TECHNOLOGICAL CAPABILITY MODEL FOR INNOVATION MANAGEMENT FOR AEROSPACE ENTERPRISE

MODELO DE CAPACIDADE TECNOLÓGICA PARA GESTÃO DA INOVAÇÃO PARA EMPRESA AEROESPACIAL

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ABSTRACT

Globalization has amplified competition between companies and increasingly demanding its ability to stay ahead of its competitors who are located far beyond their city, region or country, and innovation has become essential for organizations not only to be leaders in their markets, but also to increase competitiveness and, above all, avoid its decline, a world -class innovation management process is essential. The objective of this research effort is to present a technological capability model for innovation managing for global companies that is adaptable to their realities and aimed at knowledge-intensive industries. To achieve this goal, the research method applied was action research, starting with the mapping of the literature to identify the most relevant studies, recognize the state-of-the-art, theoretical propositions and in a collaborative way with the participation of experts and professionals that act, directly or indirectly, in the innovations development; the model is co-creation under two evaluation perspectives: the first called technological functions that represent the main areas that have an impact on the success in evaluating strategies, planning, development, execution and in the innovations results in industrial companies and the second perspective that are the competence levels, which at the highest level strongly favor and support innovation in industrial companies, so that organizations can measure themselves, compare themselves with others and, through planning, achieve excellence. In addition, as the expected goal is to obtain an indicator called Innovation Technology Index (ITC index), as well as a tool that facilitates the application and its dissemination and, later, the applicability of concepts in the real environment of aerospace enterprises. The first findings demonstrate the ease of understanding and applicability of the model for companies to analyze innovation management and identify gaps to convert them into real opportunities to leverage their businesses.

Keywords: Innovation; Innovation management; Capability; Capacity, Technological accumulation.

RESUMO

A globalização ampliou a competição entre as empresas e exigiu cada vez mais sua capacidade de se manter à frente de seus concorrentes que estão localizados muito além de sua cidade, região ou país, e a inovação se tornou essencial para que as organizações não apenas sejam líderes em seus mercados, mas também para aumentar a competitividade e, principalmente, evitar seu declínio, um processo de gestão da inovação de classe mundial é essencial. O objetivo deste esforço de pesquisa é apresentar um modelo de capacidade tecnológica para gestão da inovação para empresas globais que seja adaptável às suas realidades e voltado para indústrias intensivas em conhecimento. Para atingir esse objetivo, o método de pesquisa aplicado foi a pesquisa-ação, iniciando com o mapeamento da literatura para identificar os estudos mais relevantes, reconhecer o estado da arte, proposições teóricas e de forma colaborativa com a participação de especialistas e profissionais que atuam, direta ou indiretamente, no desenvolvimento das inovações; o modelo é de cocriação sob duas perspectivas de avaliação: a primeira denominada funções

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tecnológicas que representam as principais áreas que impactam no sucesso na avaliação de estratégias, planejamento, desenvolvimento, execução e nos resultados das inovações em empresas industriais e a segunda perspectiva que são os níveis de competência, que no nível mais alto favoreçam e apoiam fortemente a inovação em empresas industriais para que as organizações possam se medir, se comparar com outras e, por meio do planejamento, alcançar a excelência. Além disso, como o objetivo esperado é obter um indicador denominado Índice Tecnológico de Inovação (ITC index), bem como uma ferramenta que facilite a aplicação e sua disseminação e, posteriormente, a aplicabilidade dos conceitos no ambiente real das empresas aeroespaciais. Os primeiros achados demonstram a facilidade de compreensão e aplicabilidade do modelo para que as empresas analisem a gestão da inovação e identifiquem lacunas para convertê-las em oportunidades reais de alavancagem de seus negócios.
Palavras-chave: Innovation; Innovation management; Capability; Capacity, Technological accumulation.

1 INTRODUCTION

The need for greater assertiveness in launching innovative products depends fundamentally on three factors: product focus, external analysis (supported by market analysis) and internal focus on the company's competitive advantages, these three pillars are essential for the success of new products launch as they become available on the market.

Innovation for economic development has become an increasingly important practice and challenge for industrial companies and public sector agencies in developing countries (Hang & Chen, 2021). Innovation is fundamental for companies to exploit changes in their environment and maintain a competitive advantage. Access to information and the ability to quickly use available resources are key enablers for in-company innovation (King et al., 2020).

Supply chains are a very important field of any organization, as an efficient and smooth supply chain increasingly plays a major role in the global company's growth. The ability to respond to customer demands is an important player in a globally competitive world, which is the company's focus on these days (Bhasin et al., 2022). In the forefront of supply-chain management we have Blockchain-enabled innovation throughout the export supply-chain would reduce uncertainties and risks related to products flows, information and finance, and support market growth via innovative supply-chain finance solutions (Natanelov et al., 2022).

According to Rozenfeld and Amaral (2006), the main forces that influence the competitive search for speed, efficiency and quality in the development of innovations are: the increasing markets internationalization, the increase in the diversity and variety of products, the product life cycle reduction, changing competition patterns between organizations and consumer expectations regarding quality and technology.

What makes companies competitive is their ability to develop and create products, services, or even adapt them according to the customer's needs, or new processes quickly and at a competitive cost. In this way, innovation is seen as a pressing need; the ability to continuously find opportunities for new products and markets and to develop more efficient processes to produce them is understood as crucial by companies (Robert, 1995).

Organizations contribute to the economic development of the region and the country, as they develop product and process innovations that aim to meet consumer needs. However, given the environmental problems faced in the new millennium, companies need to change the way they operate in the market, seeking to reduce adverse environmental impacts, as natural resources are finite, and pollution affects the environment and people's quality of life (Severo, 2024).

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Porter (1993) when studying international business and the theories that explained the company's internationalization defended the competitive advantage theory that for him the only way for companies to succeed in international markets is through innovation. Innovation does not mean being at the forefront of technological innovation, nor does it mean making large investments in technology, or even spending millions on product research and development. Innovation can appear incrementally and in trivial tasks, the small insights results, as stated by Porter (1993).

Of the many innovation definitions found in literature, some fundamental principles can be identified. Katz (2007) established the following innovation definition: "the generation, development and successful implementation of innovative ideas that introduce new products, processes and / or strategies for a company, processes and / or strategies to support companies to achieve their goals by creating. value for stakeholders, generating economic growth and improving life standards".

Zhang et al. (2022) present that there are two broad categories of technology innovation, product innovation and process innovation, depending on the type of innovative object. Furthermore, process innovation consists of cost-reducing innovation and quality improvement innovation. Regardless of innovation type all need a structured process that needs to be centered on the user and covers four main fields: consumer identity, market cultures, consumer patterns and mass mediated market ideology that supports products and services that are desired (Saragih, 2023).

Chesbrough (2003) covers the innovation process through two typologies, the closed or traditional typology and the open typology. In the closed model, successful innovations require broad and total control. Therefore, companies must generate their own ideas and develop, implement, take to the market, distribute, finance and maintain to the market according to life cycle planned.

The open typology (Open Innovation - OI) revealed a different way to think about innovation. The successful innovation today is considered more the actors network creation than individuals or organizations in isolation (Kimpimäki et al., 2022). At the firm level, OI implies that firms must leverage their internal inventions outside their organizational boundaries simultaneously by exploring existing ideas in a firm's external environment (Chesbrough, 2003). From this point of view, this model sees innovation as a cooperation network results not only punctual, but also offers knowledge, ideas and patents for the new products and processes generation that are existing in modern business environments (Wolf et al., 2022). In this sense, the government framework to support companies' innovations plays a catalytic role in this transformation that companies are facing (Uyar et al., 2024).

Considering that a high proportion of OI is seen as an important sustainability factor for survival in an increasingly competitive environment, it provides a new perspective on human behaviors and individual absorptive capacity to enhance open innovation capability leading to a virtuous cycle for organizations, as

OI within an organization focuses on the dissemination of new knowledge among employees in different departmental units. When the willingness to share knowledge with colleagues increases, new knowledge dissemination can be achieved (Chiu et al., 2024).

Ismail et al. (2018) show that many companies are satisfied with what works and, therefore, stop innovating; point out that a company's survival depends on its ability to stay ahead of the technological curve and embrace changes in order to be, and remain, competitive with the competition, and finally they address that no company will be able to keep pace with growth if it is not willing to do something radically new.

Additionally, Lee and Quifan (2021), who have experienced the innovation ecosystems of China and the United States, specifically in Silicon Valley, approach from the competitiveness perspective that widespread cloning, through the attack by imitating competitors, in addition to forcing companies to innovate forge the formation of tenacious entrepreneurs.

Innovation really goes hand in hand with entrepreneurship, or even, in interpreneurship concept, corporate entrepreneurship, since entrepreneurial inspiration is associated with the dimensions of skills, an attitude that positively affects innovative capacity and, mediated by this, influences innovative performance, which positively affects the human development index (Neto et al., 2022).

Contributing to this discussion, Bansal and Grewatsch (2020) understand more broadly how to obtain more assertive innovations, according to the authors' view, if companies want to develop truly sustainable products instead of starting with the specific customers' needs and short-term sales should focus on promoting long-term thinking around social and environmental trends that impact businesses and society at the same time. By doing so, companies not only anticipate future customers' needs, but can actively shape the future rather than simply reacting to the present.

However, innovating without agility is synonymous with not capturing the opportunities detected, losing protagonism or being surpassed by the competition; Feitor et al. (2005) emphasize the agility importance in companies, as they conclude in their study that the organizations success doesn´t depend exclusively on how much they know about the external environment, but how the company uses, leverages its internal resources to anticipate and satisfy the customers and market's needs.

The creation of an agile and interactive environment in companies with the involvement of stakeholders in the entire development process of a new product is essential in order to organize the decision-making process, giving leadership responsibilities and support functions to each sector at each stage of development transforming the great journey of development in this way all actors are active members of the Innovation process in enterprises (Setti et al., 2023). Furthermore, co-creation leverages the organization's competitiveness, as it involves the co-creation of knowledge (Bonamigo et al., 2023).

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Emphasizing the importance of management focused on innovation, Rozenfeld and Amaral (2006) address that success in generating innovation does not fundamentally depend on the geniality of professionals who work in this process or large financial contributions, and goes further "in the last few decades, successful companies and countries cases, with regard to the products development and technologies, have demonstrated that the process performance is directly impacted by the model and the adopted management practice".

Despite the uncertainty inherent to any innovation, it is possible to manage the products development in search of better performance and learning through a methodology aimed at innovation management (Rozenfeld & Amaral, 2006). Therefore, the capacity for innovation must be understood as a differential that, according to the management maturity level, will provide a greater competitive advantage.

Evolutionary models aimed at management are understood to be the processes development and activities set, of a repetitive nature, which guarantee a high success probability, in this way, it seeks to reach a level in which management practices are institutionalized in the organization, the which consistent execution no longer depends solely on the specific professionals attitudes (Kerzner, 2006).

Becker et al. (2009) expand the discussion on evolution models in management in which the authors define it as a levels sequence in an evolutionary way in discrete stages through criteria and characteristics that need to be fulfilled to reach a particular maturity level with the lowest level representing an initial state characterized by an organization that has few capabilities under the domain, the highest stage representing a fully mature conception, and between the two extremes there is continuous progress on the evolution path towards capabilities or process performance.

From this approach, it was possible to verify in the available literature from the scientific research bases, which concepts are related and which treatment approaches in a multidisciplinary dimension, in different cultures regarding the models of technological capacity applied in organizations with strong industrial dependence.

Regarding the research methodology it is classified as qualitative in the stages of the research process, being divided into two parts: the proposed model construction and its application, the first part is supported by qualitative interviews with experts (action research) under a semi-structured script of interviews so the model is built collaboratively with experts and, the second part, refers to practical application through data collection (questionnaire) together a company representative in the aerospace sector.

Through the collaborative participation of experts and professionals from different industrial sectors, who work directly on innovations in different fields of knowledge to support better understanding and deepening and direct co-creation in the construction of the technological capacity model intended for innovation management based on two central questions that involve innovation in practice and that guide this research effort: (i) Companies fail in their innovations, whether in their strategy, lack of capacity or in their results, (ii) Companies do not assess their own capabilities in managing innovations that prevent them from taking any coordinated action within the company.

In this research effort, we have developed a capacity model designed for innovation integrating many knowledge fields: manufacturing, production planning, research and development (P&D), strategic planning, purchasing, quality management, engineering, maintenance, technology and project management because it is understood the comprehensive view that innovation has within an industrial organization for academic and practical purposes.

The scientific objective is to extract data on the current state of manufacturing companies and their strategies that leverage innovation management to obtain the factors that enable potential success providing competitive advantages to enterprises. The practical objective of this work is to allow a company to systematically evaluate innovation management and reflect on its strategies broadly and systemically in order to contribute to the competitive advantage in the search for assertive innovations.

As a limitation of this research effort, it is intended to reach industrial companies and which are not considered startups and academic companies (spin-offs), which require a different approach for this reason is also out of scope to analyze and propose corrective and improvement actions together with the company that participated in the assessment to increase its level of technological competence in the face of the identified opportunities that will be done by its team according to their management.

This work has three contributions to the state-of-the-art being: (i) The first consists of the interaction of pre-existing concepts in the literature for the model design that aims to assess the capacity in innovation management in industrial enterprises, (ii) The second is a proposal for the elaboration of an indicator that can translate the level of innovation management capacity of organizations and provide the scientific community with a unique way of measuring technological capacity, which can also be extrapolated to other knowledge areas and, (iii)The third and final contribution will be to carry out the first evaluation of a aerospace enterprise that are extremely competitive market.

As expected results of this work, we can detail in: (i) Having the model defined through the methodological integration used; (ii) Have the indicator available in order to measure the level of innovation management capability; (iii) Have the tool to support the application of the concepts developed and; (iv) Result of the application, which demonstrates the reality of the companies participating in the evaluation carried out through the indicators developed.

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In this way, the problem solution that this research proposes to carry out begins with its identification represented by the research questions, later with the solution planning and finally the model construction and, later, its implementation, represented by the application in the field demonstrating the action-research cycles of this research effort.

The paper is structured as follows. Initially, we discuss the concepts that culminate in the models of technology capacity, as well as demonstrate the evolution in the academic environment. Next, we describe the way in which the model was built collaboratively with experts, its conceptual bases culminating in the model proposed. Next, the macro-processes and respective details are presented, which involve the company considered. The results presented in the model and in the first findings of the preliminary evaluation carried out in the case study are presented. Finally, we conclude with a discussion and proposals such as linear continuity of knowledge are proposed as future research.

2 LITERATURE REVIEW

2.1 THE RELEVANCE OF INNOVATION MANAGEMENT IN INDUSTRIAL ENTERPRISES

The need to carry out innovations by enterprises is reflected in the industrial research of technological innovation carried out by Instituto Brasileiro de Geografia e Estatística (IBGE), a Brazilian federal government institution, every three years, which is used for the development of public policies in order to promote Science, Technology and Innovation (ST&I).

The last published survey (IBGE, 2020), which continues the series started in 2000, had the participation of 116,962 Brazilian companies (public and private sector), followed by the participation of 17,171 Brazilian companies (IBGE, 2016) and the last survey analyzed had 17,479 Brazilian participating companies (IBGE, 2013).When evaluating the general product and process innovation rates and identifying the innovations that generated new products to the market or a new process for the respective sector in Brazil, such as, the innovations realization rate, it was found that it increased from 55.9% (IBGE, 2013) to 65.7% (IBGE, 2016) and the end to 67% (IBGE, 2020) so the companies are increasingly making innovations.

When analyzing the expenditures directed to the innovative activities in the Brazilian ecosystem of all companies that carried out innovations over the entire period, referring to the three surveys (Fig. 1), it is detected that there was a significant reduction in investments directed to the machinery and tools acquisition from 46.8% (IBGE, 2013) to 31.5% (IBGE, 2020) and, on the other hand, there was a significant increase in expenditure on internal Research and Development activities, from 29.8% (IBGE, 2013) to 37, 4% (IBGE, 2020), in this way, it can be understood that in this evaluated period and in the companies

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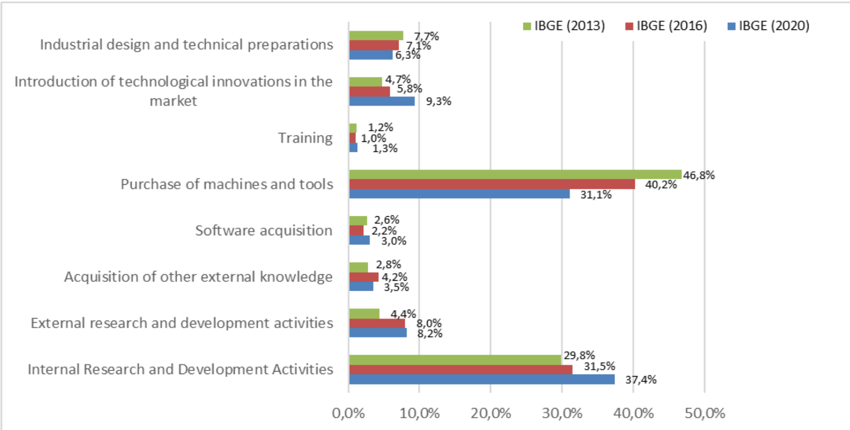
considered, R&D efforts are increasingly receiving financial resources and, therefore, being the main one of the innovation activities.

Figure 1 - Expenditure stratification used in the innovative activities in the industry of the Brazilian ecosystem (IBGE, 2013, 2016, 2020).



Source: IBGE (2013, 2016, 2020).

A broad benefit from the innovation projects is detected, not restricted to the company's permanence in the market by 81.5% of the companies; such as: increasing market share (68.4%), opening new markets (37%), improving product quality (80.1%), increasing productive flexibility (71,8%); compliance with new legislation (51.3%), labor costs and production reduction (58%) and lower raw material, energy and water consumption (52%).

The innovations are beneficial to companies and also to their employees. De Negri et al. (2005) carried out a survey with 72,000 Brazilian companies together with the Institute of Applied Economic Research (tab1), a Brazilian federal government institution. In it, the articulation of the Brazilian industry database focuses on innovation, technological standards, performance and its competitive strategies, instead the traditional company vision like size and economic sector. It shows that innovating and differentiating products is also extremely beneficial to employees. When comparing the companies that innovate and differentiate products with the ones that don't, they have a 23% higher remuneration, a higher education level (25.5%) and a greater average employment time (32%).

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Table 1 - Comparison of indicators for the Brazilian industry according to competitive strategies.

Competitive Strategy	Number of the companies	Participation in earnings of Industry (%)	Participation in employment (%)	Average billing (R$ million)	Worker Productivity (R$ *1000)	Average Remuneration (R$/month)	Average Education (years)	Average working time (months)	Salary award (%)	Average value Exports US$ million	Average value Imports US$ million
Innovate and differentiate products	1.199 (1,7%)	25,9	13,2	135,5	74,1	1254,64	9,13	54,09	23	11,4	12,01
Specializing in standardized products	15311 (21,3%)	62,6	48,7	25,7	44,3	749,02	7,64	43,9	11	2,1	1,8
Don´t differentiate products and lower productivity	55.495 (77,1%)	11,5	38,2	1,3	10	431,15	6,89	35,41	0	0	0,0024
Total	72.005	100,0	100,0								

Source: De Negri *et al.* (2005).

In addition to benefiting companies and their workers, policies aimed at innovations also provide considerable progress to countries that adopt them. Scientific and technological progress in China has provided the improvement of growth quality and efficiency in the last four decades of economic reform and opening through the innovation -oriented development strategy, to maintain the leading role in the future, there is already reflection for urgently needs to adjust the previous "Development Innovation Oriented" to "Innovation-led Development", with a focus on encouraging and supporting "lead innovation" and cultivate the market for these products as a public policy (Lin et al., 2018).

In order to understand the history and interaction of the themes that involve this work, since it is multidisciplinary, the research period was considered the publications between 2017 and 2021. For the bibliometric study, the keywords, theme of this work, or that is, innovation, innovation management, technological accumulation and capability/capacity (both used in English to demonstrate capability). When considering the articles existing in the two databases, therefore, without restriction of publication date were found 161 documents it was reviewed, among technical articles, government research and, when available, the most relevant citations.

The documents were processed by Patent Insight Pro software and 2200 keywords were found which after several refinements, for instance, consider repeated words, those with 95% of the same characters, achieved 250 keywords and even individual word analysis, that were removed from those not related to work, reached 79 main keywords; based on the network analysis, a statistical analysis between main keywords was performed. In Fig. 2 the associations among the most cited keywords in all articles analyzed can be visualized.

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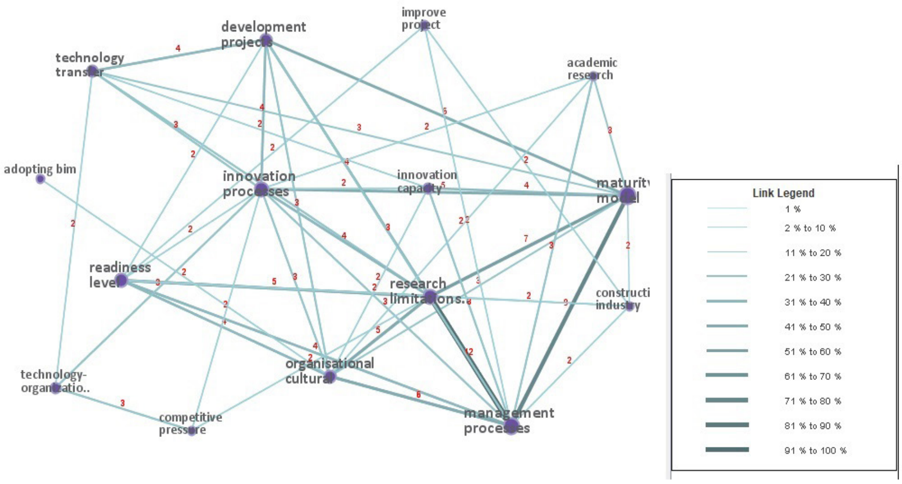
Figure 2 - Correlation diagram map among the 15 most relevant Keyword of all documents analyzed.



Source: Author´s elaboration.

Figure 2 demonstrates the establishment of a strong association between innovation capacity, process innovation and maturity model, which is also referenced to measure management capacity where the highest level has a greater probability of success in an institutionalized way in the institution, not depending on professionals, which adheres to the capacity level concept, also called readiness level.

There is also a strong association between innovation processes with project development, technology transfer, innovation capacity and organizational culture. Finally, a strong association is detected between project development with technological transfer, innovation processes and process management such associations evidence and reinforces the comprehensive view of this work, which involves innovation capacity.

Lawson and Samson (2001) recognize the innovation capacity as the business ability to extract knowledge from the balanced development of routine activities and the activities called innovative. This balanced development is determined by the following factors: vision and strategy, leveraging the company's core competence, organizational intelligence, managing creativity and ideas, organizational structure and systems, culture and climate, and technology management. Scientific studies highlight the critical importance of adapting skillsets to match the rapid technological advancements and complex demands of modern industry (da Silva et al., 2024).

Competence refers to the ability to coordinate and deploy an organization's resources to accomplish tasks (Delafiori et al., 2015). In this work, we use capacities to refer to a set of capabilities needed to design and implement innovations, which includes all activities from idea generation to delivering the product to the market.

The literature recognizes the hierarchical nature of organizational capacities and differentiates between first order operational capacities and second or high order strategic capacities, which are necessary to change operational routines (Zollo and Winter, 2002; Winter, 2003).

Strategic capacity is defined by Johnston (2009) as the set of capacities, resources and skills that create a long-term competitive advantage for companies. It is the ability to work towards a vision based on relevant value-added elements and a profit plan that strikes the right balance between taking advantage of short-term opportunities and long-term actions to achieve business sustainability.

There is a consensus in the innovation literature that linkages between key components such as technology development, R&D such as Research and Development, product and service creation driven by evolving customer needs will produce successful innovations (Berkhout et al., 2010).

The innovation capacity is understood as a dynamic capacity, as it brings together the company's skills that allow you to face changes in the face of the external environment generated by the extreme competitiveness provided by the globalized environment generated by the extreme competitiveness provided by the globalized environment through actions to adapt, integrate and adequately reconfigure organizational qualifications, resources and internal and external competences for the enterprises benefits and its stakeholders (Lawson & Samson, 2001). Few companies fully hold this competitive advantage of delivering innovations to the customer that exceed their expectations represented by achieving all the goals established when the innovation was planned.

The dynamic capabilities concept was initially proposed by Teece (2007) who defined them as the company's ability "to integrate, build and reconfigure internal and external competencies to deal with rapidly changing environments". This conception emerged in response to static assumptions of the Resource Based View (RBV) (Barney, 1991), considered inappropriate to understand how organizations could face the dynamism of their markets and the constantly changing demands of stakeholders (Bakker & Nijhof, 2002; Vargas & Mantilla, 2014). In this context, the dynamic capabilities theory can be considered an extension of the RBV, as it addresses the continuous improvement of resource configurations in the company, in the search for competitive advantages (Eisenhardt & Martin, 2000).

In the context of innovations, technological and market analysis capabilities are considered extremely impactful for the development and determination of new products; thus, these capabilities are not mutually exclusive and both need to be explored during the development of innovation (Dougherty, 1992; Danneels, 2002).

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According to Ellonen et al. (2011) there are four main components that complement each other for market analysis capability. First, understanding market needs and important actions to be collected and processed by knowledge in order to satisfy existing customers and potential new ones. Second, companies need to be able to satisfy their customers' needs by offering appropriate products and services. The third point is the focus on customer relationships, which means the ability to identify and serve groups building customer loyalty and finally communicating with customers implies the ability to communicate and use appropriate communication channels.

2.2 TECHNOLOGICAL CAPACITY ACCUMULATION MODELS

Bibliographic research demonstrates the efforts made to develop a model in which a company's technological capabilities are categorized by functions.

The evaluated models converge, in theory, that accumulation proceeds from the simplest to the most complex categories, being always accumulative throughout its existence. This metric was developed by Lall (1992), later refined by Bell and Pavitt (1993, 1995) and finally adapted by Figueiredo (2001, 2005, 2009), who developed studies aimed at the steel industry regarding the capacity accumulation technological rate, which was based on the activities that the company is able to perform throughout its existence, these are identified in basic functions with seven capabilities levels from the simplest to the most complex, called innovative.

Bell and Pavitt (1993, 1995) formulated a broad definition according to which technological capability (TC) incorporates the resources needed to generate and manage technological change. Figueiredo (2005) complements that such resources accumulate and are incorporated into individuals (such as aptitudes, knowledge and experience) and to organizational systems which led to the four-dimensional perspective on the concept: physical system, organizational system, individuals' minds and finally products and services.

The technological capabilities accumulation matrix is a company level approach that allows identifying the different technological economy sectors and the speed with which they accumulate technological capabilities over time, as well as distinguishing the most dynamic sectors and companies from the slower ones, and thus, programming differentiated measures and incentives for the different sectors, with the purpose of promoting the development of technological capacities, in countries with late industrialization (Figueiredo, 2001, 2005, 2009).

The model proposed by Lall (1992), was the basis for an assessment of the accumulated degree of the TC of the organizations. It was developed with three degrees of complexity according to the formality

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and purpose of the technological efforts, considering investment, production and relationship dimensions with the economy, being:

- Basic level - capacities accumulated through the basic routines of the production activity, that is, by-doing mechanisms. Training is necessary for companies to keep operating.
- Intermediate Level - capabilities built through activities or efforts conducted on a more deliberate basis. This training enables companies to improve the execution of improvement of the technology in use. It consists of the ability to find solutions whose performance must be superior.
- Advanced Level - capabilities that represent a higher level, in which the company should not only do better, but mainly do different, evolve or create new technologies.

In this concept Lall (1992) makes it possible to distinguish operational capability from innovative capability. Operational capability is considered synonymous with the expression know-how, which indicates that knowledge and experience are accumulated to use technologies transferred by other companies / sectors / markets; acquired by-doing efforts that constitutes a technological capability of lower aggregate complexity level. Innovative capability is understood as the knowledge, experience and capacities to understand the technology principles, and can be considered a synonym of the term know-why - its level of complexity is greater.

Lall's matrix (Lall, 1992), presented in Table 2, covers technological capacity and was constructed according to three major functional dimensions: investment capacity, production capacity and connection with other agents. Capabilities are segmented into three complexity levels: basic, intermediate and advanced, namely:

▪ Investment Capacity: Describes qualifications in planning and executing investment, considering pre-investment analyses and controls and project execution activities (Lall, 1992 as cited in Gallina & Fleury, 2013).

▪ Production capacity: Related to the basic qualifications of quality control operations, preventive maintenance, and process technology assimilation (Lall, 1992 as cited in Gallina & Fleury, 2013).

▪ Liaison with other agents: Relates the company's qualifications in relating to external agents in order to obtain, exchange, transfer and develop technologies (Lall, 1992 as cited in in Gallina & Fleury, 2013).

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Table 2 - Lall's Technological Capabilities Matrix.

			Functional Dimensions					
			Investments		Production			Connect with partnes
			Pre-investments	Project Execution	Product Engineering	Process Engineering	Industrial Engineering	
Degree of Complexity	Basic	Simple Routine (based on experience)	Technical-economic feasibility study	Construction	Reverse Engineering	Quality Control	Studies of working methods and times	Local procurement of goods and services
			Local Selection	Auxiliary services	Minor adaptations to market needs	Preventove Maintenance	Inventory control	Exchange of information with suppliers
			investment schedule	Equipment installation		Process technology assimilation		
				Commissioning				
	Intermediate	Adaptive Duplicable (search based)	Technological source search	Equipment purchase	Product quality improvement	Licensing of new technologies	Productivity monitoring	Technology transfer from local suppliers
			Supplier contract negotiation	Detailing, recruiting and training the team	Modification of products purchased through licensing	Adaptation of processes and cost reduction	Improved process coordination	Relations with technology and innovation institutions
			Information Systens					
	Advanced	Innovative (based on Research and Development)		Basic process design	Product Innovation *In house*	Process Innovation *In house*		Licensing proprietary technologies to third parties

Source: Lall (1992).

In Bell's (1997) model, the development of companies' technological capacity occurs in an accumulation process over the years in a gradual trajectory of new technological capacities acquisition, as shown in Figure 3, which illustrates the proposed model; the author splits the types of technological competence into four levels, namely:

- Skills to use and operate existing technologies, being the simplest level,
- Skills for incremental improvement of products, processes and organizational,
- Skills to copy, implement and develop existing technologies,
- Skills to develop and implement new technologies, this being the most advanced level.

The ladder steps show the evolution level for the technological competence types over the years, which is expanding and accumulating until reaching a maturity level represented by the curve identified as "accumulated technology competence" whose reference is identified by the line " international technological frontier" (Figueiredo, 2001).

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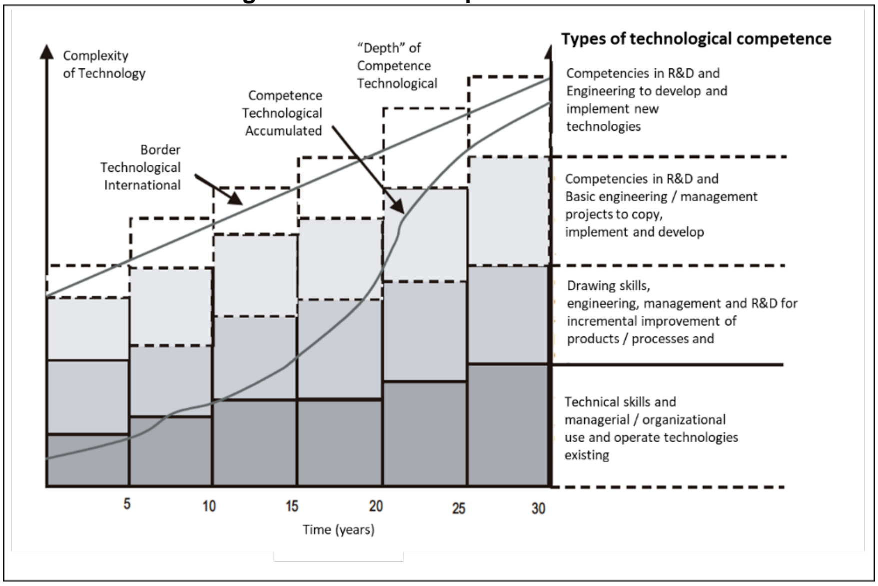
Figure 3 - Evolution steps of Bell's model.



Source: Bell (1997).

The model proposed by Figueiredo (2001, 2005, 2009) allows us to measure the accumulation of TC based on activities that the company can carry out throughout its existence. It is possible to distinguish between routine capacities, the ability to use or operate certain technology and innovative capacities, it is possible to adapt or develop the functions: new production processes, organizational systems, products, equipment and engineering projects, i.e., generating and managing technological innovation being world references, divided into seven capability levels, the most basic (level 01) and the most advanced (level 07).

It is important to note that in this model capability levels are cumulative, so being at a given level means that there is a mastery of the previous levels requirements. This model does not assume a linear sequence for evolution or that the capacities are constructed at the same time and at the same speed for the different functions, however, some levels are imprecisely and generically described as level 07 (advanced), for example, "world class management", "world class production", "world class engineering" among others as we can see in figure 4 that can be found the details on the most advanced level.

Other researchers have also built descriptive accumulation models in stages, such as Sato and Fujita (2009) whose model considers the functions of planning, production and marketing. The planning functions include market research and product concept development according to market needs. Production was subdivided into related equipment functions: input processing operation, maintenance, design and production of equipment and machines. Production management encompasses the

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organization of production activities efficiently to achieve performance goals. Finally, Marketing focuses on designing market products that strengthen relationships with customers and explore new markets (Sato & Fujita, 2009).

Fig. 4. Figueredo's model cutout, details of the most advanced capability level.

Technological Functions and Related Activities						
Levels of Skills Technological	Investiments		Processes and Organization of production	Produtcs	Equipments
	Decision and Control over the Plant	Project engineering			
(7) Advanced	World class project management. Development of new systems production via R&D.	World-class engineering. New process designs and R&D related.	World-class production. Drawings and development of new processes based on Engineering and R&D.	Design and development of products in world class. Original design via Engineering, Process and R&D.	Equipment design and manufacture worldclass. R&D for new equipment and components.

Source: Figueiredo (2001).

The technology capability concepts have been the studies subject in several areas and applications in the most economy sector, i.e.: in the agrifood industry companies (De Mori et al., 2016), mobile phone industry in China (Jin & Zedtwitz, 2008), to create competitive advantages in digital companies (Čirjevskis, 2019), associated with open innovation (Lam et al., 2021), application for R&D activities in small and medium enterprises (Davcik et al., 2021), in offshore manufacturing (Garcia et al., 2021), for healthcare organizations (Loureiro et al., 2021), for government management (Kim et al., 2022) and in higher education (Ghardashi et al., 2022); thus, in addition to the increase in publications involving technology capability models, there is also greater dissemination in several knowledge fields.

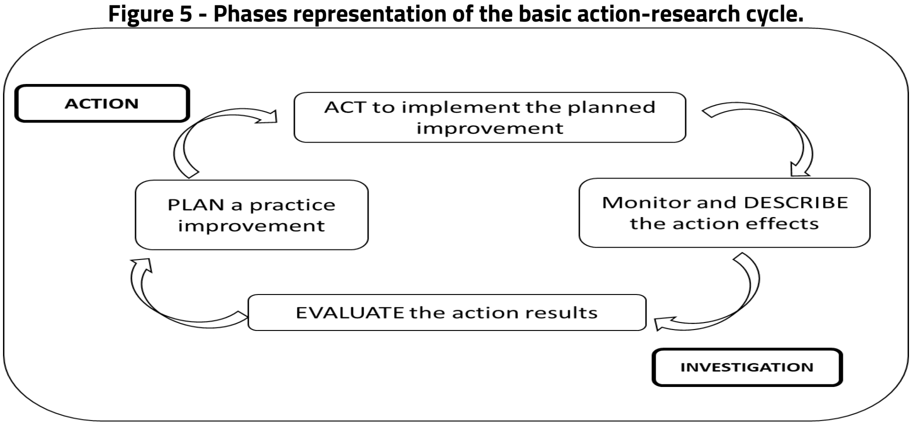
3 RESEARCH METHODOLOGY

This work has a broad view on the innovation influence in industrial companies under the prism that it is essential and ensures the competitiveness and the long-term growth in business and is one of the main levers for profitability and increasing growth.

As for the methodological approach and procedure, it is classified as qualitative in the stages of the research process, being divided into two parts: the proposed model construction and its application, the first part is supported by qualitative interviews with experts (action research) under a semi-structured script of interviews so the model is built collaboratively with experts and, the second part, refers to practical application through data collection (questionnaire) together a company representative in the aerospace sector.

According to Tripp (2005) action-research is a process that follows a cycle in which practice is improved through the systematic oscillation between acting in the practice field and investigating it. It is planned, implemented, described and evaluated to improve its practice, learning more, in the process course, both about the practice and the investigation itself (Fig. 5) and goes further by highlighting that action- research has been a participatory method since its origin which is adherent to the development of this work in which the model will be built collaboratively as well as its practical application in the real company environment.

Figure 5 - Phases representation of the basic action-research cycle.



Source: Tripp (2005).

To achieve the proposed objective, the research procedure used in this work can be divided into five distinct phases (fig. 6). An initial phase creates a thorough understanding of the product development process fields through systematic literature search for a model structure that is practical and applicable to the reality of aerospace companies.

In carrying out extensive bibliographical research, the thematic keywords associated with this work were used as initial reference: Innovation, Innovation Management, Innovation Capacity and Technological Accumulation.

To ensure academic relevance, we limited the bibliometric research of this work to the availability of full-text articles from peer-reviewed journals, containing online databases published in the last 5 years (2017-2021) in the Web of Science and Scopus databases, the data were processed using Patent Insight Pro and Endnote software.

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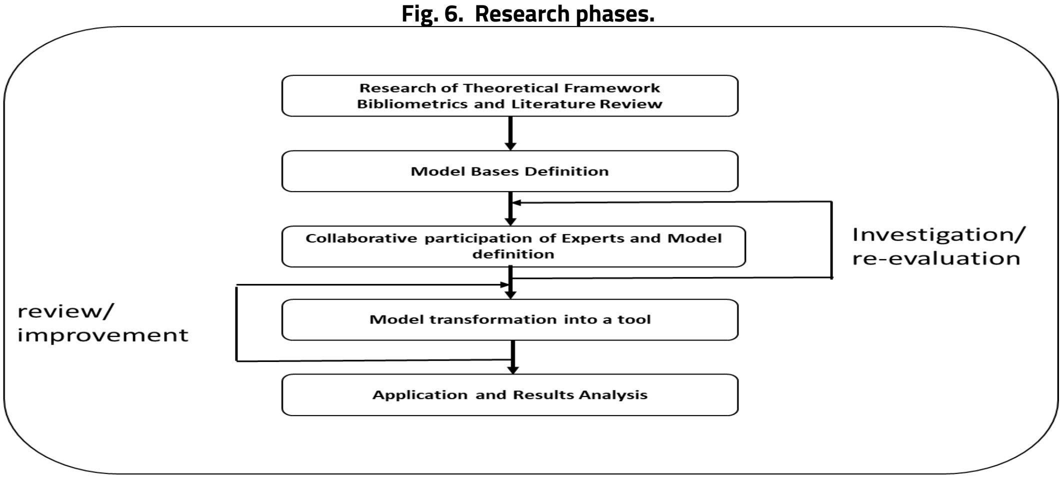
Fig. 6. Research phases.



Source: Author´s elaboration.

As the theme of this research effort is multidisciplinary, the research of the theoretical framework provided the conceptual bases identification to be used and that will permeate all the work that identifies the second phase as: (i) According to the capacity accumulation theory, functions process from simple to complex, (ii) Are cumulative, (iii) Does not assume linear evolution and, (iv) The levels are not reached at the same time and at the same speed for the different items of the dimensions considered.

In the third phase, collaborative development is carried out in order to validate the contribution importance of the items to be considered. Interviews were carried out, with the support of a semi-structured script, with forty-nine specialists from many industrial sectors who work in medium and large companies in the industrial sector (over 100 employees); does not apply to professionals who work in startups, newly created and emerging companies in the development phase, and academic spin-offs, micro-enterprises newly derived from universities.

The research participants work directly on innovations in the most diverse knowledge areas as: manufacturing (28% of participants), engineering and technology (24% of participants), research and development (R&D) (21% of participants), quality (14% of participants) production planning (10% of participants), strategic planning (3% of participants) in order to support a better understanding and deepening of the theme and to guide the model construction based under two drive questions that involve innovations in practice: (i) Companies fail in their innovation processes with regard to the industrial sector in the development of products and/or processes, due to capability lack or even of its results; and (ii) Companies do not assess their own resources in the process of developing innovations that prevent them from taking any coordinated action.

Appendix 1 presents a semi-structured script of interviews with some questions related to the objective of each investigation, based on the presented research questions.

After the discussions with the specialists made it possible to congruence the themes that have a direct influence on the innovations based on the initial concepts list obtained through the bibliographic research, in this research process and reassessment, it occurred cyclically caused by the discussions and evaluations that occurred.

Based on the defined technological functions, the requirements that define each complexity level were recommended, taking into account that the purpose of this work is to develop a generic model aimed at industrial companies whose objective is to be able to assess the technological capacity in innovation management; an indicator was also developed to quantify the technological capability level, through the interaction of the technological functions considered, called Innovation Technology Capability Index (ITC Index).

The indicator aims to demonstrate technological capacity based on the concepts of Lall (1992), Bell (1997) associated with the seven levels of accumulation proposed by Figueiredo (2001), however, directed at innovation management and through the interaction of the technological functions considered will result in the ITC Index.

The indicator (ITC Index) is calculated from the polygons area ratio, coming from the company evaluation under the model divided by the maximum possible area, in this situation when the enterprise reaches the maximum grade in all sixty-three assessment items. The index is evaluated between 0 (lowest possible value) and 100% (maximum possible value), finally a color scale that positions the company in view of the state-of-the-art is also presented.

The fourth phase is identified by model transformation into a tool that aims at practicality in the application through information consolidation, historical storage, automatic indicator calculation and that also supports the model dissemination. Transforming the model into a tool is a cyclical action process, revision and improvement in order to provide a user-friendly tool.

In the fifth and final phase, the model is applied in the real environment of an industrial enterprise through the questionnaire application and supported by interviews. The objective is to assess the level at which the company is for all technological capability functions defined according to the criteria developed.

4 RESULTS AND DISCUSSIONS

As expected, results of this research effort, we can detail in: (i) Have the model defined pointing out that the proposed methodological integration has a relevant result through the evaluations received by the specialists called "The Technology Capability Model" and; (ii) Application result, which shows the reality of the company participating in the assessment carried out using the indicator developed that will be presented in the next section.

4.1 THE TECHNOLOGY CAPABILITY MODEL (TC MODEL)

The first result of this research effort is the model with the objective of measuring the accumulation of TC based on the activities that involve the management innovation management that the company is able to carry out throughout its existence. The model presents seven cumulative levels of innovation management capacity, classified according to Figueiredo's model (Figueiredo, 2005) where the competence level goes from level 1 (basic) to level 07 (advanced), with levels 1 and 2 being considered "business routines", between levels 3 and 5 are considered "innovative" and levels 6 and 7 are considered "super innovative".

The technological functions of the model are classified as: (i) investments, (ii) production process, (iii) equipment, iv) activities related to the product and (v) innovation management. Several knowledge areas are covered by the technological functions considered (tab.3); sometimes the same knowledge area can influence different technological functions, as the approach is different, such as, quality, as it interferes with the quality of project deliveries (investments), quality control in the production process (production process and organization) equipment capability (equipment) or even quality management (Product Related Activities).

Table 3 - Knowledge areas considered in the model by technological functions.

Technological Functions	Knowledge areas covered
1. Investments	Engineering, construction, financial planning, project management, project execution, R&D, quality, process management.....
2. Production process and organization	Production engineering, Manufacturing; Process Quality Control; Mass flow balance, Maintenance, Continuous process improvement, quality management...
3. Equipment	Procurement Management, Supplier Management, Total Produtive Maintenance, Capability Management...
4. Product Related Activities	Sustainability, Product Life Cycle, Quality improvement and maintenance (PDCA, SDCA), consumer complaints management, Quality Tools...
5.Innovation Management	Innovation process, ESG Manamement; Market analysis and research, Resource Management, Customers Relationship, Open Innovation development; Stratigic planning, Stakeholder Management…

Source: Author´s elaboration.

The following (fig. 7) is a summary of what is expected for each level according to the TC model for the innovation management proposed in this work according to technological functions cited in table 3. The classification is based on the analysis of the following criteria: engineering, financial planning, project management, market analysis, governance, product development process, manufacturing process, ESG management, quality, metrics, measurement and results achievement, failure analysis and establishment of continuous improvement process for innovation management.

It is important to make it clear that it is understood that the developed model is open to future improvements and adaptations, being the starting point for further studies involving the innovation management capacity, there were incredible and profound discussions to achieve what is presented in fig. 7, for example, at level 03 of the "Product Related Activities" function, and the company is necessary to have completely analysis of the product life cycle regarding the main impacts on the environment in each phase: design, manufacturing, distribution, customers, end of life/disposal. Quality control should be systematically done preventively with the actions support to eliminate frequent deviation causes with specific forums for analyzing quality complaints and possible product correction actions, extending packaging, if necessary, also with supplier's support.

Another example is the level 04 of the "Innovation Process" function, where the company's ability to establish the relationship with Technological Centers and Innovation (CT&I), Start Ups, Spin Off in order to extend its innovations beyond of their physical source makers performing open innovation and as level 07 the existence of the continuous improvement cycle of the innovation process through assertiveness in meeting all goals that support the launch of innovations obtained through improvement actions obtained from those " Lessons learned "from previous innovations, it is important to make it clear that it is not being proposed which indicators the company should define, but that those that have been proposed are achieved.

Fig. 7. Technological Capability Matrix for the Aerospace Enterprises.

Technological capability for Innovation Management					
Technological Competence Levels	Technological Functions				
	Investments	Production process and organization	Equipment	Product Related Activities	Innovation Management
ROUTINES				ROUTINES	
(1) Basic Routine	Initial project preparation. Synchronization of construction works and installations.	Routine coordination in the factory and absorption of the productive capacity of the plants.	Equipment Installation for production with local suppliers without selection/approval criteria	Quality control in the production process by inspection by people dedicated to the Quality area. Consolidation of consumer complaint results.	Innovation process flow not established. Product definition, non-formalized team to develop innovations. Scattered initiatives and dispersed support areas without priority for the demands of innovations. New product launches without market assessment.
(2) Renewed Routine	Routine factory engineering services, undetailed scope and uncontrolled lead time.	Improved Factory Coordination. Implementation of basic quality tools (such as 5S, action plan, see and act). Use of Computerized and Management System.	Installation of equipment for production with local suppliers with selection/approval criteria and performance measurement.	Quality control carried out systematically by the operators of each equipment with immediate corrective actions to correct deviations. Analysis of the results of consumer complaints with the elaboration of actions to eliminate the causes.	Formalized cross-functional team (also matrix) for each innovation project with clear and direct support. Clear and defined innovation process flow. Prioritization of innovations by subjective criteria ("feeling").
INNOVATIVE				INNOVATIVE	
(3) Extrabasic Innovative	Project planning. Feasibility study of financial return. Detailed investment scope. Schedule tracking (Gantt) of major events only (not detailed).	Small adaptations and intermittents in production processes in factories. Consolidation of basic quality tools and implementation of new management techniques and advanced quality tools (green belt...). Specific forums for the analysis of quality complaints and possible corrective actions in the production process.	Equipment Installation for production with local suppliers with selection/approval criteria and performance measurement with corrective and emergency maintenance supported by plant team. Delivery of maintenance plans from suppliers/backup of software and parts list for inventory.	Have analysis of the product life cycle management for the main impacts on the environment at each phase: design, manufacturing, distribution, customers, end of life/disposal. Quality control carried out systematically preventively with the support of actions to eliminate frequent causes of deviation. Specific forums for the analysis of quality complaints and possible corrective actions in products, packaging, suppliers...	Innovations launch based on qualitative research. Financial study of feasibility for the support of innovation. Detailed scope and connected with supplier networks.
(4) Pre-intermediate Innovative	Basic engineering in expansions technically assisted with the technical team: engineering, maintenance and R&D. Execution of projects with the support of a detailed schedule.	Systematic expansion of production capacity, major adaptations. Use of tools to promote work safety, environment and factory performance.	Installation of equipment for production with local and global suppliers with selection/approval criteria and performance measurement with preventive maintenance supported by plant team and autonomous maintenance. Delivery of maintenance plans from suppliers/backup of software and parts list for inventory.	Quality control support through consistent plan of PDCA (quality improvement) and SDCA (quality maintenance) associated with the results of consumer complaints.	Launch of innovations based on qualitative and quantitative research. Prioritization of innovations with subjective criteria. Flow defined. Product breakdown and packaging. Relationship established with ST&I, technology hubs, start-ups, spin-offs in order to carry out Open Innovation.
(5) Intermediary Innovative	Detailed engineering for hiring support. Integration of scope, cost, and schedule. Provision of technical assistance, analysis of resources (internal and external).	Continuous process improvement. Implementation of an integrated management system for the entire factory. Implementation of autonomous maintenance by the operator.	Installation of equipment for production with local/global suppliers with selection/approval criteria and performance measurement with preventive maintenance supported by plant team and autonomous maintenance. Agreed theoretical and practical training and capacity building plan and with verification of practical learning.	Support of quality control through consistent PDCA (quality improvement) and SDCA (quality maintenance) plans associated with the results of consumer complaints, supported by direct actions of internal and external stakeholders of the production process.	Launch of innovations based on a marketing plan and structured product planning. Objective criteria for the approval of innovation. Have a defined innovation flow (such as innovation funnel, stage gate, ...) for prioritization and evaluation through pre-established criteria. Detailing and minimum control of scope, time, cost and risk of innovations.
SUPER INNOVATIVE				SUPER INNOVATIVE	
(6) Upper Intermediate Innovative	New processes designed with support from R&D and suppliers based on clear sourcing and supplier validation requirements. Project scope, schedule, cost, time, stakeholders, risk, and communication management. Control over investments.	Total Operating System Consolidation. Engagement in continuous improvements by the Operation. Innovative improvements in processes with the support of the technical and operational team.	Installation of equipment for production with local/global suppliers with selection/approval criteria and performance measurement with preventive maintenance supported by plant team and autonomous maintenance. Agreed theoretical and practical training and capacity building plan and with verification of practical learning. Elaboration of Hand Over plan between suppliers and plant operation.	Support of quality control through consistent PDCA (quality improvement) and SDCA (quality maintenance) plan with quality tools of intermediate levels (green belt) such as Ishikawa diagram, pareto diagram, correlation diagram, prioritization, 5W2H, associated with the results of consumer complaints of the products supported by internal and external stakeholders.	Launch of innovations aligned with strategic planning and supported by competencies. Evaluation of the consistency of innovation deliveries compared to what was planned, with financial and non-financial goals. Environmental, social and corporate governance (ESG) practice with the network of suppliers of inputs, raw materials and packaging associated with the management of innovations.
(7) Advanced Innovative	Evaluation of the consistency of the project after one year delivered: financial, quality (deliveries made), lesson learning with feedback on future projects.	Reference in design and development of new processes supported by R&D / engineering and quality through improvement works stabilized at six Sigma level.	Installation of equipment for production with local/global suppliers with support of R&D technical areas with selection/approval criteria and performance measurement with achievement of the agreed performance targets. Preventive maintenance performed directly by the equipment operators. Hand over plan fulfilled. Improvement actions for upcoming projects based on the "lessons learned" approved by the committee and incorporated into future innovations.	The quality control achieved at the six sigma level achieved with the support of advanced quality tools (black belt) such as: Reaction Map, DOE (Experimentation), (EVOP) Evolutionary Operation, for fine-tuning to achieve the reliability of six sigma levels of quality acceptance.	Existence of the continuous improvement cycle of the innovation process. Assertiveness in meeting all the goals that support the launch of innovations obtained through improvement actions obtained from the "lessons learned" of previous innovations.

Source: Author´s elaboration.

4.2 THE CASE-STUDY: AEROSPACE ENTERPRISE

In this section we present the model application based on a real case study in the aerospace enterprise.

To apply the model, Brazilian manufacturing companies with relevant roles in the aerospace ecosystem and expressive innovation activities development were chosen and in order to represent the application, two companies with different profile from the same ecosystem will be presented.

Both enterprises were registered in the Aerospace business catalog which was developed by the Institute for Promotion and Industrial Coordination - *Instituto de Fomento e Coordenação Industrial* (IFI) an institute within the structure of the Department of Aerospace Science and Technology - *Departamento de Ciência e Tecnologia Aeroespacial* (DCTA) of the Brazilian government.

The IFI role as a link between Brazilian institutes and industry. Their mission is to foster, coordinate and support activities and endeavors aimed at the development and consolidation of the aeronautical and

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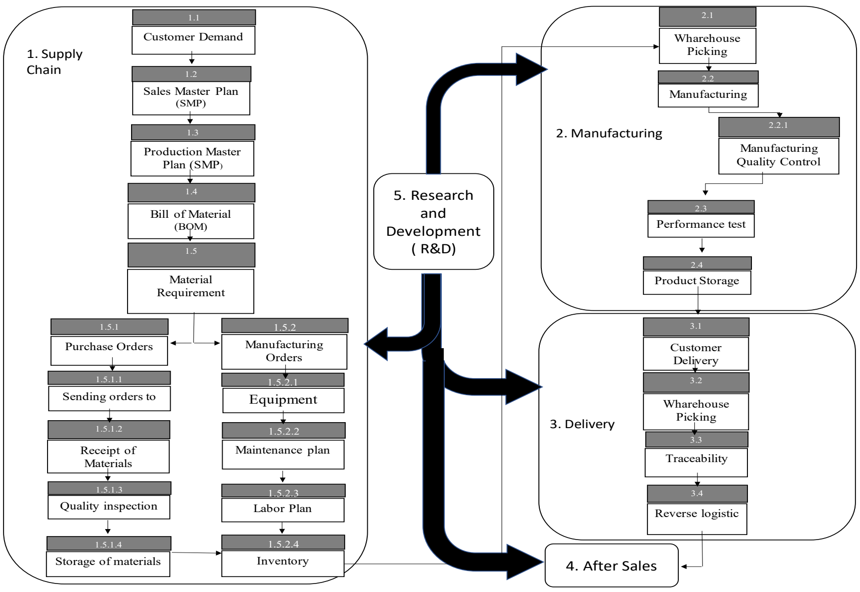
space industries in Brazil. It conducts certification / validation and metrology activities in the aerospace industry and technically and legally supports the transfer technologies generated from the institutes to the industries.

The Aerospace Business Catalog (IFI, 2018) demonstrates the company's relationship which are in the Brazilian territory and have the capacity to develop high tech reliable products.

The company that participated in the research has a global presence and is headquartered in Brazil. They develop products, technologies, electronic solutions and aerospace industry products, with approximately 20,000 employees worldwide and have a high level of innovation development and are often associated with their industrial processes, so they can produce new products. Some of the company's processes are sequential and others are initiated in parallel (fig. 8), the 5 macroprocesses and these are unequally distributed in 26 processes.

Fig. 8. Details of macro business processes.



Source: Author´s elaboration.

In the case studied (Fig. 8), the R&D area has an interface with areas that demand innovations, which come from many sources, such as new market needs (new products), product improvements (new specifications), and supplier replacements (purchasing). The interfaces may change according to the impact of the innovation, for example, registration of new materials (with purchasing and engineering); determination of new process parameters, control or verification items (with manufacturing and quality); transportation, storage, stacking and handling parameters (with logistics); or complaints, main actions,

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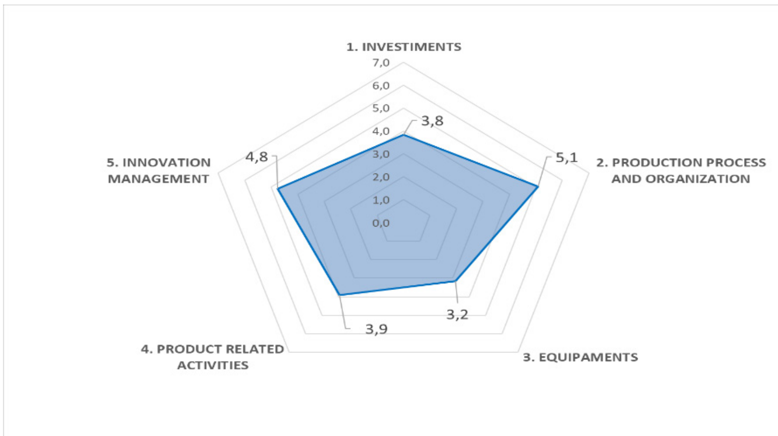
causes and effects of the main non-conformity problems, in addition to feeding the after-sales service and regulatory entities. It is important to mention that all actions coordinated by R&D are carried out together with the company's internal and external stakeholders.

After the self-assessment, which included the participation of fifteen managers and those responsible for the innovation process in their own management areas, the data were collected by technological function and the arithmetic mean of the areas was obtained: Research and Development (R&D, strategic planning, innovation planning, supply chain, inbound logistics, outbound logistics, manufacturing, maintenance, quality, regulatory, marketing, procurement, finance/controllership, sustainability/ESG and customer service the answers were then inserted in the software tool to show the levels, calculate the indicator and create the report. In fig. 9, it is possible to visualize the application level in each function according to the matrix of technological capacity developed, the values correspond to the averages of all evaluations received.

Fig. 9. Radar Chart in technological functions.



Source: Author´s elaboration.

It is noticed that the company that obtained the best score in the process was the production process and organization / innovation management (rated 5.1) and the worst result was in equipment (rated 3.2). According to the result with fig. 9, the Innovation Technology Capability (ITC) Index is calculated, based on the ratio between the areas of the polygons formed, with the area of the hatched figure, which is the result of the company's evaluation divided by the maximum area formed, in this case, where the company was evaluated in the maximum score in all evaluated items (level 7), thus the Innovation Technology Capability Index achieved by the evaluated company was 38.8% of 100%.

Fig. 10 shows the association between the proposed color scale with their respective bands, and the positioning of the evaluated company (38,8%), as follows: (i) Red grade (very low level): The company has

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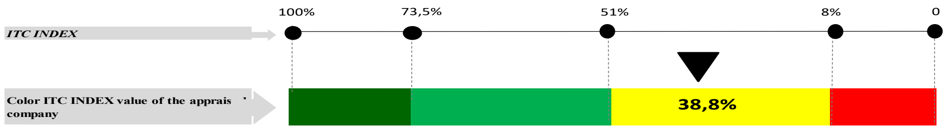
the value up to 8.0% of the Index, for that the area of the built chart after assessment done is equivalent to the area of a regular pentagon which levels is 2.0 in the five dimensions, (ii) Yellow grade (low level): The value of the Index is between 8.01% to 51.0%, for that the area of the built chart after assessment done is equivalent to the area of a regular pentagon between levels from 2.01 to 5.00 in the five dimensions, (iii) Green grade (relevant level): The value of the Index is between 51.01% to 73.5%, for that the area of the chart built after assessment done is equivalent to the area of a regular pentagon between levels from 5.01 to 6.0 in the five dimensions and (iv) Intense Green grade (high level): The value of the Innovation Technology Capability (ITC) Index is between 73.51% to 100.00%, for that the area of the chart built after assessment done is equivalent to the area of a regular pentagon between levels from 6.01 to 7.0 in the five dimensions.

Fig. 10. Illustration of the enterprise result evaluated in the ITC Index scale.



Source: Author´s elaboration.

The result in the company's assessment was well below its expectations, however, it showed many opportunities in its activities involving innovation, for example: (i) making investments based on more detailed engineering, on the one hand, more time is spent in this phase, since, after contracting, suppliers have a greater possibility of achieving the expected results in terms of time, innovation cost and, mainly, service to the market, (ii) with greater detail and knowledge of the needs, it is possible to work in a more organized way with global suppliers, which had an impact on Equipment, (iii) in innovation management, in addition to being aligned with consumer surveys, it is essential to have a broader innovation analysis, whether it is aligned with the company's strategy as well as connected with ESG practices, mainly for new materials and suppliers and not just having this approach for existing products/materials, the need to launch an innovation should not be the shortcut for non-sustainable paths.

After consolidating the results, we collected feedback from the assessed company on the clarity of the developed model, transparency, improvement opportunities tool consistency and presentation methods. They were positive along the way and led to a broad reflection identifying improvements that will be discussed in the next section, as well as suggestions for future work in order to broaden the acquired knowledge.

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5 CONCLUSION

From the objective placed in the focus of this work to measure the accumulation of technological capability (TC) eliminating the subjectivity that currently exists (Lall, 1992; Bell, 1997; Figueiredo, 2001) based on activities that the company is capable of carrying out throughout its existence, the capacity accumulation model for innovation management was proposed.

There are two main contributions of this research effort, the first is the proposal of cumulative levels of innovation management capacity from the most basic level (level 01) to the most advanced (level 07); with a broader vision of innovation management in the global supply-chain enterprises, the company at the highest level is not restricted to having an established innovation process, but having clear metrics, established governance, results achieved from innovations, the failures that may occur will be analyzed in the analysis of causes-root of the process and improvements implementation identified in the next innovations. The second contribution is the transformation of the technological capacity competence into a quantitative indicator called the Innovation Technological Capacity Index (ITC Index) calculated through the areas of the figure after carrying out an evaluation that can also be used as an indicator that allows an evaluation comparison between companies (benchmarking).

The classification is based on the analysis of following criteria: engineering, financial planning, project management, innovation management, market analysis, product development process, manufacturing process, sustainability/ESG, quality, metrics, measurement and results achievement, failure analysis and establishment of continuous improvement process for innovation management.

The technological capability matrix is broken down into five functions, namely: investments, production processes and organization, equipment, product related activities and innovation management.

From a practical point of view, the technological innovation management capacity of a global industrial company was systematically evaluated and the concept applicability and methodology developed in the real enterprise environment where the first evaluation was carried out was verified, which allowed a reflection on the companies' strategies to address the state-of-the-art in innovation management and that despite the company's understanding of being at a high level in innovation management after using the model, several opportunities were detected, this goes beyond its execution, as it also they must be decisive and support the achievement of the organization's goals.

The need to assess the level of innovation management capacity is a basic requirement for business continuity. It does not mean ease and simplicity in implementation, it requires a lot of discipline, focus and determination to avoid frequently proposed shortcuts that do not provide consistent results.

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The tool is capable of collecting information electronically and the software automatically calculates the developed indicator (ITC Index). The possibility of inserting the action plan in the historical evaluations made and associated with each dimension was seen as an opportunity for improvement. Thus, it will be possible to have all the information in a single tool, avoiding additional files and documents.

As a limitation of this research effort, it was intended to reach industrial companies that are not considered startups and academic companies (spin-offs), as they require a differentiated approach, the focus was on global companies when analyzing all their established and standardized processes.

This assessment will serve as a starting point to compare with others global enterprises and, secondly, to compare with regional and even local companies in this very competitive sector.

Finally, we emphasize that many companies fail to develop innovations throughout their existence with drastic consequences for the business and the model proposed in this research aims to provide a compass so that they can assess their skills and have a clear goal of achievements; also as a future work aims to provide benchmarking references for industrial sectors the proposal will be to start in companies that carry out a high level of innovation development: electronics manufacturing, as according to the technological innovation survey developed by the Brazilian government (IBGE, 2020), it is the sector that most performs innovations, followed aerospace, automotive, manufacturing machines and equipment, pharmaceutical and petrochemicals, which will also be evaluated.

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Appendix 1 - Cutting interview form questions.

Question no	Open question for the specialists, managers who participated in the research	Investigation Purpose
1.	What does it mean for you for an innovation, whether in a product or a new/improved process, to be successful?	Understand what success means to the interviewee from the perspective of innovation in order to align expectations for the interview.
2.	Considering the last 3 years, has there been, in your company, failures in innovations? (Leave it open so that any type of failure can be mentioned: delays, non-compliance with goals, rework, complaints from users above expectations, failures in handover, training...etc...)	Understand the history of the main failures of innovations in order to assess whether there are causes and whether they are repetitive over the period evaluated.
3.	What are the necessary skills for a team that works with innovation in order to be successful in its deliveries?	Having the interviewee's vision of the key competences so that people can make their deliveries and avoid failures/errors. Always try to guide the interviewee to sample the innovations he experienced in his company in order to avoid correlates of other innovations that occur without his participation in order to focus on the testimony.
4.	In your view, what are the essential areas of knowledge so that innovations (*) can be delivered as planned? These core knowledge areas can be called "dimensions". (*) In this case, we will use the broad concept of innovation, and for a new product there may be a need for adjustments/improvements or even the acquisition of machinery and equipment for the production process	Understand from the interviewee which would be the main management areas that are fundamental so that innovations can be delivered as planned and opening a dialogue in order to extract the relevant areas in the strategic context of innovations, associating them with the operational one to deliver it.
5.	According to the previous answer, let's explore what the basic, intermediate and advanced levels mean in what represents the areas of knowledge identified by the interviewee as relevant in innovation management.	The objective of this moment is to deepen the main areas addressed by the interviewee in the previous question and understand what would be basic, intermediate and advanced level.
6.	In your view, what justifies (or supports) companies being assertive in their innovations throughout their existence?	Understand with the interviewee if there are activities that involve the area of knowledge mentioned in the previous answer, but that go beyond the prism of innovations only, but that these can be assertive and contribute to the success of organizations over time.
7.	Is there an assessment of the skills needed in view of the portfolio of innovations to be delivered by the company? How is this done? Is there an association with previously delivered innovations?	Apparently, this question could be similar to question 03, however it is approaching the issue of competence from different perspectives, while question 3 is evaluated on the individualized theme of innovations, this question refers to the context of seeing repetitions in the systematic management of
⋮	⋮	⋮

Source: Author´s elaboration.