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Innovation management in the aeronautical sector: the 5F3D model

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ABSTRACT

The aeronautical sector is one of the most innovative sectors internationally due to the rigorous levels of safety and quality required of aircrafts. However, we currently have limited knowledge of how firms develop the innovation management processes. The present study proposes an innovation model to evaluate how the innovation is strategically managed through factors and determinants that enable the innovation processes in an aeronautical firm. Based on a case study to a relevant firm in the aeronautical sector, the results show the validity of the proposed model and evaluate the efficiency and robustness of the innovation management process in the aeronautical firm by means of the definition of three indexes. An index of innovation indicates the development of the innovation management process of the analyzed firm. A second index measures the maturity of the determinants that enables the innovation in the firm, and a third index measures the level of global maturity of the innovation process.

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1. Introduction

Thanks to important efforts in research, development, and innovation, the aeronautical sector has achieved significant resilience and the sector has continued to grow even during the worst years of the crisis. It is expected to continue to grow and play a fundamental role in the development and recovery of countries in the medium term. While it is true that the current context of uncertainty about the situation generated by COVID-19 makes it difficult to foresee the impact it will have on the sector, firms must adopt specific measures to sustain their activity (TEDAE, 2020). Despite the current pandemic and its impact in aeronautical sector, medium-to-long-term forecast studies suggest that growth in air transport will be maintained or increased (AIRBUS, 2019; TEDAE, 2020).

This study is motivated by a wish to achieve a deeper understanding of the management of innovation from an economic and business perspective in the aeronautical industry, as a strategic variable to face the new challenges and future scenarios that

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may arise in this industry, as well as to study the impact of technological change and globalization on the strategic direction of these firms. The aeronautical sector has four particularities that need to be considered when analyzing the innovation management strategies. First, it is a global market in terms of regulation, manufacturing, maintenance, operability processes, and customer experience. Second, it is an industry that has a long economic cycle because of the scope of the products developed in terms of employment, investment, size, costs, delivery times, technology, life cycle, and return of investment. Third, the sector has very strong entry barriers that make it difficult for new competitors to enter into the market, which means that few countries have the capacity to develop the industrial network necessary to manage the complex system required for the development and manufacture of aeronautical products. Fourth, the high impact on society and public administrations make this industry a focus for receiving significant investments and subsidies to a much greater extent than other sectors.

Depending on the environment where the innovation processes are developed, the level of maturity, the rate of technological progress, the institutional interdependencies, and the kind of knowledge or organizational structures are affected, as is the case of R&D activities in high technological sectors (Malerba, 2005). The above-mentioned characteristics of the aeronautical industry require differences in innovation management (leadership models, organizational structures, radical or progressive innovations, incorporation of new technologies) to better adapt the innovation to the organization reality, and are necessary for the design of innovation policies and strategies. The current scenario makes it increasingly difficult to access investments, so firms must explore new methods to drive innovation and avoid disruptive technologies (Deloitte, 2015). More and more technology firms recognize the importance of integrating new methods of innovation to increase the return on investments, creating new alliances with universities and start-ups to generate new technologies. The risk of not acting in this regard can lead to firm disruption, as has been demonstrated in the past with leading firms in other sectors (Moore, 2011).

The present study aims to design an innovation management model that allows the analysis of innovation management processes through the identification and definition of the key factors and determinants that enable innovation in the aeronautical firms. To achieve this aim, it is necessary to answer the following questions:

- i. What is the level of innovation in an aeronautical firm through the definition of several indexes?
- ii. What is the influence of leadership, management levers, and continuous improvement in the degree of maturity innovation in this firm?

The remainder of the article is organized as follows. Section 2 summarizes the theoretical framework and introduces a model that makes it possible to analyze the management of innovation in aeronautical firms through different factors and determinants. Section 3 presents the research methodology, and Section 4 describes the empirical study and variables. Section 5 summarizes the main results, and Section 6 presents the main conclusions and limitations of the study.

2. Theoretical considerations

2.1. Innovation and aeronautical sector

Globally, innovation in products, the presence of foreign markets, and diversification of customers are necessary to consolidate one of the engines of economic development (Bailey et al., 2010). From a firm's perspective, innovation is an essential factor to determine its economic growth, improve its efficiency, and increase its business competitiveness (European Central Bank, 2017; Gerguri & Ramadani, 2010). Taking into account the importance of innovation in the improvement processes of a firm, innovation management requires a structure that systematizes and supports the optimization of activities aimed at generating new results.

The benefits of integrating an innovation strategy in management have been widely proven, not only for the firm, but also for the other components that comprise it (employees, suppliers, stakeholders, etc.), since it promotes its development and its ability to take on new challenges, and generates greater competitiveness in its environment (Barsh et al., 2008; Dodgson et al., 2008). However, if innovation is not properly managed it can lead to failure because it implies a change that generates uncertainty about the result (OECD, 2018; Van der Panne et al., 2003). It is necessary to design methodologies and strategies oriented towards innovation, and also to use tools to analyze the factors that intervene in the innovation process and detect the opportunities and threats that exist in the different scenarios (D'Alvano & Hidalgo, 2012).

Therefore, innovation management is a voluntary management principle or approach that is not ruled by legislation, but can be implemented through non-binding standards and models. The current lack of reference of a single model for the application of innovation management in aeronautical firms has led to the existence of multiple reference documents, before which organizations were not clear on how to develop a strategy in this area. Thus, a firm can find normative documents that directly address R&D management (such as the UNE 166000 series of standards), models that set guidelines, either directly or indirectly (such as the EFQM model), or models that provide a reference framework in this area (Tidd & Bessant, 2009).

Currently, the global market for civil and military transport aircraft is controlled by two manufacturing firms (Airbus in Europe and Boeing in the USA) that have a global market share among all segments of around 50 percent. These two firms practically form a perfect duopoly in a market, with high margins, growing demand, and strong entry barriers for potential competitors. One of the most likely future scenarios would be the appearance of new competitors in this lucrative market, motivated by the commercial interests of customers and airlines, which would seek to increase competition to reduce prices. Traditional firms will face the emergence of new competitors in the medium and long term (Mordor Intelligence, 2020), and a true transformation of firms will be necessary to internalize the new models of innovation management and be able to start developing the skills that will be required in the near future (Schoemaker et al., 2018).

The following main reasons justify the importance of innovation management in the aeronautical sector. First, the aeronautical industry needs to develop long-term

agreements that incorporate innovation in new products and technological improvements that allow the investment to be recovered. Second, innovation in new materials and component integration (integrating platforms) are key to increasing customer value (Moeller, 2008). Third, process innovation (increasingly automated and intelligent processes that aim to eliminate bottlenecks in project execution) are critical for coping with changing market needs and customer expectations, which implies a complete digital transformation throughout the product life cycle (Quintana et al., 2010). The fourth reason is the need to improve the supply chain management, which involves improving delivery reliability, flexibility levels, reducing inventories, quality improvements, and increasing the speed to introduce new capabilities (Grijalvo & Sanz-Samalea, 2021). The final reason is the need to integrate the internal processes of firms with those of suppliers and customers, which implies an organizational change between the actors (Lu et al., 2020).

According to the literature review, most of the classical models were related to technological innovation. The technological innovation audit model (Chiesa et al., 1996), the pentathlon model (Goffin & Pfeiffer, 1999), and the process of innovation management model (Tidd et al., 1997) are focused on the innovation processes and do not explicitly consider the determinants and factors that enable these innovation processes. On the other hand, the latest innovation management models, which are more oriented towards the study of innovation in service organizations, usually present limitations that make them inadequate in terms of being applied to the analyzed sector. For instance, some models are only focused on technological firms, without considering the non-technological dimensions that influence the innovation (organizational aspects, resource management, etc.) (Geldes et al., 2017), while others do not consider the particularities of the sector, markets, or customers (Tether, 2002).

With the objective of evaluating the maturity of the innovation management of aeronautical firms, which implies identifying strengths, weaknesses, and potential opportunities for improvement of innovation management, the following innovation management models have been selected.

- i. The TEMAGUIDE model focuses on analyzing innovation processes from an organizational point of view, making a clear pragmatic approach demonstrated by multiple successful applications (COTEC, 1999). The model aims to measure the degree of development of an organization's innovation process, allowing comparisons between firms, and has been widely applied in different industrial (Hobday, 2005) and service sectors (D'Alvano & Hidalgo, 2012; Hidalgo & Herrera, 2020; Orfila-Sintes & Mattsson, 2009).
- ii. The Multi-Dimensional Framework of Organizational Innovation provides the foundations and key concepts on the determinants of innovation. These determinants emerge from the existing literature into three distinct meta-theoretical constructs: innovation leadership, managerial levers, and business processes (Crossan & Apaydin, 2010).

A set of standards have also been identified that, while not being models as such, define a generic innovation management system that is applicable to any type of

organization. The UNE 166000:2014 standard establishes the bases for certification of an innovation management system and defines a standard upon which to build and evaluate this system and create a comparative framework between firms. The technical specification UNE-CEN/TS 16555 (AENOR, 2016) is a guide that aims to evaluate the innovation management system and its operation.

2.2. 5F3D innovation model

In order to analyze the management of innovation in the aeronautical industry as a strategic variable to face new challenges and future scenarios, it is necessary to identify both the organizational and the determinant factors at the level of capabilities that characterize it. None of the selected models cover this set of factors, so a model called 5F3D has been proposed in order to represent the reality of innovation in aeronautical firms. This model seeks to assess an organization's innovation management through the different phases of the innovation process and the determinants that enable them. This model is composed of the five factors of the TEMAGUIDE model (scan, focus, resources, implementation, and learning) and three determinants of innovation (innovation leadership, management levers, and continuous improvement).

The following five key factors of innovation management enable firms to adapt their organization to change:

- *Scan* – Any business environment is dynamic, which implies being attentive to what happens in it to anticipate changes and adapt, as well as to seek new market needs that must be satisfied or turn threats into opportunities. In the framework of innovation, this surveillance is necessary to be aware of new knowledge that arises, new needs, and R&D advances.
- *Focus* – Related to the innovation strategy that is necessary to allocate resources. The challenge is to prioritize activities that maximize the competitive advantage.
- *Resources* – Once the objectives of the innovation have been defined, it is necessary to acquire skills, human capital, equipment, and other resources that are necessary to generate or acquire the new knowledge so that it is combined with the existing one innovation is generated.
- *Implement* – This involves all the activities related to the conversion of the innovative idea into reality, which implies decision-making, the design of actions, and the dissemination of the value for the client.
- *Learning* – A consequence of the innovation process. It is important to document all the steps and decisions to capture the knowledge generated and be able to use it in future innovations.

Determinants compile variables and parameters at the individual and group level (innovation leadership), at the firm level (management levers), and at the process level (continuous improvement) that enable and support the innovation. *Leadership* is considered the trigger of the innovation and establishes the framework for innovation success (Agbor, 2008). This determinant refers to the influence and direction that the leaders exercise on other people to create the desired innovation culture, as well as to

define the mission, vision, and values of innovation within the organization; that is, the innovation strategy (Dogan, 2017). Through leadership, all the processes necessary to innovate are articulated, clear objectives are established and adequately communicated, and the necessary resources are allocated. According to the leadership determinant, innovation leadership is a process that begins with the firm's strategy and ends with the management of change and the transformation of business culture, implementing the policies, measures, and actions defined to achieve the innovation objectives.

Management levers enable innovation through the alignment of innovation strategies with other relevant functions of the firm such as the assignment of responsibilities, the availability of necessary skills and competences, the definition of communication channels, intellectual property, and external collaboration policies. There are five types of levers (Crossan & Apaydin, 2010):

- i. Organizational mission and strategy establish the direction that the organization must follow, defining and communicating to all employees the objectives and values to achieve.
- ii. Structure and systems refer to organizational complexity, processes, bureaucracy, specialization, responsibilities, and number of employees.
- iii. Location of resources includes the intensity of R&D that measures the degree of dedication to innovation activities, the commitment of financing, the annual return, and flexibility.
- iv. Organizational learning refers to the work environment that leaders create by facilitating experimentation, being tolerant of failure, promoting employee learning and development, and promoting diversity in groups. Knowledge management facilitates the use of innovation management tools to support the identification of risks and opportunities, the management of relations with universities and other organizations, and the frequency of contact with the clients.
- v. Finally, leaders create innovative culture by having a clear, achievable, and shared value vision, promoting autonomy, taking risks, and motivating. The attractiveness of the organizational climate can be assessed using appropriate scales through job satisfaction and group cohesion.

Continuous improvement is the organization's ability to make modifications and adaptations to the products and processes. This determinant aims to increase the efficiency of a process by eliminating inefficiencies that imply the consumption of resources that do not add value. It also complements the innovation process so that all the changes implemented are subsequently susceptible to requiring small and constant adaptations over time to improve their efficiency and effectiveness (Bessant & Caffyn, 1997). Innovation, along with continuous improvement, means permanently questioning the way of doing things in search of possible improvements to meet expectations and to adapt to changes and needs that may arise (Furlan & Vinelli, 2018). It also allows the effectiveness of the innovation management process through the measurement of key performance indicators and the evaluation of the innovation management techniques used.

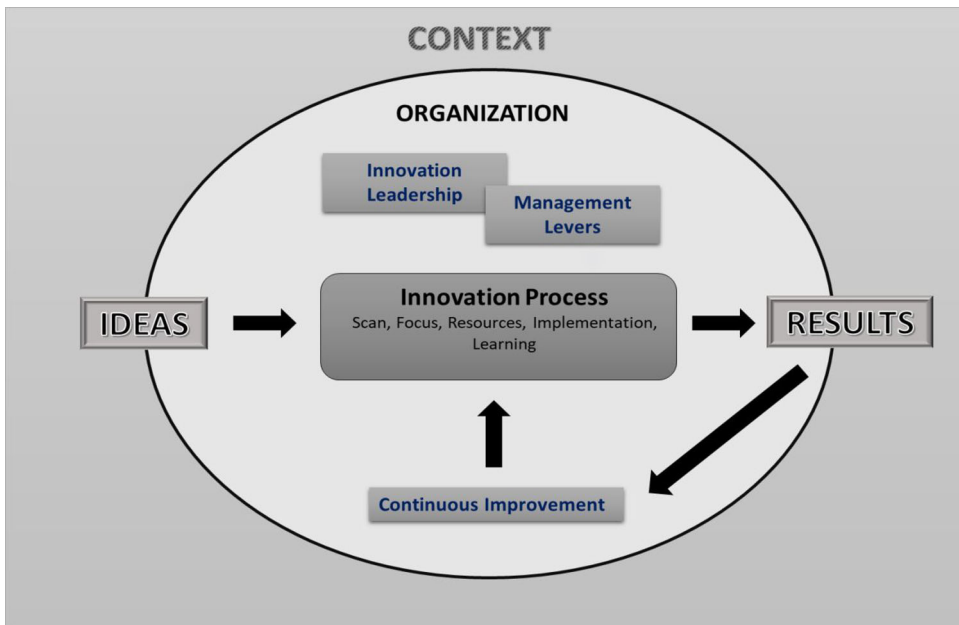


Figure 1. 5F3D innovation management model.
Source: Author's own elaboration.

Figure 1 shows the 5F3D model, where the factors of the innovation process are in the center and the determinants create the necessary environment to enable the innovation.

3. Research methodology

The methodologies of an existing theoretical framework and its comparison with the new hypotheses are not easily applicable in the current reality due to the dynamics of accelerated change in the business environment. For this reason, the research methodology used in this study is the case study, which allows the phenomenon of innovation in firms to be analyzed in a real context, using different sources of information, both objective and subjective (Darke et al., 1998). According to Yin (2003), the case study method is suitable for studying complex phenomena that must be analyzed together with their context, environment, or when there are a large number of variables and factors that significantly affect them. Since there is no well-defined theoretical framework on the management of innovation in the aeronautical sector, the case study should explore the existing situation upon which to base the research results to verify that the proposed theoretical model represents reality of an innovation management system in a leading firm in the sector.

The subject of this research is a reference firm in the European aeronautical sector. With the objective of analyzing the level of maturity of the innovation management processes of the firm, three indexes are defined: IPMI (innovation process maturity index), IOMI (innovation organizational maturity index), and IMDI (innovation management development index).

The innovation process maturity index (IPMI) aims to measure the development degree of the innovation processes and depends on the activities, frequencies, methods, and tools applied in the different phases of the innovation process. As the proposed 5F3D model to describe the innovation processes is composed of five phases (scan, focus, resources, implement, and learn), each phase is evaluated by the average values of their n -variables. The IPMI index is calculated using the following formula:

$$IPMI = \sum_{i=1}^n \frac{(S_i, F_i, R_i, I_i, L_i)}{5}$$

The innovation organizational maturity index (IOMI) aims to measure the maturity of the determinants (innovation leadership, management levers, and continuous improvement) that enables the innovation in the firm. Each determinant is evaluated by the average values of their n -variables. The IOMI index is calculated using the following formula:

$$IOMI = \sum_{i=1}^n \frac{(L_i, M_i, C_i)}{3}$$

To evaluate these variables in both cases, a Likert scale from 1 (minimum) to 5 (maximum) is used. The greater the value of the variable, the higher the degree of development of the innovation process.

The innovation management development index (IMDI) is the average of the previous indexes and indicates the global maturity level of the innovation management process of the analyzed firm. Aeronautical firms with a more developed innovation process show a greater value of IMDI. The formula for calculating the IMDI index is as follows:

$$IMDI = \sum_{i=1}^n \frac{(IPMI, IOMI)}{2}$$

The correlations made between the global index of the innovation process carried out by firms in the aeronautical sector (IMDI) with the indexes of the factors and determinants that constitute the model (IPMI, IOMI) are all significant, direct, and positive.

4. Empirical study and variables

To determine the applicability of the 5F3D model, a research instrument (questionnaire) was designed through the following steps: preparation of a draft based on the results of in-depth interviews with experts from the firm, initial testing, and correcting the identified problems to specific questions. The questionnaire was configured around a set of 58 questions with 50 variables distributed among the three determinants (innovation leadership, management levers, and continuous improvement) and five factors (scan, focus, resources, implementation, and learning) of the 5F3D model. [Table 1](#)

Table 1. Variables selected to evaluate the 5F3D model.

Determinants		Title	Activity (Ai)	Frequency (Fi)	IMT (MTi)
Innovation Leadership	L1	Innovation Activities	X		
	L2	Innovation Vision	X		
	L3	Innovation Strategy	X		
	L4	Innovation Culture	X		
	L5	Innovation Organization	X		
Management Levers	M1	Alignment between Strategic and Innovation Goals	X		
	M2	Innovation Roles	X		
	M3	Resources Allocation	X		
	M4	Skills and Competences	X		
	M5	Communication Channels	X		
	M6	Innovation Documentation Accesibility	X		
	M7	IP management	X		
	M8	Innovation Collaboration Policy	X		
	M9	Innovation Climate	X		
Continuous Improvement	C1	Innovation Indicators	X		
	C2	Innovation Results Communications	X		
	C3	Improvement Actions of IMS	X		
	C4	Innovation Deviation Identification	X		
	C5	Innovation Evaluation	X		

Factors		Title	Activity (Ai)	Frequency (Fi)	IMT (MTi)
Scan	S1	Market Intelligence Activities	X		
	S2	Technological Surveillance Activities	X		
	S3	Regulatory Oversight Activities	X		
	S4	Patent Analysis Activities	X		
	S5	Ideas Generation Activities	X		
	S6	Sources of Information			X
	S7	Market Intelligence Tools			X
	S8	Surveillance Tools			X
Focus	F1	Innovation Activities		X	
	F2	Ideas Selection Activities	X		
	F3	Ideas Generation Tools			X
	F4	Ideas Selection Tools			X
Resources	R1	Skills and Competences acquisition	X		
	R2	External Technology Acquisition	X		
	R3	Innovation Training Plan	X		
	R4	IP protection activities	X		
Implementation	I1	Development Innovation Activities	X		
	I2	Innovation Plan Techniques			X
	I3	Innovation Scope Plan Activities	X		
	I4	Product Innovations	X		
	I5	Product Innovations Frequency		X	
	I6	Proess Innovations	X		
	I7	Process Innovations Techniques			X
	I8	Process Innovation Frequency		X	
	I9	Market Innovations	X		
	I10	Market Innovation Techniques			X
Learning	I11	Market Innovation Frequency		X	
	I12	Organizational Innovations	X		
	I13	Organizational Innovations Frequency		X	
	A1	Learning Activities	X		
A2	Knowledge Capture Activities	X			

Source: Author's own elaboration.

describes the set of variables used to calculate the indexes, their classification in groups and their allocation, depending on whether it is an activity, frequency, or tool variable.

To calculate the IPMI index, 31 variables were used that are related to the innovation processes of the 5F3D model, based on the five phases of the innovation

processes: eight variables for scan phase (S_i), four variables for focus phase (F_i), four variables for resources phase (R_i), 13 variables for implementation phase (I_i), and two variables for learning phase (L_i). To calculate the IOMI index, 19 variables were used that were linked to the three determinants of innovation defined in the 5F3D model: five variables for innovation leadership (L_i), nine variables for management levers (M_i), and five variables for continuous improvement (C_i).

A beta test was launched to 113 people with the objective of verifying the functionality of the survey, and it was then targeted to a wider innovation population (377 people in the firm). This population were innovation managers or employees who had extensive knowledge in innovation and were able to answer the questions of the survey, which were sometimes difficult to understand if the person was not familiar with the concepts. Sixty answers (12.3 percent) from the total population of 490 were received and an Cronbach's Alpha value of 0.95 was obtained, meaning that the internal consistency of the research instrument and its reliability was excellent (Streiner, 2003).

To obtain a more in-depth qualitative view of the aspects related to the innovation management process in the firm, five in-depth interviews were conducted with five senior managers who had extensive experience in the management of innovation at a high level in the firm. The interviews lasted approximately one hour each and consisted of several open questions related to the factors and determinants of innovation. The purpose of these interviews was to find the opinion of these leaders about the proposed innovation management model and their ability to represent the reality of the firm in relation to innovation management. This included exploring the need to define weighting criteria for the different factors and determinants in order to consider the relative importance of each of them in the calculation of the indexed.

To complete all the information necessary for the case study, the following secondary sources from internal and external documents were used: innovation management policies, innovation processes description, market forecast and strategies, business plans, innovation annual reports, R&D strategy, roadmaps or golden rules for innovation management, and press release notes.

5. Results

5.1. Analysis of the innovation process maturity

The value of the IPMI index (3.39) indicates that the five phases of the innovation processes and activities from idea generation, development of innovation projects, and implementation are well established and managed. However, there is room for improvement, as reflected in the following statement from an interviewee: *'Innovation is when a product comes to a market/customer. Without a customer what we do is an invention but not an innovation. We are inventing a lot but not innovating enough; that is, we lack market results and value added to customers. Innovation ecosystem is dynamic but scattered. It lacks group-wide coordination and requires regular get-togethers'*.

The scan phase ($S_i = 3.73$) summarizes the global perception of employees on how the firm manages the market and technological intelligence surveillance activities, regulations, intellectual property, or idea generation. These ideas are selected in the focus

phase and the factor ($F_i = 3.80$) reflects that the instruments, methods, tools, and processes that the firm uses are quite efficient. There are specific departments responsible for these activities and programs aimed at processing ideas and managing portfolios. As the CIO of the firm stated, *'IdeaSpace is our common innovation platform for receiving, storing and processing all innovative ideas. Become inspired, post ideas, take part in the discussions and join the initiatives at IdeaSpace'*. The employees also perceived the good practices on these phases of the innovation process: *'We made a lot of progress in the recent years, compared to our state of practice ten years ago. Now, there are hackathons, contests, idea boxes (IdeaSpace), etc. I think strong drivers for the innovation are linked to digitalization (data science, artificial intelligence ...) but in the upcoming years it will certainly be related to green aviation and societal challenges'*. Figure 2 shows a visual representation of the ideas generation program.

The resource phase ($R_i = 3.24$) indicates that the firm has established processes to acquire external knowledge and technology, to train and develop the necessary skills and competences to success on innovation. The management of these resources is affected by budgetary restrictions that translate into lower performance in the development of innovation projects: *'We could be more innovative, but are hindered by the overall product policy and the fact that those who are not bold enough or unwilling to invest on program don't want to buy it. The cost of change is too high; therefore, the innovation is shelved'*. The implementation phase ($I_i = 3.28$) means that the firm has implemented management practices, planned new innovation developments using project management methods and tools, and developed product, process, and service innovations as a continuous process of generation, selection, development, and implementation of ideas.

Finally, the learning activities ($A_i = 2.88$) clearly show an improvement margin. There are no indicators to measure the effectiveness of innovation projects, the innovation managers do not have goals related to innovation, no activities are carried out in innovation projects evaluation and learning from previous experiences in a systematic way, and there is no procedure that allows the suppliers/clients to participate in the evaluation of innovation projects. In summary, once an innovation is implemented, the lessons learned in its process are not systematically incorporated into the management practices under which new projects are developed.

5.2. Analysis of the organizational innovation maturity

In relation to the determinant of leadership in innovation, the firm carries out numerous innovation activities, such as internal R&D, acquisition of new technology, machinery, and equipment, or the introduction of innovations in the market ($L_1 = 3.89$). The managers established an innovation vision and strategy that defines the objectives that the firm wants to achieve in the field of innovation and how to achieve it ($L_2 = 3.37$ and $L_3 = 3.17$), but employees do not perceive that they have communicated adequately within the organization. This is highlighted in the following statement: *'Not a clear strategy, neither enough budget and resources. No communication to other involved functions. Most of the time the decisions are based more on political reasons than on technical or financial'*.

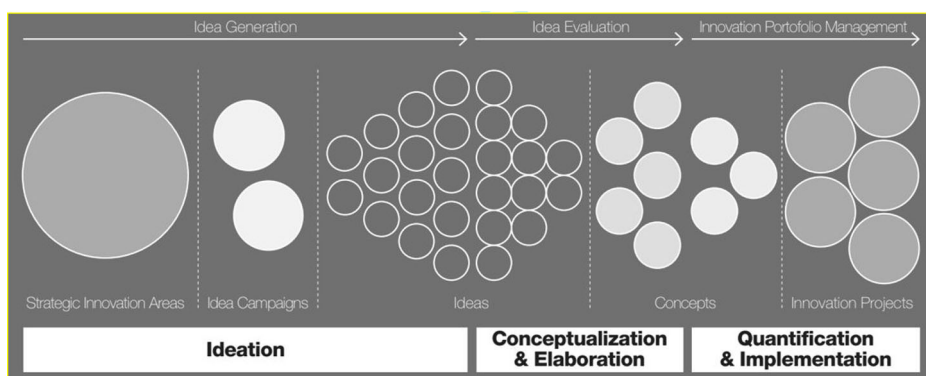


Figure 2. The ideas generation program applied in the case study firm.

Source: IdeaSpace – Corporate Innovation.

Leaders in innovation processes do well to promote a culture of innovation ($L4 = 3.58$), although possible improvements have been identified: *'The entire culture of innovation needs a boost so that everyone understands the need for their participation and contribution'*. They have also created an organization to which they have assigned the relevant roles and responsibilities and have communicated them within the organization ($L5 = 3.58$). However, some participants recognize that the organization of innovation is not well integrated into the overall strategy of the firm, which reduces efficiency and profitability: *'R&D is not well organized and the culture of innovation is not formally implemented in all levels'*.

The analysis of the determinant relative to management levers shows that the innovation strategy objectives are quite well aligned with the firm's strategy objectives ($M1 = 3.65$). Although it seems that the goals and strategy of the innovation are not clear enough and their communication could be improved, the employees perceive that the innovations generated in the firm contribute to the strategic objectives: *'Lots of independent storming, but unfortunately not always linked to our strategy that results in conflicting messages/signaling to customers/suppliers/institutions/public'*. The firm has defined and implemented the main responsibilities of innovation management to achieve the objectives ($M2 = 3.39$), although *'the engineer is only in contact with innovation when he has an idea that he thinks is worth patenting. There should be more initiatives based on a clear strategy for innovation. This strategy should involve all employees, as our internal knowledge is not yet exploited well'*. There is a clear lack of the resources, both human and financial, required for the design, implementation, maintenance, and continuous improvement of innovation management ($M3 = 2.95$), and the necessary skills and competencies in people who carry out innovation activities ($M4 = 3.15$). According to one participant, the *'lack of internal profession in the field of experts/management on innovation and, hence, lack of well-trained staff and experts'*.

The internal and external communication channels relevant to the innovation management process are defined within the organization ($M5 = 3.15$), but employees are not fully aware of them: *'It should be better implemented by linking the R&T department with the operational departments'* or *'innovation is in the firm DNA but not connected among the different departments. There is no visible/working link*

between market needs, innovation process, R&D and new development programs. Too many departments are based on different functions and centers of competences'. There is no official documentation accessible to the entire organization with the information about the innovation management process determined as necessary (M6 = 2.78). Some information is available on the intranet about innovation initiatives and organization, but not easy to access, not well structured, and not widely communicated.

There is an IP management policy within the organization that the employees know well and use to introduce new ideas (M7 = 4.05). New technology is confidential until the patent is filed; otherwise, the firm runs the risk of losing all its rights. There is a policy within the organization for internal and external collaboration on innovation (M8 = 3.53). When working with a third party, such as a university or a supplier, the employees must have a non-disclosure agreement (NDA) in place before there is any exchange of information or work starts. Any relevant deviation from the NDA must be agreed with the legal department. Finally, the innovation climate is defined as the perception of employees about innovation in the organization and it has been considered potentially improvable (M9 = 3.07): *'The whole culture of innovation needs a booster, so that everyone understands the need for her/his involvement and contribution'*. The firm intends to engage employees every day to bring new ideas. The firm offers them support through an innovation network, which is a program consisting of a rapid decision-making process and creative methods.

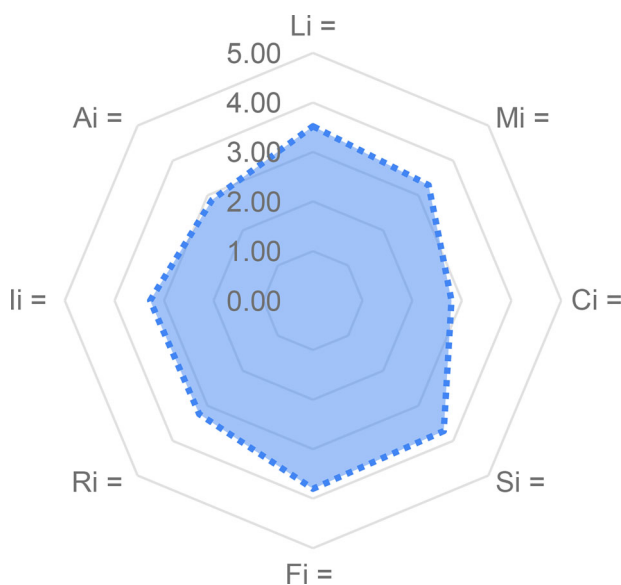
The analysis of the determinant relative to continuous improvement shows that the organization is trying to determine the indicators, methods, frequency, and criteria for evaluating the operation of the innovation management process (C1 = 2.91). These indicators cover the commercial value, the adjustment to the firm's objectives, the effort made, and the exploratory nature of the operations, but their definition is not complete. The use of key performance indicators is essential to monitor the innovation process. As Drucker (2012) said, *'what gets measured gets managed'*. The evaluation of the results of the innovation management process is not properly documented or communicated, which does not help the firm to improve its operation (C2 = 2.53): *'One of the main objectives in innovation is to learn. The main gaps that I have identified in recent years are the analysis and capture processes, lessons learned, etc., in innovation projects'*.

The organization has not yet implemented a process to continuously improve the adequacy, suitability, or effectiveness of the innovation management process based on the evaluation of its operations (C3 = 2.79): *'The lessons learnt loop closure needs to be strengthened and the KM needs to be systematically developed, in all areas'*. The firm is not capable of identifying deviations and establishing corrective actions to improve the efficiency and results of the innovation management process (C4 = 2.71): *'Sometimes it is hard to see if all initiatives are properly monitored and the outcomes are well captured and shared with others'*. Finally, the interviewees evaluated as poorly innovation management techniques that could contribute to the improvement of innovation management process (C5 = 2.98): *'Innovation today is like a hospital, subject to financial objectives. To innovate, you have to accept being wrong. To make a mistake is not serious; the main thing being to learn, and to capitalize. Innovation is learning from our past mistakes, and capitalizing on these mistakes, so as not to reproduce them. Therefore, a robust and user-friendly capitalization system is necessary'*.

Table 2. Determinants and factors variables results from the case study firm.

Leadership	Li =	3.52	Determinants
Managerial Levers	Mi =	3.30	
Continuous Improvement	Ci =	2.79	
Scan	Si =	3.73	Factors
Focus	Fi =	3.80	
Resources	Ri =	3.24	
Implement	li =	3.28	
Learn	Ai =	2.88	

Source: Author's own elaboration.

**Figure 3.** Radar chart of determinants and factors variables results from the case study.

Source: Author's own elaboration.

Taking these considerations into account, the innovation organization index (IOMI) has a value of 3.2. This result shows that the analyzed firm performance leads the innovation and creates the necessary environment that enables it. However, the use of the 5F3D model has made it possible to identify an important set of weaknesses to improve in order to increase the level of efficiency of the innovation management process. As a summary, Table 2 shows the results of factors, determinants, and variables for the studied firm.

According to Chambers et al. (2017), it is useful to show multivariate observations with an arbitrary number of variables using radar charts. Figure 3 shows the values of the factors and determinants, which allows the establishment of a comparative evaluation (benchmarking) of the innovation management with other firms in the aeronautical sector.

5.3. Analysis of the innovation management development

The innovation management development index summarizes the overall maturity of this process in the firm and helps to identify organizations that use best practices and have their most developed innovation processes. The value of the IMDI (3.29) shows that the firm has quite a robust innovation management process, but, as described

above, there is a potential margin for improvement in some of the factors and determinants that characterize it.

6. Conclusions

Since the 1990s, many traditional manufacturers of airplanes have disappeared, despite being successful in the past. Among the many explanations for this situation are the creation of noncompetitive products or good products at the wrong time. The particularities of the aeronautical sector linked to their products and services, together with the effects of globalization that lead to an increase of competition and the potential entry of new players in the market, will force traditional firms to develop new innovation management strategies in order to keep their leadership.

In this context, it is necessary to identify models that make it possible to analyze how companies in the aeronautical sector manage innovation processes and design strategies aimed at deploying available resources in an efficient way. The literature contains different models to explain the management of innovation in technology firms, but it also shows some gaps when applied to highly innovative firms such as aeronautics. In this context, and based on the analysis of different innovation models, the 5F3D model has been designed to evaluate the level of maturity of the innovation management in this sector.

The 5F3D model set up five organizational factors and three determinants that establish the reference framework to allow the evaluation and analysis of innovation management in aeronautical firms. From the application of this model to a reference European aeronautical firm, the main results obtained can be summarized as follows.

6.1. From the perspective of organizational factors

The analysis of the innovation process maturity index reflects that four phases of the innovation process (scan, focus, resources, and implementation) are well implemented, although there is a margin for improvement that must be analyzed by the firm. Nevertheless, there is an exception in the phase related to learning, which presents a lower level of development. The analysis highlights that learning from previous experiences is not incorporated in a systematic way in the innovation process. No indicators are implemented to measure the effectiveness of innovation projects, and there is no procedure that allows the suppliers and clients to participate in the evaluation of innovation projects. This factor highlights the need to make efforts to increase the level of learning at the organization level.

6.2. From the perspective of determinants

Innovation leaders play a relevant role in the innovation management process. They are the catalyzers of innovation and their decisions make the difference between success or failure of innovation. Nevertheless, in the firm the innovation leaders are constrained by the rest of the organization and their influence is limited to some key driver parameters, such as human resources, budget, schedule, or organizational changes. These limitations make it difficult to establish a well-defined innovation

strategy with clear objectives to achieve. The communication within the organization of these objectives is also affected by not being fully transmitted to the employees.

Management lever maturity is a direct consequence of the innovation leadership and shows a positive correlation with it. The innovation strategy is aligned with the global strategy of the firm, but the lack of influence of innovation leaders in the top management leads to a clear mismatch between the skills, competences, and resources (both, human, and financial) necessary to succeed at innovation. Top-level innovation communication external to the firm is well managed, but not so clear internally within the organization. Policy documents, innovation reports, and details of activities are either not easily accessible to the employees or sometimes even non-existent. However, the firm manages the intellectual property and intangible assets well within the organization and with external parties. All these results derive from a culture of innovation that, despite being perceived by the employees as existing, shows potential room for improvement.

Continuous improvement is the less mature determinant. The innovation indicators and management techniques are still under development, so there is no harmonized way to measure the efficiency of the innovation management process and results are not properly documented or communicated within the organization. Consequently, the innovation management process cannot be properly evaluated and improvements are not identified, so it is not continuously adapted and suited to the needs of the organization.

Finally, the limitation of this research is linked to the context that the results are obtained from one single source, even if this source is a reference of the aeronautical sector.

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