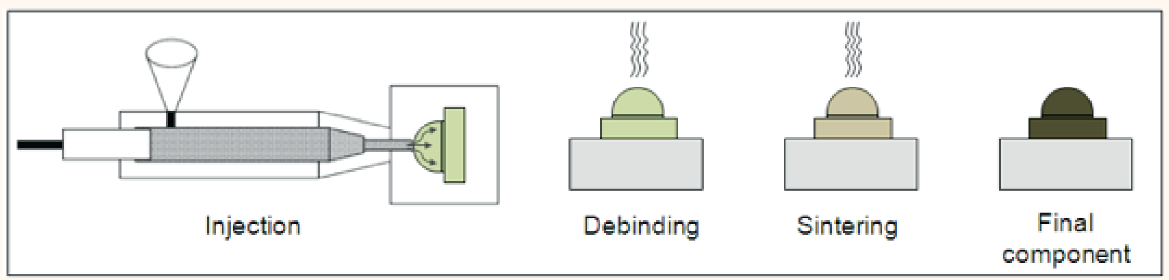


FIGURE 9. *Powder injection molding process main steps*

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	Scarcity and inimitability of knowledge involved
Image	Low-tech or high tech image associated with other applications 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 2. *Assessable characteristics of each value creation*

	Process adaptation cost	Investment costs	Unit manufacturing cost
Enterprise	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
Parent company	Non applicable	External alternatives: no investment cost. Internal alternatives: UC << SC < PIM	PIM < SC << UC

TABLE 3. *Assessment of financial value creation for the enterprise and its Parent Company.*

3. Conclusion

In this study we focus on the question of disruptive innovation management in the context of SMEs. Our literature review demonstrates that this issue is not addressed for this specific situation. This analysis also highlights that the main issues posed by such developments is the identification of and access to relevant knowledge *(technology and market-related)*. We were faced with the following issue: Given the fact that SMEs are not able to follow traditional models of innovation processes, what are the main aspects that should be the focus of disruptive technological innovation projects? In order to answer this research question we elaborate a model that aims to help managers to monitor innovation projects through the control of critical decisions. The application of this model allows the creation and representation of knowledge helping a decision-making process. It proposes to identify relevant stakeholders, determine and prioritize their expectations for the company and the importance of or otherwise meeting those expectations. It then supports the assessment phase of alternative solutions through two dimensions:

The value these solutions create given the expectations of stakeholders.

The nature, occurrence and impact of risks associated with these alternatives.

Based on this information, decision-makers can rationalize and enhance the quality of their choice, selecting the alternative that ensures the value creation that is best suited to the company's strategy. This model takes the product itself into account as well as the innovation value chain. It ensures that the decisions made are based on the strategic, tactical and operational aspects of the project. This high level of information presented enables decision-makers to guide the project in the most appropriate direction. By repeating this operation on each critical decision, decision-makers can monitor the project toward the most suitable value creations for the company.

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 4. *Risk probability and impact evaluation scales*

1^{st} level	2^{nd} level	3^{rd} level	4^{th} level	5^{th} 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
	Significantly higher the 1^{st} level	Significantly higher than the 2^{nd} level	Significantly higher than the 3^{rd} level	Significantly higher than the 4^{th} level
		Much higher the 1^{st} level	Much higher the 2^{nd} level	Much higher than the 3^{rd} level

TABLE 5. *Five levels qualifying value creations.*

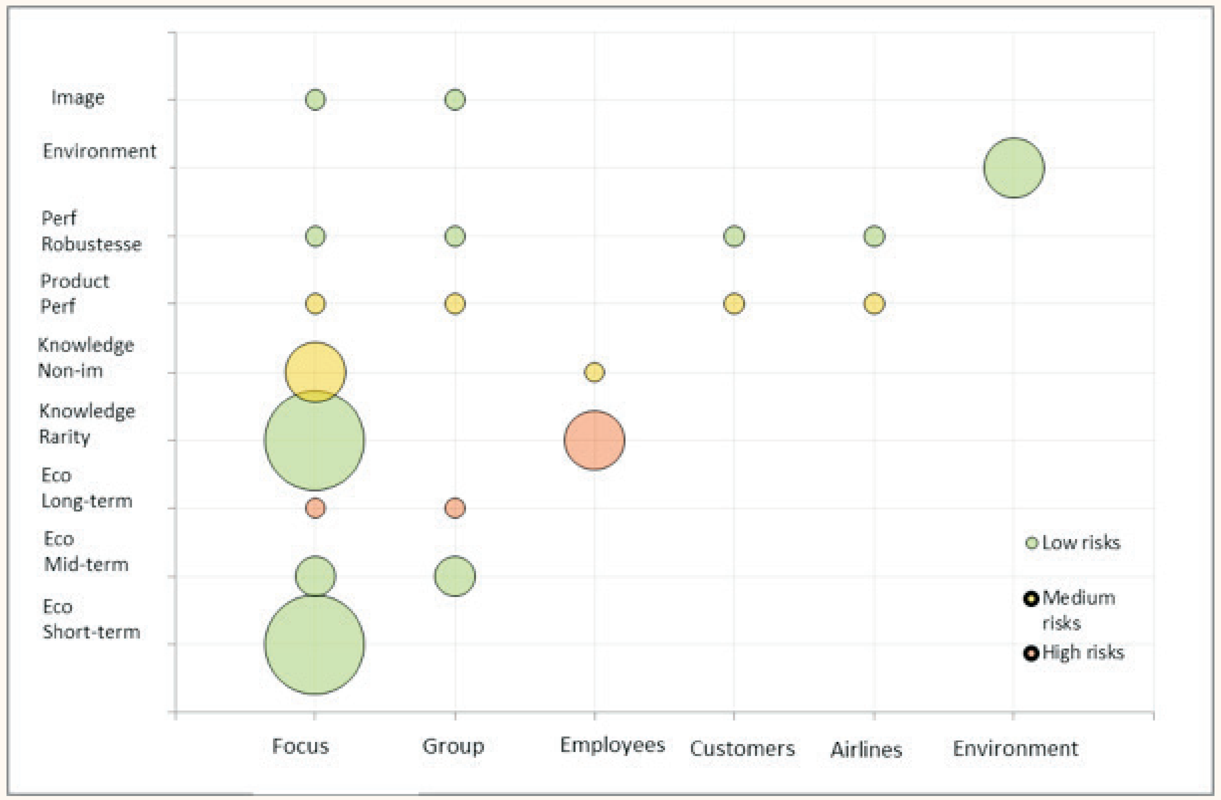


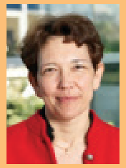
FIGURE 11. *Summary of value creations for the uniaxial compression alternative (internal option)*

FIGURE 10. *Summary of value creations for the powder injection molding alternative (internal option)*

Uniaxial compression (int)	Slip casting (int)	PIM (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	• 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	• 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)	**Slip casting (ext)**	**PIM (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	• 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	• 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

FIGURE 12. *Synthesis of information enabling the assessment of short-term financial value creation.*

authors



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