DECISION-MAKING IN DISRUPTIVE INNOVATION PROJECTS: A VALUE APPROACH

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ABSTRACT
Disruptive technological innovation projects are very challenging for small firms, especially in industrial sectors with very high reliability expectations. Because of their complexity, the final outcome of the innovation depends of the quality of the decision throughout the innovation process. In this article we present an approach that aims to facilitate decision-making in disruptive technological innovation projects. It advocates using potential value creation for the stakeholder of the innovation and risks threatening this value creation as criteria during the decision-making process.

Keywords: innovation, decision-making, risk analysis, value management

1 INTRODUCTION
In some industrial sectors like aeronautics were the expectations in terms of reliability are very high, innovation can be very challenging. The uncertainty related to the value the innovation can create is often an important dissuasive factor. It can be managed if a robust innovation process exists in a company or if the innovation is characterized by a feeble degree of novelty. However for small companies dealing with disruptive technological innovation it represents an important challenge. In the following article we are going to present an approach dedicated to the innovation projects that aim to provide decision-makers with necessary information that objectivize the decision-making. This approach is based on the identification of the values potentially created by the innovation and the technical and commercial risks threatening this value creation. We start by presenting different innovation processes models and show that they may not be adapted to small firms of the aeronautic sector dealing with radical innovation. On the next part, we show that value creation, being the purpose of innovation, should be the key criterion in decision-making along with the risks threatening this value creation. We present then a short case study conducted with an aeronautic integrator developing an innovation significantly different from the products they usually design and sell. We apply our approach to the choice of a manufacturing ceramic process. The article ends with a conclusion summing up our findings and discussing the limitations of our approach.

2 DISRUPTIVE AND TECHNOLOGICAL INNOVATIONS IN SMES: COMPATIBILITY WITH CLASSIC MODELS OF INNOVATION PROCESS

In order to help firms achieving innovation, numerous studies have been developed describing innovation processes. These processes aim to help firms to adopt an organization that increases their innovation abilities and efficiency. However, with the rich variety of innovations existing in multiple and various contexts, one can ask whether these models can achieve enough flexibility to be applicable in particular cases without losing their prescriptibility. In the next paragraph we are going to focus on some of the main innovation process models described in the literature and used in the industry. We will discuss their merits and drawbacks.

2.1 Innovation processes
Without claiming exhaustiveness we expose here the principal models proposed by the literature to manage the whole innovation process.

- <u>The chain-linked model:</u> Kline and Rosenberg [1] 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 between activities.

- The stage-gate system: The stage-gate system proposes a methodology to ensure a better management of the innovation process[2]. 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 the quality of the deliverables required to enter the stage. 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.
- The model of Pahl and Beitz: The Pahl and Beitz model [3] presents a functional interpretation of the different steps that must be conducted during a new product development process in order to rationalize it. However, this model 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.
- The C-K theory model: The C-K theory [4] is a design theory that describes the design process as a combination of operations and spaces of concepts and knowledge. 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.

Each model exposed in this chapter underlies that customer needs have been fully identified in a precedent step even if they are not translated into technical terms or requirements. The enterprise choices about the principal characteristics of the product or service innovations and about the value chain offering the possibility of its industrialization have been already established. In a complex environment constituted of numerous stakeholders (whose importance varies for the company) with contradictory expectations, the definition and the respective value of these characteristics is not easy to establish. Furthermore, these models assume that the company disposes of the organization and resources required to accomplish the complete product definition, manufacturing and commercial distribution. However, this is not always true, especially in companies like SMEs with a real technical know-how. In the next chapter we examine the nature and design practices of the small company we will study in this article.

2.2 Main characteristics of our case study

In this article we will study the case of an aeronautic integrator developing a disruptive innovation. Our first step is going to extract the structuring properties of the environment of our innovation. This will help us to assess which innovation process is most relevant to our case study. In the next paragraphs, we will restrain our study to a specific kind of industrial environment in specifying the industrial sector and the size of the firms we choose to consider. Along with this precision of our field of investigation, we will precise the structuring properties of the environment we describe, especially when it comes to innovation. This study will only focus on technological disruptive innovations.

2.2.1 Industrial sector

This study will focus 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 must accommodate with a heavy regulation and documentary constraints that represent a barrier to creativity. Furthermore, the adoption of innovations based on new technologies will be impeded by the deficit 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*"[5].

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. Products 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. 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 products previously developed. In this way, they would be able to distribute them through retrofits on older programs.

2.2.2 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. In this paper, we will focus on Small and Medium Enterprises (SMEs). 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. They often have scarce human and financial resources which can handicap them in accessing specific knowledge that could be key for a step of the innovation development. They also are characterized by very flexible organizations where work relations are informal and management processes barely defined. This informal process of communication allows a good sharing of tacit knowledge [6] in return this knowledge is rarely formalized [7].

2.2.3 Conclusions

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. 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. These precisions on the kind of environment concerned by our study allow us to estimate more precisely the applicability of the models we have presented. Even though they can be used in multiple situations, they are not sufficient for the environment we have described. Either they are not prescriptive enough regarding the kind of organization that needs to be adopted. Or they assume that the different activities that constitute the innovation process are well defined (linear processes, stage-gate system) in the enterprise, a hypothesis that is acceptable for incremental innovation development but not for radical ones. Some are also more adapted to companies whose strategy relies on frequent innovation developments (C-K theory for example).
In the next part we propose guidelines adapted to innovation projects. It intends to help small firms to manage the development of innovations having a very high level of technological uncertainty and new not only for the firm but for the whole industrial field.

3 PILOTING DISRUPTIVE INNOVATION PROJECTS IN TECHNICAL SMES

The innovation process 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. Thus, a good piloting of disruptive innovation projects comes to guaranteeing that this decision accomplishes the purpose of innovation: ensuring the right value creation for all the stakeholders of the project. In the next part, we will justify through a short review of the literature that the purpose of innovations is value creation. We will then focus on the different aspects that this value creation can take. The next step will be to describe the risks that negatively impact this value creation. We will then conclude by a short overview of decision-making domain in the context of the product innovation.

3.1 Context

3.1.1 Purpose of innovation for enterprises

According to Van Horne[8], the purpose of innovation is value creation. This notion of value creation is inseparable from innovation. Schumpeter presents it as one of the main causes of economic activity and growth[9]. In his work about the stage-gate system, Cooper[2]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*". Obviously, the creation of economic value is key in an innovation development: for Garcia and Calantone[10], "*an innovation differs from an invention in that it provides economic value*".
However this value cannot be taken for granted. The innovation process is full of uncertainty and with this uncertainty come risks threatening the potential of value created by the innovation. These risks need to be taken into account, evaluated and managed. They are due to the uncertainty that lies in two

main aspects: technical performances of tools and method used in the development and market answer to the innovation [11]. These subjects are developed in the next paragraph.

3.1.2. Risks in innovation projects

Project risks can have significant impacts in innovation projects as in any product development project. According to Ferney-Walch and Romon [12], the more radical is the innovation, the higher is the incertitude regarding the technical feasibility and the economic feasibility. Other authors[11, 13], underline that two important domains in which risks appear in innovation projects are: technology and market. In order to increase the performance of innovation projects, it is thus crucial to adopt an effective risk-management strategy.

a) Technological risks: Technological risks include all risks related to uncertainties caused by the technologies key for the innovation. Technological risk can arise from two major sources: lack predictability or of capability [14]. 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[15]. The general approach to technological risks treatment consists in engaging actions to decrease the uncertainty of the technologies involved. 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 Readiness Levels TRL[16]. Another possibility is to externally acquire mature technological knowledge in order to reduce technological risks [13].

*b) Market risks:*Market risks derive from uncertainty or bad evaluation of the innovation market. This uncertainty can be sourced to several factors [13]: risk perceived by customers, customers needs misevaluation and inaccurate prediction of economic parameters. Firms usually rely on brainstorming, focus groups, social analysis, experts' analysis or on the use of check-list and risk typologies to identify market risks. Specifics approaches however exist to treat the different kinds of market risks. Some advertise to focus on the customer in order to decrease the risk perception or to strengthen the trust relation between enterprise and customer in increasing the level of commitment between them[17]. Another approach is to engage in actions to increase knowledge of the customer: "*the most important areas of information necessary for product development*"[18]. This can be done in involving the customer into the innovation design process [17] or through inquiries or interviews.

Consequently two dimensions must undoubtedly be treated in order to manage a process of radical innovation: value creation and risks. 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. 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.

3.1.3. Decision making in innovation

Multiple decisions have to be taken during innovation projects: project team set-up, choice of concepts and technologies, marketing strategy, etc. In the following paragraph, we will take a look at the bases of decision supports methods. Their purpose is to increase the quality of decision taken, taking into account the limited rationality and access to information of the decision maker. Different 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 [19].

- 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.
- Step 4. Identify alternatives that could solve the initial problem.
- Step 5. Define criteria that are objective measures of every goals achievement.
- Step 6. Select a Decision-Making Tool that would enable an evaluation of the alternatives.
- Step 7. Evaluate alternatives against criteria using the selected decision-making tool.
- Step 8. Validate solutions against problem statement

This approach postulates that decisions need to be fully rationalized. The steps six and seven offer tools whose purpose is 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 criteria are involved. 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. Several methods exist that take multiple criteria into account. We can cite Pros and Cons Analysis, 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 decision-makers with a single piece of information: the unique best solution, defined through the evaluation of the different criteria, taking into account the fact that some are more important than others to the decision-makers.

3.2. Our approach

In our industrial context however, we think this should not be done. Due to the number of criteria, the process used to weight each criterion is very opaque, could lead to errors and would then result in a final ranking of the alternatives for an innovation project that would seem artificial and hard to trust for the decision-makers. Furthermore, the implementation and use of most multi-criteria decision tools require important time and knowledgeable resources that small firms usually cannot have. However providing an evaluation of the alternatives according to several criteria is still useful as it would give decision-makers more information on the decision to make [20]. 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[21]. The approach we develop in divided in three phases: problem identification and translation, alternatives identification, value and risks evaluation.

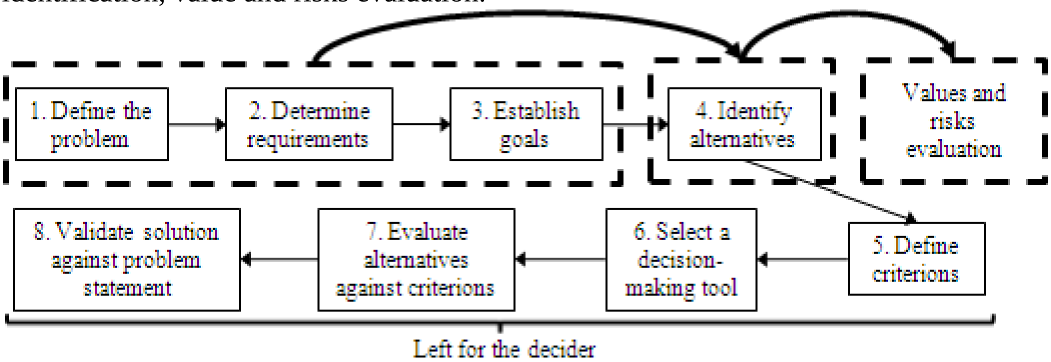

Figure 1. Knowledge creation process for decision-maker information

3.2.1 Problem Definition and translation

The first phase consists in realizing the three fist steps of the decision-making process described before. This is done through the realization of a series of interviews inside and outside the company. The methodology we propose is based on that advocated by Dudezert[22]. The interviews must enable to gain a wide knowledge of the innovation related decision and its environment. Each interview should take place at the subject’s desk or work station to ensure he is as comfortable as possible. It should begin with a rapid presentation of the objectives of the interview to help him to understand the purpose of the meeting. A open discussion should then be established centered on the identification of the different stakeholders impacted by the decision and the interest they have in this decision.
The realization of these interviews must enable the creation of a clear picture of the decision environment: its stakeholders and their relation and their expectations. The expectations of the stakeholders are then to be translated in values whose creation they would be interested in. Some of these values creation must reach a minimum level for particular stakeholders. This defines the different requirements (technical as well as economical) that bound the decision. Every value creation beyond these requirements can be seen as goals. Functional and value analysis can be completed at this stage to complete and formalize the knowledge.

3.2.2 Alternatives identification

The identification of a vast and rich list of alternatives in a decision in an innovation project can make the decision very complex but also decreases the risk of overlooking satisfying solutions. In a review of the different theory on how decision-makers uncover alternatives, Nutt [23] lists four main tactics: Idea, benchmarking, 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. Their implementation may require more resources.
- 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.
- 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.

Not all these tactics are applicable in the context of decision in an innovation projects and the multiple decisions of the project may require different tactics. Using design tactics for every decision could lead to an explosion of uncertainty, development costs and time.

3.2.3 Value and risks evaluation

The next stage is to proceed to an evaluation of the value created by the different alternatives. For each of the stakeholders identified in the first stage an evaluation of the different values created by each alternative should be conducted. Depending on the level of information and on the type of value, this evaluation can be quantitative or qualitative. This evaluation is completed by a risk analysis conducted for each of the alternatives as described above. The results are then presented to the decision-maker who will then be able to compare the different values created for the different stakeholders in each alternative and an analysis of the risks associated to each value creation.

3.4.5 Decision

The information gathered is then given to the decision-maker in order to help him in his decision. This approach we propose does not fully rationalize the decision process. The decision-maker is left with several alternatives. However, he as access to the information we deemed the more useful in decision-making: the value and risks characterizing each selected alternatives. This enables him to maintain some autonomy in his decision, thus increasing his level of involvement in its implementation.

3.5 Conclusion

In this part, we have studied the main purpose of innovation: value. We identified it as complex and non agregable since it can take different forms and involve different stakeholders. This value creation is threatened by risks related to innovation that can be separated in two main categories: technological and market risks. We then postulated that taking those criteria – values and risks – into account in the multiple decisions of an innovation project is necessary to ensure its success. We finally settled on the fact that the evaluation of these criteria should not lead to a formal ranking of alternatives but rather to an enlightening of the decision-makers on the possible impacts of their decisions.

4 EXPERIMENTATION

In order to assess the benefits of our approach, we applied it to an innovation project in a small aeronautic company. In the rest of the article, we will expose our experimentation and some preliminary findings.

4.1 Case study presentation

The innovation project we are studying is developed by an aeronautic integrator. This company is a small enterprise comprising a hundred of employees whose engineering department, specialized in development rather than research deals mostly with incremental innovations. Their products are critical for the security of the aircraft. They thus face very high expectations in term of reliability. This company is part of a bigger American group that validates some of its strategic orientations.

While visiting the facility of a supplier, the firm's chief technical officer came across scrap ceramic parts which presented a peculiar characteristic. If a technical process leading to this characteristic could be mastered, it could lead to an innovation that could provide significant savings in maintenance costs for the customer as well as ensure a diminution of highly polluting gaz. However, it would directly replace one of the firm's cash cow products.
The decision to launch the innovation project was taken. A creative approach using TRIZ methodology was conducted to find several solutions admissible. A technology was adopted. The most critical component of this new system would be a device made of a particular ceramic not commonly used in the industry. First prototypes were made using uniaxial compression method but the result was not very satisfactory. A decision was then taken to study the eventuality to change to a ceramic manufacturing process that would enable the innovation project to go further. We applied our methodology on this decision and it is the results of this experimentation that we are going to present.

4.2 Problem definition and translation

4.2.1 Stakeholders interviews and value creations identification

The objective of this phase was to define the problem and identify the values that could be created and destructed for the stakeholders of the innovation. This would enable us later to assess the impact of the alternatives of the decision. We conducted a series of interviews inside the company. External interviews that could have been very valuable could not be conducted for confidentiality reasons. The people interviewed were working in different areas of the company in order to obtain as broad a vision as possible. Nine persons were interviewed: the chief executor, 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. A discussion as free as possible was established 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 innovation internal and external stakeholders and their characteristics.

Through these interviews identified nine different stakeholders and seven different kinds of value created by the new product (see summary on figure 2).

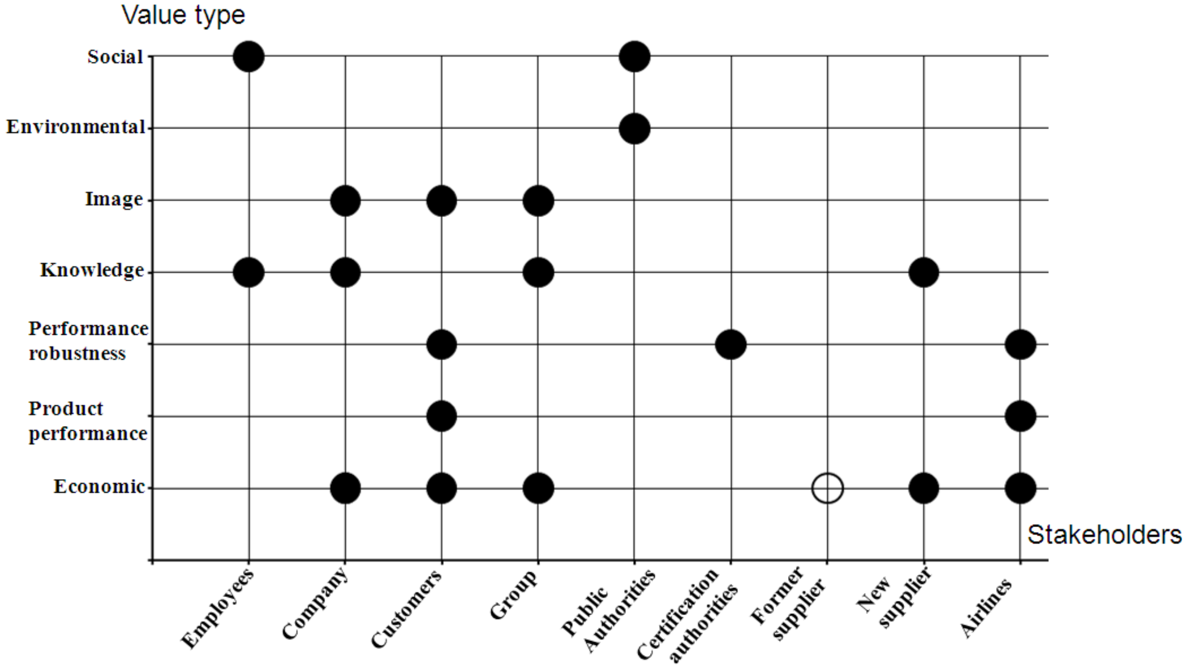

Figure 2. Stakeholders of the innovation and expected values.

4.3 Alternatives identification

Search tactic was used to identify alternatives. A subcontractor and a research center were contacted and given the specification. Three processes used for other types of ceramics were proposed:

- Continuing with uniaxial compression: the ceramic powder is pressed with a small amount of adjuvants to form a cylinder that undergoes a thermal treatment. Afterwards, it is machined into the right shape and sintered to obtain its mechanical properties.
- Adapting a slip casting process: The ceramic powder is put in solution and poured on a porous mold that absorbs the liquid. The component is then removed from the mold and sintered.
- Adapting a Powder Injection Molding (PIM) process. The ceramic powder is mixed with adjuvants, heated and injected in a mold. After it has been removed from the mold, it undergoes a thermal treatment to remove the adjuvants and is sintered.

4.4 Values and risk evaluation

4.4.1 Alternatives evaluation in terms of value creation.

Having explicated the different values created by the innovation and the possible alternatives manufacturing processes, we were able to bring to light the impact that the selection of a particular process would have in term of value creation. Out of the ones described above, six relevant stakeholders and five relevant values were identified. For each alternative, we compared the value creations for the stakeholders.

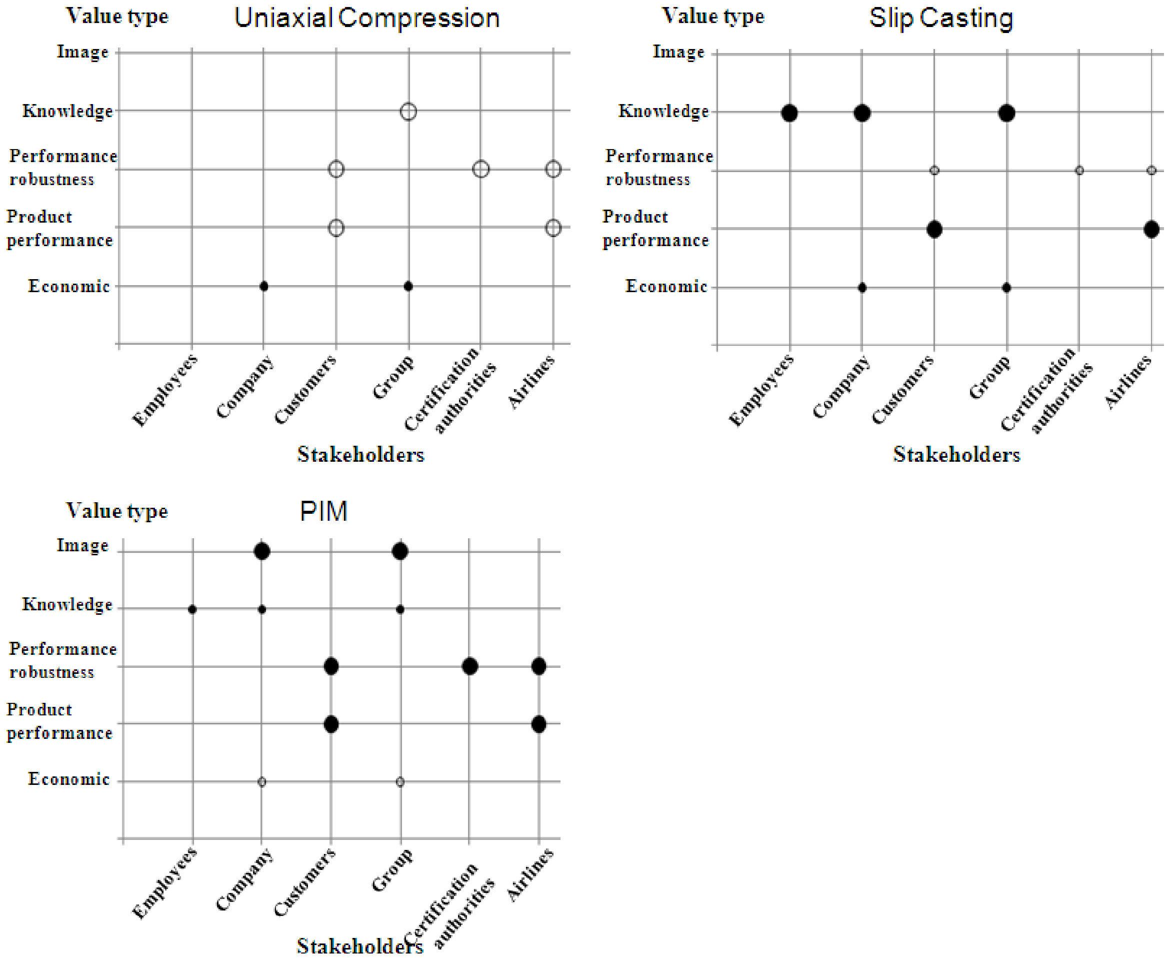

Figure 3. Stakeholders/expected values for uniaxial compression, slip casting and PIM process. Value creations range from Very low value creation (big empty dot) to very high value creation (big full dot)

4.4.2 Risks identification

Due to the technical aspect of the process evaluated, the technical part of the risk analysis was performed by experts belonging to the company subcontracted. Tools used included brainstorming, FMEA and qualitative evaluation of risks. To complete this view, we performed another risk analysis focusing on the risks impacting the value chain. From these data, we studied the impact of the risks identified on the value creations. Results are sum-up in table 1. The criticality for the total risks threatening each value creation is rated minor, medium, major or critical.

Table 1: Quantitative risks comparison evaluation for uniaxial compression, slip casting and PIM.

	Uniaxial compression	Slip casting	PIM
Economic		Medium risks impacting the final cost of the component. Stakeholder impacted: group /company/customers/airlines.	Medium risks impacting the final cost of the component. Stakeholder impacted: group /company/customers/airlines.
Product performance	Critical risk of not complying with technical specifications Stakeholder impacted: group /company/customers/airlines.	Medium risk of not complying with technical specifications Stakeholder impacted: group /company/customers/airlines.	Minor risk of not complying with technical specifications Stakeholder impacted: group /company/customers/airlines.
Performance robustness	Critical risk of high dispersion in the characteristics of the final product. Stakeholder impacted: group /company/customers/airlines.	Medium risk of high dispersion in the characteristics of the final product. Stakeholder impacted: group /company/customers/airlines.	Major risk of high dispersion in the characteristics of the final product. Stakeholder impacted: group /company/customers/airlines.
Knowledge	Risk of knowledge/know-how not being easily transferable. Stakeholders impacted: group (minor)/company (minor)/ employees (minor)	Risk of knowledge/know-how not being easily transferable. Stakeholders impacted: group (minor)/company (major)/ employees (minor)	Risk of knowledge/know-how not being easily transferable. Stakeholders impacted: group (minor)/company (minor)/ employees (minor)
Image	Risk of unexpected failure of the system resulting in a significant loss of image. Stakeholders impacted: company (critical)/group (critical)/customers (major)/airlines (major)	Risk of unexpected failure of the system resulting in a significant loss of image. Stakeholders impacted: company (major)/ group (major)/customers (medium)/airlines (medium)	Risk of unexpected failure of the system resulting in a significant loss of image. Stakeholders impacted: company (minor)/group (minor)/customers (minor)/airlines (minor)

4.5 Decision

This analysis was supplied to the project steering committee. This analysis enabled them to have a vision of the values created by each alternative. For each kind of value creation a risk analysis was supplied evaluating the impact a risk occurrence could have. The rest of the decision process was left to the steering committee. Eventually, decision was taken to develop the PIM process. An interview of the project manager conducted afterwards revealed that the decision was mostly based on the risk threatening the product performance and performance robustness values. However other information was also seen as useful to help the decision-makers. The analysis supplied was deemed helpful for the decision-makers and some of the work done during this study will be reused for the future major decisions of the innovation project: go/no go decision, make or buy problematic, etc.

5 CONCLUSION AND DISCUSSION

In this article, we showed that, depending on the context, classic models may not be sufficient when it comes to developing an innovation. In focusing on the purpose of innovation, we showed that two dimensions that need to be controlled during the decisions of the innovation process are the values created by the innovation and the risks threatening this value creation. We then exposed the approach we propose for the management of technological disruptive innovation projects in small companies in the aeronautic and defense sector and presented an example of application on a case study. We can say through the feed-backs from the project manager that the information we provided were key in the decision-making process. It gave the steering committee significant and sufficient information to help them in the decision-making process. Our next step will be to try and adapt this approach, using more quantitative data on the potential value creation in order to be able to present more relevant information to the decision-maker faced with more difficult problematic.

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