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The Impact of Artificial Intelligence on Innovation Management - A Case Study of Aveiro Region

Maria João Maia Correia

Master in Business Administration

Supervisor:
Professor Florinda Maria Carreira Neto Matos,
Invited Assistant Professor, Department of
Marketing, Operations and General Management
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Resumo

No mundo altamente globalizado em que vivemos, as empresas apostam cada vez mais na inovação como uma estratégia para aumentar a competitividade.

A Inovação não é mais um agente residual e isolado, mas considerada um *mindset* que deve ser incutida em todos os trabalhadores e todas as atividades de uma empresa, pois a inovação tem o potencial de melhorar não só a performance da empresa, mas também as condições de trabalho.

A Inteligência Artificial já não é ficção científica, mas sim realidade presente na cadeia de valor das empresas. O propósito desta pesquisa é perceber como é que os sistemas de inteligência artificial estão a influenciar os processos de gestão de inovação das empresas.

A metodologia de análise baseia-se num estudo de caso qualitativo e está suportada em entrevistas aplicadas a uma amostra de 5 empresas, localizadas na região de Aveiro.

Os resultados obtidos permitiram concluir que a Inteligência Artificial está progressivamente a ser incluída nas diversas atividades das empresas, alterando a forma como os gestores desenvolvem soluções e formulam os processos de gestão de inovação. A Inteligência Artificial está também a ter o papel de consciencializar para a necessidade de melhorar alguns dos mais importantes indicadores de uma economia inovadora como a produtividade, a qualificação, a cooperação, forma de pensar inovadora e bem-estar dos trabalhadores e consumidores.

Palavras-Chave: Gestão de Inovação, Inteligência Artificial, Empresas Portuguesas, Caso de Estudo.

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Abstract

In a highly globalized and competitive marketplace, companies have started to bet more on innovation as a source of competitive advantage. Innovation is no longer an isolated and residual agent, but a crucial mindset that should be embedded in all workers and all activities of a company, as innovation has the potential to improve not only an organization's performance but also employees' well-being and working conditions.

Artificial Intelligence is no longer science fiction, but a reality present in the value chain of companies. The purpose of this research is to understand how AI systems are impacting innovation management processes within companies.

The analysis methodology is based on a qualitative study supported by interviews directed to a sample of 5 companies based in Aveiro region.

The results obtained led to the conclusion that Artificial Intelligence is being progressively included in firms' activities, changing the way how managers develop solutions and innovation management processes. AI systems are also raising the awareness of improving some of the most important indicators of an innovative economy such as: productivity; qualification; cooperation; entrepreneurial mindset and stakeholder's satisfaction.

Keywords: Innovation Management; Artificial Intelligence; Portuguese Companies; Case Study

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List of Abbreviations

AI – Artificial intelligence

EU – European Union

R&D – Research and Development

CEO – Chief Executive Officer

USA – United States of America

OECD - Organization for Economic Co-operation and Development

IP – Intellectual Property

WIPO – World Intellectual Property Organization

ASI – Artificial Super Intelligence

ANI – Artificial Narrow Intelligence

AGI – Artificial General Intelligence

ML – Machine Learning

DNN – Deep Neural Networks

IT – Information Technology

GDP – Gross Domestic Product

SME – Small and Medium Enterprises

Chapter 1 - Introduction

1.1 Contextualization

Modern society exists in the context of a globalized and highly competitive marketplace, where companies face more pressures and constraints like never before. Addressing the current social, economic and environmental challenges demands new ideas and multilateral cooperation.

Academics and managers have long been discussing the importance and role innovation management plays in the competitive advantage and organization's growth.

When facing so many obstacles, only through the ability to promote changes and innovation companies can better adapt and improve not only their products, profit margin, but also their employees and customer satisfaction while reducing their environmental impact.

As Griliches (1957, p.2) once said, by enabling innovation across many applications as a "invention of a method of inventing", innovation management has the potential to have a much larger impact in companies than the development of any single new product (Cockburn, Henderson and Stern, 2018). Measurement of the innovation processes is critical for both firms and academics to understand the effectiveness of innovation actions (Adams, Bessant & Phelps, 2006). But how it can be managed is still not fully understood.

In this context, it is broadly accepted that Artificial Intelligence may greatly increase the efficiency of the existing economy. But despite the so expected AI revolution hasn't quite happened yet, the human being has already the major challenge in bringing together computers and humans in ways to improve human life.

Artificial Intelligence (AI) is no longer science fiction but part of our lives, helping humans solve problems in a wide range of subjects. Most developed economies are predicting the game-changing nature of AI (European Commission, 2018). In the business sphere, companies need to adapt to those changes or risk losing out on the opportunities offered by AI, becoming a consumer of solutions developed by others.

In this context the author aims to analyze the potential of AI in innovation management, more precisely the way AI is influencing how companies innovate.

When analyzing the evolution of innovation performance in the context of Portuguese companies, 2019 marks the year that Portugal changed from a moderate innovative country to a strong one according to the Innovation Scoreboard (European Commission, 2020). Having this achievement as a starting point is crucial to understand the evolution of innovation in Portuguese companies in the last years. The main purpose of this research is to analyze what has been the influence of Artificial Intelligence in that evolution.

The research will be conducted in Aveiro region due to its relevant and strong industrial activity, and also for being the city where the author was born and grew up. For these reasons the author is interested in analyzing the innovation performance of the companies located in the region, aiming to contribute somehow to the study and development of the business sector in the Aveiro district.

1.2 Motivations and Research Aims

We can no longer discuss a subject from the perspective of Portugal as an isolated economy, but as an agent integrated in the Eurozone and Europe.

Europe was once an economic power, but nowdays with the global competition and emerging economies needs to find new ways to prosper in the global market. Companies are putting more effort than ever in coming up with strategies to achieve competitive advantage as the threat of new local and global competitors is inevitable (Crossan & Apaydin, 2010). Innovation has a key role in achieving that success and should be seen through the lens of a business capability process and outcome in managerial practice.

The fragile economic business structure of Portugal, and the increasing concern of the European Union on leveraging innovation across European companies are the starting point of this research, as Portuguese companies need to improve their performance regarding productivity, innovation and labor conditions.

AI systems are helping humans solve some of the biggest challenges in society such as detecting diseases, predicting events or maximizing the potential of data. In the business sphere AI might as well play an important role in leveraging innovation performance by improving innovation processes within companies. Therefore, the author aims to understand the potential and role of AI in innovation management activities and detect possible constraints to the innovation capability and implementation of AI systems within companies.

1.3 Research Questions

To accomplish the proposed objectives, the present research was elaborated to answer the following investigation questions:

- Are companies using innovation as a management capability?

- What is the impact of Artificial intelligence in the innovation management of companies?

- What are the main challenges and implications for companies regarding the implementation of AI systems and Innovation?

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Chapter 2- Literature Review

2.1 Structure

Knowledge production within the field of business and innovation research is accelerating at a very fast pace, while at the same time remaining fragmented and interdisciplinary. This reality creates a challenge in narrowing and keeping up with the wide collection of data, evidence, and studies in this particular area (Snyder, 2019).

To examine the vast amount of literature available in this field, a literature review was elaborated as a research method to understand and evaluate what was written specially in the last 10 years.

Data was collected mainly from Scopus. This database was chosen because of the availability of different publications' analysis regarding authors, citations and sources. Another factor was the up to date and relevance of the available articles.

The research process was elaborated using the keywords "Innovation management" and "Artificial Intelligence" in the academic and business sphere.

This analysis is fundamental to clarify the definition of such broad and subjective concepts such as Innovation management and artificial intelligent, so that a relation between the concepts can be more concretely established and studied. Furthermore, what are the gaps and important aspects still missing in the literature.

At last, in this chapter a review was conducted on how artificial intelligence presence is impacting innovation management procedures and models and the overall strategy within a company in the context of enterprises of different sectors, following the academic viewpoint. Afterwards, the Portuguese business scenario will be analyzed more specifically.

2.2 Innovation Management

2.2.1 Definition

In the Scopus database, despite there was a significant volume of publications available before the year 2000 was when the number of articles about innovation started to increase more significantly. Probably due to the growing interest of academics and firms regarding the subject, and the technological advancements. Being the USA followed by Germany the countries with more publication on the subject of innovation management.

The number of articles published regarding innovation has continued to grow steadily in the last decade. In Scopus there were published 1899 articles about the subject of "innovation management" since 2016. Establishing a comparison, in 2010 there were published 236 papers on the innovation management subject and in 2020 the number of articles is already 361.
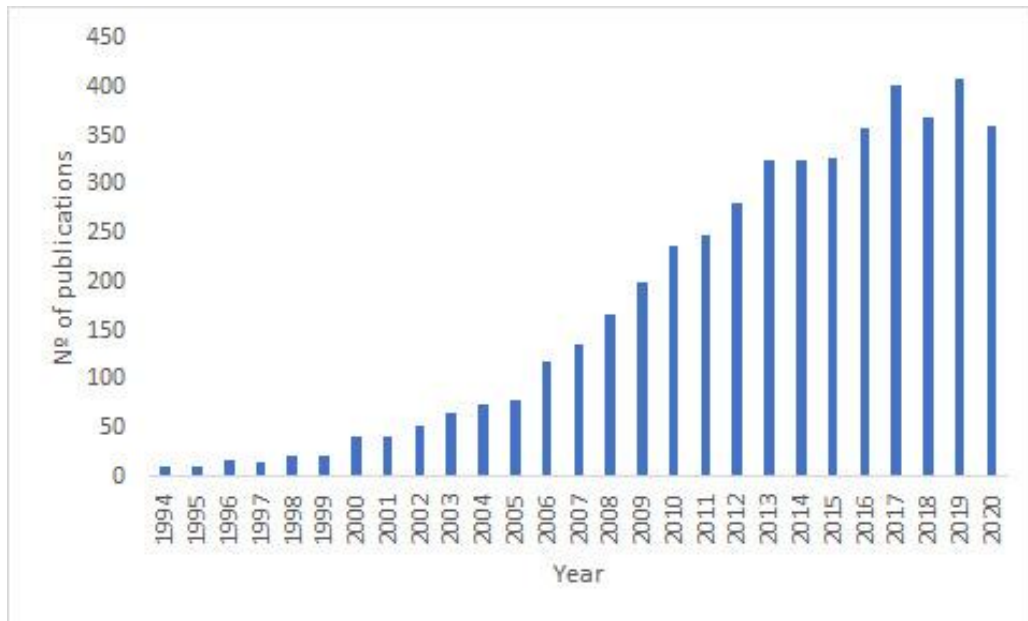
Figure 1 - Evolution of the number of articles published in Scopus throughout the years
Source: elaborated by the author

One of the objectives of this work is to look at innovation from the perspective of innovation management concept as there is a consensus that despite its diversified character, innovation management is an important mechanism for the competitiveness of companies and countries (Narciso, Canen & Tammela, 2018). Innovation capability can and should be conceptualized and measured (OCDE, 2018), since it holds the potential to create novelty and knowledge (Zheng, Liu & George, 2010; Lawson, & Samson, 2001).

A considerable literature was found and analyzed for this research, on the subject of "innovation", its origins and history. At first, the literature seemed rich and vast but since the focus of this research is not on "*innovation*" itself but on innovation management models the author could verify a fragmented and diverged literature.

The lack of a generally accepted definition is partially due to the ambiguous nature of the concept of innovation itself and also the multidisciplinary nature of the field (Lopes et al., 2017).

There are measures of aspects of innovation management frequently proposed that respond to some needs of both companies and researchers to understand the application and effectiveness of innovation however, this information is fragmented (Adams, Bessant & Phelps, 2006).

Despite some gaps in the literature, this research looked for convergent perspectives, common activities and frameworks, as there have been some relevant articles regarding innovation management models especially in the last 10 years.

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Innovation applied to management and organizations is much more complex than the simple meaning of "creating something new" as the definition of innovation implies, and it covers a considerable diversity of phenomenon perspectives. Therefore, its overall definition can only be possible through complementary contributions of different authors analysis and frameworks.

Before the 2000s, there seems to be a lack of consensus on innovation management as a concrete and defined discipline transversal and applicable to all activities within the organization.

Chesbrough (2003) opened the way for the open innovation model with many scholars considering that his contribution created a new paradigm for the analysis of the innovation process. Open innovation encourages companies to open up their innovation process, giving up their closed and hierarchically rigid processes. The author defines innovation has a process of information creation only possible to be developed out of social interactions, thus companies cannot rely only on internal resources and knowledge anymore. They have to look outside and try to identify new skills and knowledge to complete their own. The ability to innovate combining internal and external knowledge is becoming one of the most critical aspects that lead to a sustainable competitive advantage (Lopes et al., 2016).

This new approach has contributed to changes in companies' dynamics, either internally (changing behaviors towards innovation, but also the way people and departments interact) and externally, changing how they gather information and relate to other organizations (Trott, 2017; Chiaromonte, 2004).

Nowadays, evaluating and benchmarking innovation competence is still a complex issue either for companies or academics and is still a challenge to identify the processes that influence the organization's innovation (Adams, Bessant & Phelps, 2006).

In recent years, scholars have focused on the practical experience of many companies as a source of information, gathering data and adapting the concept of innovation from a highly technology-oriented to a more integrative one. Stressing the importance of cooperative work not only between new product development and marketing departments, but also including other activities and areas of specialization that can contribute and improve the innovation outcome (Chiaromonte, 2004).

Trott (2017), argues that this process can only be possible through the adoption of a business perspective, which is embedded not only in each activity but in each employee. Being necessary to shift from a closed system that is focused mainly on using and work internally information of a firm, to a new model of open system involving many other players that integrate the up and down supply chain such as suppliers, competitors etc. This open innovation model is only possible to exist and succeed in a new knowledge-based economy (Trott, 2017; Chesbrough, 2003).

Lewrick and Raeside (2010), mention that too much emphasis is attributed to individual characteristics, regarding successful innovation practices.

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Authors stress that senior managers must be able to spot opportunities and foreseen possibilities, also their mental power must be based on flexibility otherwise there will be few opportunities for innovation.

Authors agree about the importance of establishing a path to examine and gather information about innovation management styles, not focused on individual factors such as leader's personality but in systemized attributes of management approached through structural, dynamic and creative perspective (Trott, 2017).

Yasini (2015), talks about one of the contradictions of putting innovation management theory into practice which is the necessity to create a link between great freedom to innovate and the need to systemize and commit to discipline.

2.2.2 Innovation management determinants

The contribution of different authors allows us to gather a diversity of factors that are considered of key importance in the creation of an organization where innovation is embedded and systematic.

Despite in the past innovation was mainly associated to technological development, many authors suggest that high levels of R&D are not an evidence of good innovation practices, but only one of the many determinants that contribute to the innovation process.

Knowledge management, which is responsible for gathering, using and communicating ideas has been considered a crucial promotor of the innovation performance. The three areas of knowledge management important for innovation management are: idea generation, knowledge repository (implicit and explicit knowledge) and an effective information flow.

In the beginning of the innovation process when ideas are explored, its measurement tend to be quantitative and easier to verify. But as the process develops and uncertainties with feasibility, patent issues, etc are reduced measurement approaches become more qualitative and complex to determine (Adams, Bessant & Phelps, 2006).

In the organizational context, the right leadership style and vision are determinants in an organizational culture that promotes innovation. An authoritarian and rigid leader, who has a traditional vision of control and power dynamics will influence and constrain the flow of communication, the focus on continuous learning, creativity, and proactivity (Vala, 2013).

Another important characteristic of innovation management is that it has to be integrated into the overall strategic vision of the company. The creation of an innovative environment is regarded by many authors as a key factor of innovation development. Tidd and Bessant (2009, p. 131) consider the construction of a creative environment involves systematic development of organizational structures, communication policies and procedures, reward and recognition systems, training, and an implementation plan.

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Despite the difficulty in measuring each individual's contribution to the innovation outcome, academics have given attention to that since ideas are the raw material to innovation.

Employees are regarded as key elements in which its contribution is determinant to the firm's success. Factors such as workers with different backgrounds or high levels of educational attainment are associated to more innovative companies (Adams, Bessant & Phelps, 2006).

Thus, they have to be encouraged to be free to develop innovative ideas which can only happen if they feel there is a sense of mission of the individual in the company. Therefore, all employees independently of their function most have an active role in the company's innovation process since they are a source of ideas, solutions, and they think strategically (Day & Shea, 2020; Dobni, 2006).

Another important determinant to the innovation process is the interdepartmental cooperation. Sharing information among the different activities and departments of the organization must has as a main goal to enhance and maximize the development of innovations.

This determinant is related to the determinant of creating a flexible organizational structure. Many authors stress the problem of companies having very rigid structures and one-way direction communication. Tidd et al. (2009) say that rigid hierarchical organizations in which there is little integration between functions and where communication tends to be top-down and one way, are unlikely to be supportive of the information flows and cross functional cooperation.
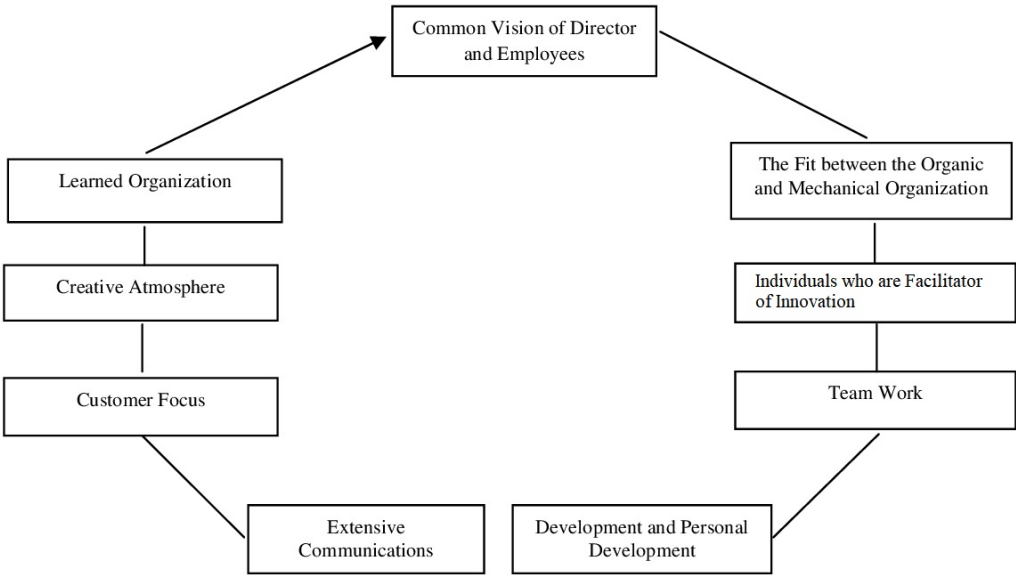

Figure 2- Specific characteristics of innovation management process
Source: Yasini (2015, p.3)

There is some level of consensus in the literature that Innovation can be classified into four types (OECD, 2018): Product innovation (new product or improved one); process (introduction of a new method or significantly improved one); organizational innovation, (new organizational method that has not been previously used); marketing innovation (introduction of a new marketing method) (Lopes et al., 2016) and some authors also include technological innovation (Lopes, et al 2016 ; Dosi et al., 1988).

2.3 Models of Innovation Management

In the past, many studies have treated innovation as an art fact somehow detached from knowledge and skills and not embedded in the know-how, but innovation needs to be viewed as a process (Trott, 2017, p. 11) No single discipline deals with all aspects of innovation. Hence, to get a comprehensive overview it is necessary to combine insights form several disciplines.

There is not a unique formula for innovation management, nor an innovation model that fits all companies. Innovation carries multiple facets and definitions, and this characteristic turns it understandably difficult to recognize which innovation model should be adopted in each company (Lopes et al., 2016).

Before the 1960s, and early 1970s, the word *model* rarely appeared in the literature of innovation. Instead, academics viewed innovation in terms of a process composed of "sequences" and "stages" called "*frameworks*" "*paradigm*" or "*conceptualization.*" The estimates of innovation contribution were focused on the residual- the share of economic growth, these approaches treated innovation as a leftover, something that was unmeasured (Fagerberg, Mowery & Nelson, 2006).

New growth theories and models were developed in the 1980s, when the effects of innovation started to be incorporated in growth accounting (Romer, 1990) through the informational properties of ideas and their potential for reuse.

Innovation management is a set of critical skills and practices that starts in the director or leader of a firm but spreads to the whole structure of the organization (Yasini, 2015).

 Innovation models have been continuously criticized and updated, namely a very influential one in the past, the liner model of innovation- which begins with basic research, applied research and then development, following commercialization. This model of innovation management targeted mainly product innovation (Godin, 2017).

 Academics and economists have disseminated the linear model of innovation widely among companies, justifying government's support to science using this model for many years (Godin, 2005). Despite of its popularity, nowadays the linear model of innovation a theoretical framework, is widely rejected since it is viewed as incomplete (Godin, 2017, p. 1)

Different models are present in science, technology and society studies, broadly defined including studies of technological and science innovations (policies, management, economics) (Fagerberg, Mowery & Nelson, 2006).

Date	Model	Characteristics
1950/60s	Technology Push	Linear Model, simple linear sequential process, emphasis on R&D
1970's	Market-pull	Simple linear sequential process, emphasis on marketing, R&D has a reactive role.
1970's	Dominant design	An innovation system goes through three stages before a dominant design emerges.
1980's	Coupling model	Emphasis on integrating R&D and marketing
1980'/90s	Interactive Model	Combination of push and pull models
1990	Architectural Innovation	Recognition of the role of film embedded knowledge in influencing innovation
1990s	Network model	Emphasis on knowledge accumulation and external connections
2000s	Open Innovation	Chesbrough's (2003) emphasis on further externalization of innovation process in terms of linkages with knowledge inputs and collaboration to exploit the knowledge outputs
2000s	Disruptive innovation	When disruptive innovation occurs, the changes are significant and not continuous

Table 1- A typology of innovations
Source adapted from: Trott (2017)

There are common components essential to all innovation management models. The absence of each component might compromise the innovation process.

The author analyses some of the activities that must integrate innovation management, so that companies can successfully implement innovation processes such as (OECD, 2018, p. 35):

- R&D activities
- engineering, design, and other creative work activities
- marketing and brand equity activities
- intellectual property (IP) related activities
- employee training activities
- software development and database activities
- activities relating to the acquisition or lease of tangible assets
- innovation management activities.

There can be established some common major parts of the innovation process:

- The entrepreneur manager plays a crucial role in stimulating innovation within the organization by connecting other departments, inviting other skills to help solving problems or improving processes and has direct involvement in projects.
- New products and ideas are created in working groups.
- The project level, which is the extensive interchange of communication and knowledge of different skills. Having informal relations leads to better flow of communication and increase organization's success (Damanpour 1991; Imai, Nonaka & Takeuchi, 1985 cited by Yasini, 2015).
- Product efficacy, which is the ability to develop new and successful products with reasonable prices (Yasini, 2015).

2.3.1 The cyclic model of innovation

As mentioned before, in the past the development of innovation was perceived as a linear process however, some authors agree that once the process of innovation starts, communication about it will increase with the human capital. In the last decades, market-pull and speed have been introduced in innovation models. Society and organizations are diffusing the process to all activities and people, making the model more non-linear. Therefore, Innovation is more open and non- sequential reflecting not only the adaptation of innovation to the market, but also the ongoing and changeable character of the process, that is transformed by multiple agents and factors of the ecosystem (European Union, 2020).

Despite the existence of many innovation models, the author proposes one that combines aspects of European Union (2020) and Trott (2017).

By adopting an approach of interconnected cycles, firms will not have rigid and simple one-way communication channels, but interconnected cycles with feedforward and feedback connections from linear to non-linear thinking. This model will also stimulate the continuous learning process and a dynamic network environment is created, where innovative products and processes are conceived from the linkage between engineering, social and behavioral sciences and society inputs that in turn connect with market goals (Trott, 2017).
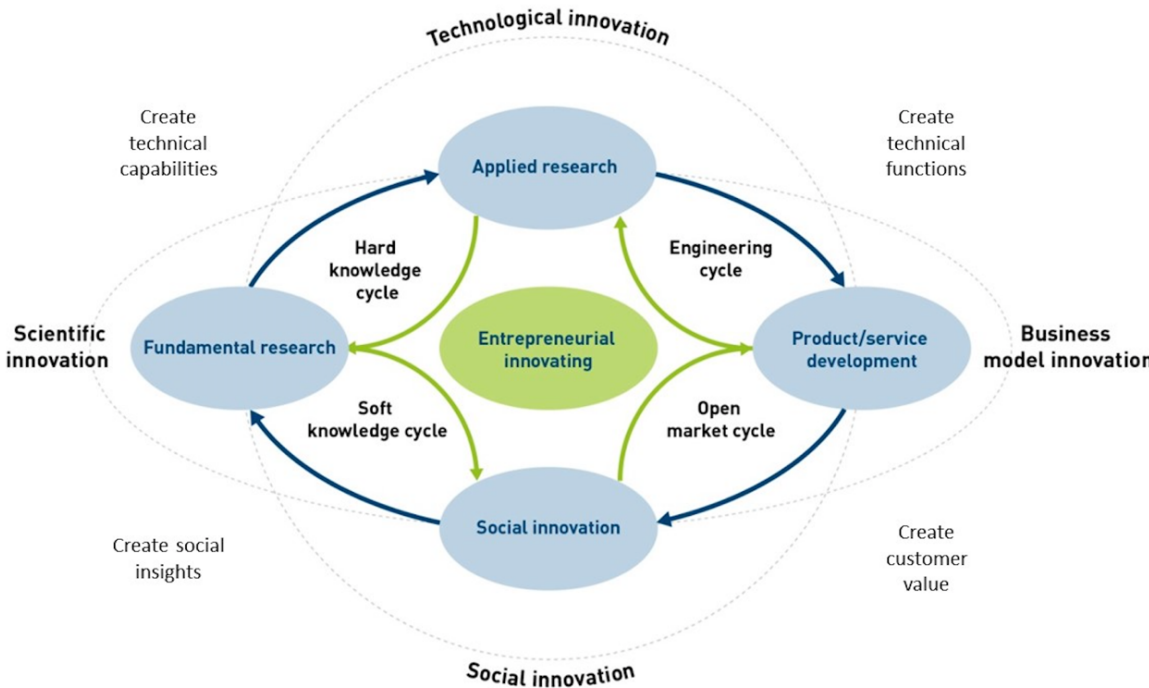
Figure 3- The cyclic model of innovation with interconnected cycles.
Adapted from: EU (2020) and Trott (2017)

2.4 Innovation Management Impact in the Organization

When we consider the whole organizational structure, innovation management can only be put into practice if all activities work in a cooperative and in an integrated manner (Trott, 2017). Therefore, by creating an invention of a method of innovation, enabling innovation across many applications instead of creating a single new product, innovation management has the potential to have a much larger economic impact (Cockburn, 2018).

Despite its significance within firms, studies suggest that for many companies it is hard to predict how innovations will spread in a dynamic environment. Some authors stress the lack of measurement

procedures to help managers evaluate innovation performance. This, results in uncertainty about whether an innovation is adequate to become a sustainable business model (Johannning et al., 2020). For many organizations, innovation is not just an alternative to present new products or increase production capacity, but a way to influence and change the industry they belong (Lopes al., 2016).

An empiric case that sustains the idea of innovation management as a system´s approach rather than only focusing on product development is the Whirpool case.

A company that until 1999 had focused only on engineering and marketing innovations. On that time, the CEO David Whitwam predicted the "industry stalemate" threat, which translates in the possibility of low differentiation in a market with growing price pressures and anemic growth (Day & Shea, 2020).

In order to respond to these problems, alongside with his leadership team they developed a set of capabilities for continuously innovate whirlpool which originated a brand focused value creation strategy. This strategy created a consumer devotion on the brand, differentiating the company from its competitors and internally aimed to create changes in every process and every product.

In order to achieve this objective all employees would have to become participants of the innovation efforts. On that time, the CEO leadership message to all employees *was "Innovation will generate from everywhere and everyone, if you have a concept put it forward"* (Day & Shea, 2020, p. 41). The problem was that the system in place was not prepared for this mindset. Whirpool had an extremely conservative budget control process and bureaucracy that put many restraints in funding innovations and new ideas. Despite of the obstacles, there was a disruption in processes and an innovation management model was created and put into practice with all employees being trained with "innovation mentors." This was the genesis of an initiative that in retrospect changed Whirlpool forever (Day & Shea, 2020; Cronin & Dearing, 2017; Surrab & Bouassami, 2013).

Establishing a comparison, the whirlpool case represents the situation of many companies today where innovation exists since long time but in an isolated and fragmented manner, using models that target only some types of innovation such as research and technological development.

2.5 Oslo Manual

The Oslo Manual (OECD & Eurostat, 2018) is regarded as a methodological reference for producing innovation statistics at international level and provides a review of innovation definitions and measurement, only possible due to the vast economic and management literature available on European and worldwide companies' innovation procedures.

The Manual defines the concept of innovation as "a new or improved product or business process (or combination thereof) that differs significantly from the firm's previous products or business processes, and that has been introduced on the market or used into the firm" (OECD & Eurostat 2018, p. 20)

The evolution of the Oslo Manual guidelines reflects the changes in the perception of innovation definition, only possible due to the following factors: the ongoing changes in the economic and social conjuncture, the vast economic and management data, and literature available nowadays about sharing experiences among enterprises and academics analysis.

Both the first (OECD & Eurostat, 1992) and second (OECD & Eurostat, 1997) editions limited innovation to only new or improved technological products or processes. Whereas the third edition (OECD & Eurostat, 2005) expanded the innovation measurement framework giving relevance to the external networks, namely the linkages with other firms and institutions in the innovation process. Another significant change was that no longer product and process innovations were associated only with technological change.

Regarding the most recent edition (OECD & Eurostat, 2018), the manual improvements focus on some key topics such as: The most updated models of innovation such as the open innovation models; the digital perspectives, providing guidance on measuring innovation in digital products, platforms and data capabilities; How statistical data on innovation can be used to support management, research and policies; The importance of survey methodology, plus the implications of data collection methodologies. And the strategic use of accumulated evidence over the past decade to address current critical challenges such as: the thematic of subjectivity and international comparability, quantitative measurement of innovation results, or the requirements to improve innovation procedures.

2.6 Obstacles to Innovation Management

Nowadays, in knowledge-intensive industries, there is an agreement about the necessity to adopt best innovation management practices for the success of both start-ups and established companies.

Many start-ups, small and medium size companies do not count on experienced management teams and "knowledge" especially those that are stablished in more isolated areas with emerging innovation networks, opposed to those companies that are located in robust regions of complex innovation and entrepreneurship.

This reality often translates in critical obstacles such as the bottleneck knowledge problem that prevents companies to achieve regional and global competitiveness. Small firms often lack the knowledge required to implement technology innovation processes and have to look for those skills externally (Frigolett, 2015).

Despite the knowledge bottleneck problem has not been fully analyzed in both industry and academia, there are empiric studies that prove companies located in advanced clusters therefore complex innovation networks, were more committed in investing in resources required to obtain outbound innovation. This often translate in an accelerated international expansion to other markets.

In the case of companies that operate in more basic clusters, it becomes more difficult to implement innovation strategies. These companies tend to evolve with more focus on inbound information. Meaning their innovation strategy involves importing technology and services from more innovative clusters, creating a process of local knowledge diffusion. But those companies lack key enabling assets to form complex innovative networks that in a medium and long term will be an impediment to the development of sustained innovation capabilities, that are enablers of competitive advantage and market differentiation (Frigolett, 2015).

2.7 Artificial Intelligence

2.7.1 Definition

Despite the concept of Artificial Intelligence have started to be developed throughout the 20th century, its exponential growth happened only in the beginning of 21st century.

Scientific publications date back decades but the boom in published literature related to Artificial Intelligence started only around 2001 (WIPO, 2019).

In Scopus database, during the 1990's the number of publications regarding AI was approximately the same each year. From the beginning of year 2000 and onwards, there has been a steady growth in the number of publications per year.

This research focused mainly on literature published in the last 5 years. From 2016 to 2020 there are 129,114 publications available related to AI in Scopus database.

We can conclude that there has been a very significant growth in the number of articles published related to Artificial Intelligence in the last 20 years.

When the research words are "Artificial intelligence definition", curiously, there are only 3 publications available in Scopus.
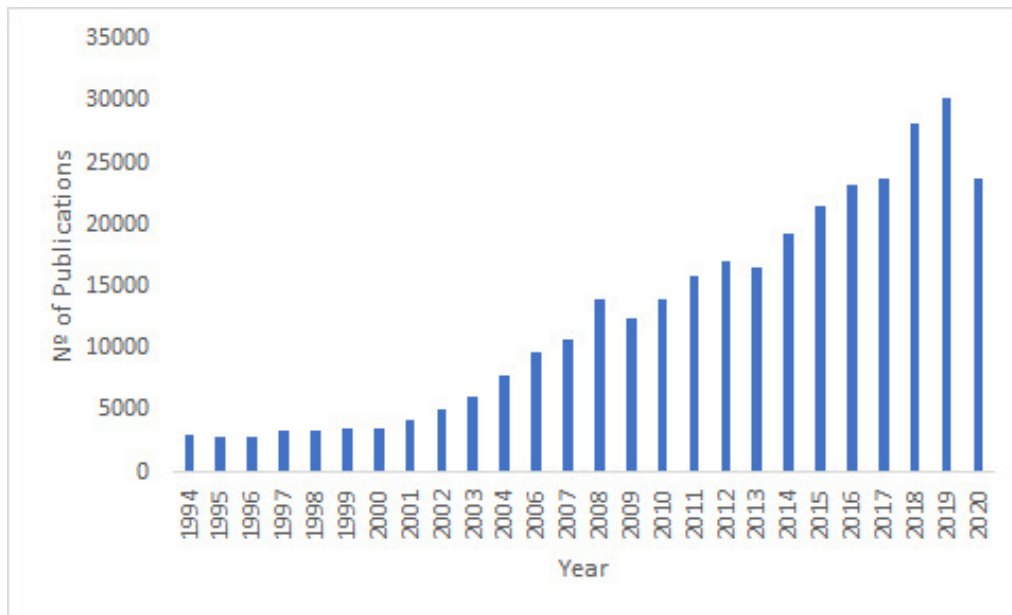
Figure 4 - Evolution of Artificial Intelligence publications throughout the years in Scopus
Source: elaborated by the author

The concept of Artificial Intelligence is very broad and not fully defined and understood in the literature, despite the great volume of articles published in a vast range of fields and business activities.

Modern Artificial Intelligence (AI) research began in the mid-1950s, with a conference at Dartmouth College that led to a great enthusiasm in the area among scientists and researchers. From that time, AI laboratories soon were created at major universities and institutes (Oliveira, 2017).

In the 1950s, the term "artificial intelligence" was originally used, to describe the simple idea of human intelligence being exhibited by machines. Although this assumption might not be very accurate, since computers use techniques to solve problems in different ways, human brain process information to solve the same problems.

For instance, a chess player AI system use speed to evaluate millions of positions per second – a strategy not possible to be used by a human chess player (Oliveira, 2017; Muthukrishnan et al., 2020).

When analyzing the semantics of the word (AI), it contains explicit reference to the notion of intelligence, however since intelligence is a very vague and elusive concept, although vastly studied by scientists, physiologists, neuroscientists, AI researchers use mainly the notion of rationality. Which can be defined as the ability to choose the best action to achieve a certain outcome given the resources and certain criterion that can be optimized. However, rationality is not the only characteristic analyzed in AI concept (EU Commission, 2019; Oliveira, 2017).

For Weizenbaum (1976) AI will never develop into human reason because the two are fundamentally different.

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Some authors have theorized that there are challenges for achieving Artificial *Wisdom,* because of its intrinsic nature.

The principal reason for this challenge lies in the philosophical distinction between practical wisdom and practical intelligence. Hacker-Wright (2015) explains that instrumental rationality or cleverness is getting the aims right, rather than reasoning well with a view to fulfilling aims. Skills are the instruments of rationality while practical wisdom demands to reflect about what end to follow. Therefore, an agent is wise if he can deliberate well about the final goals of the domain (Tsai, 2020).

Despite the challenges of inspire Artificial Intelligence in human reasoning, the literature shows some degree of consensus about the use of AI in practical intelligence. Which is the construction of programs that mimic the behavior of human intelligence step by step using deduction, reasoning, planning and scheduling. Even though scientists were able to develop AI systems that perform some tasks, there are many difficulties researchers face behind the creatin of models based on the human reasoning, since many activities of our daily lives are intractable and computationally hard to formulate.

Alan Turing, widely considered as the father of modern computer, anticipated some of the objections to its own AI definition present in the known Turing test.

Since the Turing test forces the computer to imitate the human behavior and it has to possess human like reasoning, nowadays researchers agree that the test has some limitations as it is difficult to apply in today most advanced AI systems.

For now, the absence of emotions can be used to differentiate AI from human intelligence even though computers might be able to interpret human emotions and feelings in the future (Oliveira, 2017; D'Acquisito, 2020).

2.7.2 Types of AI

There are two types of AI mentioned in the current literature. The Artificial Narrow intelligence (ANI), which focus on one task with limited range of abilities. Most AI systems that exist today and are applied in the industry and in our lives are ANI.

The second type of AI mentioned in the literature is the Artificial General Intelligence (AGI). These systems would be at the level of human mind and outperform them, in the sense that they can solve complex problems in a variety of different domains (Pennachin & Goertzel, 2007; cited by Tsai, 2020 p. 1). Due to the fact that we still do not possess a total knowledge and comprehension about the human brain, AGI is still a concept and in development idea, rather than a reality.

Another concept about the type of AI which is only theoretical for now and would be an evolution of artificial general intelligence, is the Artificial Super Intelligence (ASI). These machines will have a

"*conscience*", and an intellect much smarter than the best human brain possibly in every field. This is a complex and controversial subject, because these AI systems would not only be able to perform tasks, but perhaps would be capable of having emotions and create relationships (Muller & Bostrom, 2016; Wooldridge, 2020; Tsai, 2020).

2.7.3 AI subfields

Regardless of its particular definition or objectives, it is consensus that AI has the potential to mechanize intelligence. For Cockburn and Henderson (2018) AI is regarded as branch of computer science usually separated in three distinct but interrelated areas such as robotics, neural networks and symbolic systems (Cockburn, Henderson & Stern, 2018; Di Vaio et al,.2020).

When analyzing the literature, it is possible to verify a general agreement regarding AI being a term used as an "umbrella" that includes many sub areas such as machine learning and deep learning.

A very important subset of AI is machine learning, (ML) which has the ability to "learn" and improve from tremendous amount of data taken from computers. These AI systems mimic the biological intelligence, specially of humans. Many breakthroughs in machine learning are inspired by the studies of neurosciences, biology and physiology. In fact, understanding how human brain function is crucial for AI development.

Machine Learning has been intensely researched and widely used such as in object recognition (Zou et al., 2019), speech recognition (Graves et al.,2013) or engineering design optimization (Deng et al., 2020).

Deep neural networks, (DNN) also known as deep learning, is regarded as a subset evolution of machine learning, increasing the accuracy of a machine learning model.

Geoffrey Hinton was responsible for theorizing about deep learning in the 1980s. Thanks to the creation of the concept of artificial neural networks, a representation of a system of interconnected "neurons". Deep learning algorithms have the capacity to make neural connections from multiple hierarchical data levels. A distinctive feature of neural networks is that it is trained by being exposed to thousands of examples and then, it has the ability to adjust internal parameters to improve its performance (Helm et al., 2020; Sarvepalli, 2015).
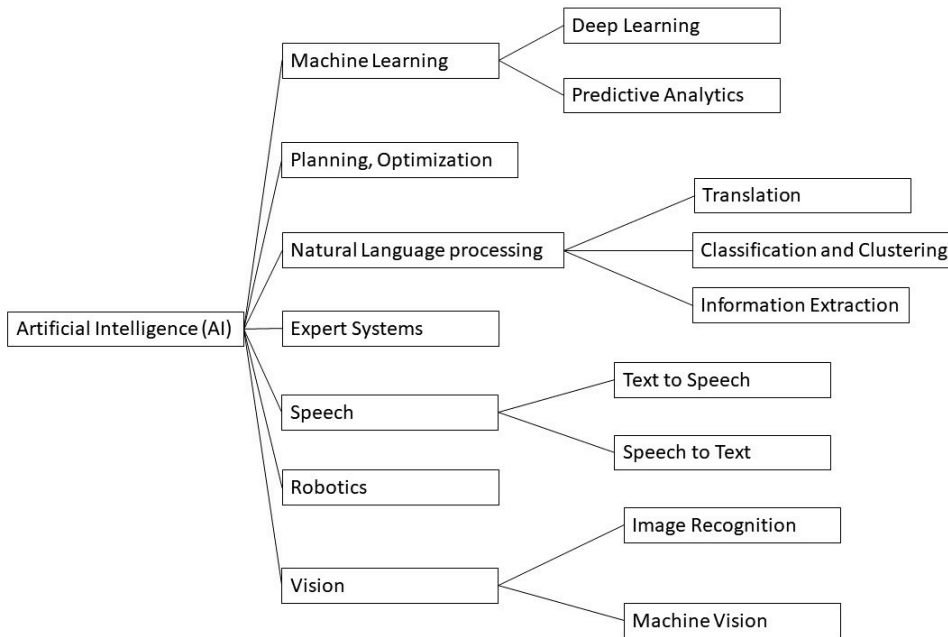
Figure 5 - Artificial Intelligence Subfields
Adapted from different sources

2.7.4 AI applied to business

 In the past there was some resistance to Artificial Inteligence importance in corporate management, but some authors mention that since AI has become financially viable, it is a critical time for its adoption in businesses.

First AI commercial applications have been in relatively narrow fields such as robotics, but the learning algorithms that are being developed suggest that AI systems can be used across a wide range of company's activities (Cockburn, Henderson & Stern, 2018).

Artificial intelligence stands within the technological innovation, but it is transversal to all activities such as research and development, financial and commercial ones. These systems are already being considered "a general-purpose technology" and will likely be an important component of future work. (Hilb, 2020; Ghosh et al., 2019).

Approximately 80% of large companies have adopted some form of (AI) into their core business, an increase of 70% in the last years (Ghosh et al., 2019).

AI technologies are being associated to better performance, efficiency and more accurate results and reduced error rate, production and processes wise, becoming relevant in almost every organizational function. This fact is making teams rethinking their management strategies (Davenport & Kirb, 2015).

In the last years, thanks to computer science advances AI applications are now able to interpret huge and complex amounts of data while performing better regarding energy efficiency.

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Perhaps the most economically successful application of AI has been in the field of robotics, through "industrial robots" used in manufacturing tasks.

In robotics, the concept of "robots" as machines that can perform human tasks date back at least 1940s, but this field started to flourish significantly in the 1980s, through the combination of advances in numerically controlled machine tools and the development of more adaptive but rules-based robotics that already rely on the active sensing of an environment.

Nowadays in some industry sectors, there are assembly lines nearly 100% automated. If 20 years ago machines had to have human supervision nowadays*," AI systems are replacing mental tasks rather than physical ones, which were the targets of previews waves of mechanization"* (OECD, 2017).

While analyzing the literature, it is relevant to mention one important distinction between providing innovation incentives and companies investing in robots purpose built for narrow tasks, versus technologies with a wide range of domain applications.

Despite that, most considerable advances in AI have been in the field of narrow -intelligence systems- specially in technologies with a narrow domain of applications. In the last years there have been some advances in the deepening of Artificial General Intelligence study, but the focus of this study is the recent and already implemented AI systems in companies, and those are despite their great efficiency, in the domain of narrow intelligence definition.

Across industries there are AI systems in the fields of automation, data analytics and natural language processing are streamlining operations and improving their efficiency.

Organizations are using AI systems to perform jobs that used to require human intelligence such as applicants' selection for job positions; distributing payments to supply chain partners, through blockchain enabled smart contracts, or AI chatbots used in customer service, among many others (Murray, Rhymer & Sirmon, 2020).

2.7.5 AI applications

Most common types of activities involving AI are digital and physical tasks. AI based systems can be purely software based, acting in the virtual world or can be installed in hardware devices (European Commission, 2018). AI can give support in three important business needs such as automating business processes, formulating insights through data and engage with customers and employees.

Process automation is a type of AI that is usually used in back office administrative and financial activities of companies, using robotic process automation. These systems consume information from multiple IT systems and analyze information similarly to humans. They transfer data from emails and call centers for systems of record; read legal and contractual documents using natural language

processing; update costumer profiles; solve error systems by extracting information from multiple documents among other tasks.

Another type of AI are the systems that provide a cognitive insight, such as algorithms that detect patterns in large volumes of data and interpret their meaning. Natural language processing and automated speech (software-based AI systems also called digital voice assistants, can understand the meaning of natural speech or text as part of applications such as Siri. Advancements in natural language generation also allow AI to respond to people's voice or text.

The recent new version of google translator based on deep learning, represents a huge improvement in the quality of translation between languages. Instead of combination of words that could be translated together, deep learning looks for dependencies across whole sentences (Sejnowski, 2018).

Long time ago, it was said that computer vision could not compete with the visual skills of a one-year-old child, this is no longer true. Nowadays, computers can recognize objects in images like adults (Sejnowski, 2018, p. 4).

Another important application of AI is in self-driving cars. It is estimated that around 90% of road accidents are caused by human errors (European Commission, 2016). AI could be the answer to solve the big problem of road traffic accidents. Despite still not materialized, many advancements in the last years in AI applied to automated cars predict a disruption in the car industry in a near future.

Experts state that in some years people will not have to buy cars, and taxi drivers and other drivers will be replaced by automated self -driving cars. This will cause a great impact in the amount of time people spend driving and parking. Structural changes will happen in the cities, since cars can park outside of cities freeing the space for more productive buildings and structures.

Companies are increasingly using AI systems as business capabilities rather than technological ones. Researchers have enquired managers who are familiar with their company's use of AI intelligence systems, and many believe that AI will significantly change their companies within three years.

2.7.6 AI threat of job replacement

Some authors have focus on the idea (or possibility) of AI systems such as machine learning replacing humans, taking over the workplace and reshaping existing organizational processes (Brynjolfsson & McAfee, 2017).

Ernst, Merola and Samaan (2018) discuss the outcomes that the current wave of technological changes and advancements in artificial intelligence might have in the workplace. The rational fear of jobs replacement for AI and growing inequality is a thematic that has already been addressed by many organizations worldwide.

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In 2017 the Director-General of International Labour Organization convened an Independent Global Commission on the Future of Work, with the objective to produce a report on how to achieve a future for work that provides decent and sustainable work opportunities for all.

In the European Union context, in 2019, the high-level expert group on AI has presented *"Ethics Guidelines for Trustworthy Artificial Intelligence"* (European Commission, 2019).

2.8 Impact of AI on Innovation Management

There is little empirical work published on the impact of AI and the challenges it brings to innovation management to date. Contrasting with the great amount of investment in studies about the overall potential of AI technologies, not only published by academics but consulting firms as well (Prem, 2019).

In Scopus database, when using the research words "Artificial Intelligence and Innovation" there were available 37 publications, being the first one published in 2006.

In the same database, when the research words were "Artificial intelligence impact on innovation" there were no results available to date.

On google scholar, there were available 191 results regarding "Impact of Artificial intelligence on Innovation" on the last 5 years.

Though innovation is quite complex to achieve for every organization, studies show that organizations are looking towards IT as an enabler of process innovation (Anand et al., 2013).

Recently, researchers have shown some interest in the idea of AI and machine learning possibility of replacing humans and take over the workplace roles, changing the organizational structures and processes. The amount of literature on this subject has been growing steadily in the last years (Brynjolfsson &McAfee, 2017).

The general concern about jobs replacement by machines, has to do with the inherent human limitations regarding the capacity to process and work information when comparing to AI systems. The later can deliver high quality, greater efficiency, and better outcomes than some human experts (Agrawal et al., 2018 cited by Haefner et al., 2021).

The reasons why some managers and companies want to use AI systems in their innovation processes cannot be explained without having in account the context in which such transformations occur: high volatile and changing environments, political systems and an increasing competitive global market, while the technological advancements and rivalry continue to grow.

At the same time, the amount of information available continues to increase. Human beings had never in its possession such great volume of information available as they have now.

The term big data, which gained momentum in early 2000s refers to data that is so large, fast and complex that becomes very difficult to process using traditional methods.

There is a reciprocal relationship between Big data and AI, as the latter depends on the former to succeed, while helping organizations to unlock the potential into their data sets. AI systems are able to help innovation managers to process much larger amounts of information than humans could possibly do on their own, adding that AI algorithms perform at a great speed, impacting the learning process momentum.

This fact is creating a phenomenon that Porter and Heppelmann (2017) describe as a disconnection between the huge amount of digital data available nowadays and the limitations of the physical world, in which information can be applied.

Some authors believe that the baseline for competitiveness of organizations lies on the information treatment and the problem-solving capacities.

If AI systems play a crucial role in collecting and analyzing data, then the way innovation is organized and its processes need to be challenged and adapted to the introduction of AI because those systems have important cost advantages in information processing (Haefner, 2021).

On the other hand, supporting innovation processes with AI can generate real value for the company by reducing waste, risks and costs generated by innovation processes.

There are two important trajectories within AI- Robotics and deep learning with authors discussing that these subfields might play different roles in the future of innovation (management) and technical changes.

In the field of robotics, robots already play important roles in manufacturing sectors and have the potential to substitute human labor in the production of a wide range of products. Robots technologies can bring implications and changes in leadership styles, human resources, or human capital management processes. But for now, there is a relatively low potential to create changes in the innovation management and its processes.

Regarding deep learning, it is the field that that possess the biggest potential to create changes in innovation structures. The capacity to learn and improve is a general-purpose transversal to all fields (Cockburn, Henderson & Stern, 2018),

In the past and the present, managers have faced several obstacles while coming up with ideas and developing them such as: information processing constraints that limit the amount of information needed to develop ideas since human's cognitive abilities to absorb and process information are limited. The second obstacle is the ineffective local search routines in which the implementation of AI systems might give an important help identifying and evaluating more creative and exploratory ideas. By identifying managers working process limitations and decrease the barriers between them and AI systems, overcoming the above-mentioned obstacles becomes possible to create a framework that integrates potential creative areas of AI that contribute to the innovation process.

Artificial intelligence has not achieved a general intelligence yet, since most AI systems used nowadays display narrow inteligence in the sense that are extremely efficient in one or two tasks. Even though, they already excel largely human abilities in processing information in the area of idea development.

Current most advanced AI systems rely on deep neural networks that need and are able to process vast amounts of data at a great speed. Big data field plays a crucial role in the success of AI.

This way, in innovation processes' stage of design thinking and implementation, AI can support managers in the development of ideas, and solutions. These developments are already creating significant value for companies (Roose, 2019 cited by Haefner et al., 2021).

To support the above affirmation with empiric evidence, there are some examples of AI applications. One of them is AI use to optimize battery components and solar cells by Machine learning based methods that are used to predict the most promising materials, speeding up the innovation process (Charington, 2018).

Another example is the business analytical tool application developed by Outlier (2020). The firm uses machine learning algorithms to process raw metrics data into information that humans can read. After analyzing the company's data, Outlier generates a set of resumed customized insights and "stories". In doing so, these AI systems improve managers capacity to spot opportunities and come up with innovative ideas in many activities. This AI system is transversal to many sectors (Haefner, 2021; Outlier, 2020).

To conclude the idea, AI systems ability to process and analyze data have the potential to be a powerful source of competitive advantage in a wide range of activities of the value chain, such as in R&D, marketing and customer service.

As a general insight, the author concludes that AI systems have the potential to free managers from more technical and exhaustive research tasks and enhancing creative processes, by giving resumed insights about an amount of data that on their own managers would not possess the time or cognitive ability to analyze properly. AI and humans can work in a cooperative manner by using the information provided by AI. This way, managers can focus more on creativity applied to problem solving and, in the conception, and development of strategies.

2.8.1 AI as a general method of innovation

Technology advancements have replaced human organization and so, they might as well be a catalyst of changes in how companies innovate.

Artificial Intelligence is part of the technological revolution and influences all activities of a company's value chain: Products and services; production processes; employment and human resources. Some

authors agree that AI also has the potential to reshape how innovation processes and R&D are organized, having the potential to change innovation nature (OECD & Eurostat, 2018; Cockburn, Henderson & Stem, 2018; Haefner et al.,2021).

Cockburn, Henderson and Stern (2018) are a few of the researchers that have focused on the potential of recent developments in deep learning, to serve as a general-purpose method of invention (Agrawal et al., 2017).

Despite the lack of data on the subject of AI impact on innovation management, some authors have found some qualitative evidence about the repercussions of deep learning multi layered networks, in a range of tasks that include computer vision and other prediction tasks. AI expert on deep learning Geoffrey Hinton (2020) suggests that there were some great and rapid advances just in the last few years, on small algorithms related to multi-layered neurol networks. These last developments on AI make some researchers believe that a new method of invention was created: machine learning.

Despite in its early stages, the potential of machine learning and deep learning might create a new revolution, when focusing on organizational and policy consequences of AI. If there are increasing valuable outcomes in the scope of data acquisition that firms can obtain and use, it is possible that new and aggressive entrant companies in a particular sector might be able to create a significative competitive advantage over potential larger and older rivals. Merely because of control over data and not the usual formal intellectual property or demand network effects. This possibility can shift the way companies innovate. Even though, pressures and incentives to keep data private will weaken new entrants and researchers' ability to study (Cockburn et al., 2018; Oliveira, 2017).

Algorithms should help managers make better decisions, generating a shift in which a large amount of data complex connections helps in the decision process. These mathematical models simplify work and have the ability to catalogue and organize information sets in a way that some models are more efficient than human decisions (Sousa & Rocha, 2019).

Machine learning as an invention of a method of inventing, might not only have an impact reducing costs of innovation activities, but it can generate a new approach and mindset towards innovation. A conceptual framework that integrates AI tools can lower-costs on research.

Within the research activities, some AI innovations improve access to knowledge and contribute to "lab productivity."

Some authors stress that the economic impact of some research tools is not limited to reduce costs of specific innovation activities. From an organizational perspective, probably there will be significant changes towards research. Taking advantage of the combination of large datasets and deep learning algorithms, will create complex interdependencies also affecting interactions and communication among departments and workers. Changing the way organizations process information to a more

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inclusive and less centralized way, as workers who were not involved in the innovation processes in the past become part of it (Haefner, 2021).

Also, in the organization there is likely to be a shift from a more routinized labor-intensive research effort (testing hypothesis in small purpose-built datasets) towards research that takes advantage from large datasets and enhanced prediction algorithms.

2.8.2 Expectations and limitations of AI

The question if humans are closer to create generally intelligent machines than they were 20 years ago, cannot be analyzed without mentioning the controversial topic of *consciousness*. From a scientific viewpoint, consciousness is a state that arises when a biological brain interprets the flood of sensory input received from the world around it leading simplistically speaking, to somehow the conclusion that an entity exists.

Despite not well understood, most of us can conceive this notion that results in "thoughts" and among those thoughts are concepts of *individual* existence such as "I exist" "I am a human" "I am experiencing thoughts".

If the definition of Artificial General Intelligence needs to be at the level of human consciousness, therefore AGN systems need to possess that level of awareness about the world around, the notion of conscience.

Despite the relevance of the topic, the author objective is not to explore the concept of AGI.

There has been reports of artificial systems beating humans in games and other tasks, however, those machines act more like a tireless learner rather than an intelligent one, having in account the amount of data they analyze, and energy consumed. Despite its rapid evolution in the last years, AI is still in its initial stage (Deng et al., 2020).

Some authors identify a gap that exists between the expectations that have been built up specially in the last 10 years, and what AI has actually achieved which is success with specific and defined problems, (Artificial Narrow Intelligence) backed up by large sets of trained data. But what is still missing today is a broad (or general) intelligence (Wooldrige, 2019, p. 2).

In order to understand AI capabilities' potential in assisting humans in the innovation process, it is important to understand some key technical features of those systems that are usually constrained by human capabilities: AI systems are created by humans who establish objective functions generally sparse, since human researchers who are programing the systems couldn't know all the objectives of managers. The same happens for AI applications solution space, which are also pre-defined by humans thus, current AI systems tend to have a limited ability to explore the solution space autonomously (Haefner et al., 2020).

To conclude, the latest AI systems have some technical limitations in redefining and exploring both problems and solutions. However, advancements in deep learning suggest AI may indeed be able to overcome those limitations.

However, some skills have not yet been acquired by machines such as creativity, imagination and critical thinking (Deng et al., 2020; Elish & Boyd, 2019).

Thus, they have a supporting function but not taking over the entire innovation process for now, as it is improbable that whole series of connected tasks can be totally automated.

In spite of the potential of AI and the increasing investment of companies, especially large ones, there is evidence that firms do not experience rapid beneficial outcomes, ending up blaming AI initiatives a possible failure. A survey by Boston Consulting Group and MIT discovered that seven out of ten AI projects generated little impact or not the expected outcomes, which made implementation projects drop from 20% in 2019, to 4% in 2020 (Makarius et al., 2020).

The lack of IT and AI experts is one of the biggest challenges for companies, as most firms' human capital lack those skills, even recent computer science graduates still do not possess enough expertise (European Commission, 2019).

Another barrier are the costs of creating the required know-how for innovations, as AI techniques require many trial and error cycles during the development process.

The lack of technical predictability can be a challenge for innovation management, if expectations are high about AI possibilities. Experts warn about the danger of disappointment of modest performance of AI solutions. The disappointment might mean that companies delay too long to explore potential solutions (Penn, 2019; Haefner et al., 2020).

2.9 Innovation in the Portuguese Context

In this chapter, Portuguese economy context will be analyzed with the focus on Portuguese companies' innovation performance through the analysis of the European Commission Country Reports (2020) and other institutional documents.

The European Innovation Scoreboard created in 2010, provides comparative assessment of research and innovation performance of European Union country members. The data allows countries and regions to assess strengths and weaknesses of national research and innovation in organizations.

Since 2010, Portugal has been evaluated as a moderate country regarding innovation performance in organizations. However, in 2019 the country jumped from being a moderate innovative economy to a strong one, occupying the 13º position among 27 countries. Comparing to the European Union, Portugal is still below the average. Regarding the economic performance and thanks to a weaker external demand, the GDP has decreased from 3,5% in 2017 to 2,0% in 2019.

When analyzing the 2019 European Union report on Portugal performance on innovation, the country registered limited progresses regarding the application of innovation recommendations directed in 2019 (European Commission, 2020).
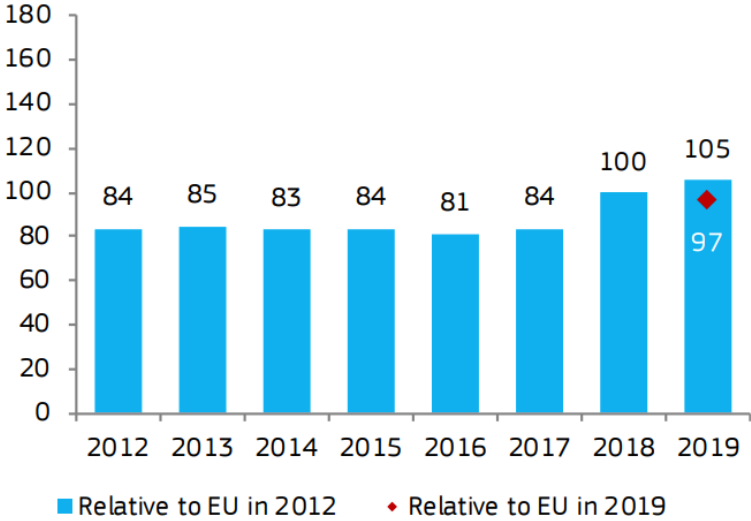

Figure 6 - Evolution of Portugal Innovation Performance
Source: European Commission (2020, p.1)

In this chapter, some of the indicators used to evaluate innovation performance in organizations and countries, are going to be analyzed in the Portuguese case. The following image highlights the main indicators to have in account, when measuring innovation performance.

Human Resources
➢ Doctorate graduates
➢ Population with tertiary education
➢ Lifelong learning

Attractive research systems
➢ International scientific co-publications
➢ Foreign doctorate students

Innovation-friendly environment
➢ Broadband penetration
➢ Opportunity-driven entrepreneurship

Finance and support
➢ R&D expenditure in the public sector
➢ Venture capital expenditures

Firm Investments
➢ R&D expenditure in the business sector
➢ Non-R&D innovation expenditures
➢ Enterprises providing training to develop or upgrade ICT skills of their personnel

Innovators
➢ SME´s introducing product/process innovations
➢ SME's introducing marketing or organizational innovations
➢ SME's innovation in-house

Linkages
➢ Innovative SME's collaborating with others
➢ Public-private co-publications
➢ Private co-funding of public R&D expenditures

Intellectual assets
➢ PCT patent applications
➢ Trademark applications
➢ Design applications

Employment impact
➢ Employment in knowledge-intensive activities
➢ Employment in fast-growing enterprises

Sales impacts
➢ Exports of medium and high-tech products
➢ Knowledge-intensive services exports
➢ Sales of new-to-market and new-to-firm product innovations

Figure 7- Innovation Performance Indicators
Source: Adapted from EU (2019, p.33)

2.9.1 Innovation in the business sectors in Portugal

Portugal economical structure is still based on traditional low and medium-low tech sectors. Despite the low exportations of medium and high-tech products, they are increasing predicting a slow structural change.

This might help to explain the low levels of research and development comparing to the EU average. Investment in intellectual property, intangible assets including R&D and digital competences weigh on productivity and is also below the euro zone

Regarding qualifications, Portugal is increasing the numbers of science and engineering graduates which might contribute to the advances in innovation.

Despite the increasing internationalization of its research and development sector, Portugal still ranks low in the scientific co-publications comparing to other EU countries (EU, 2020).

2.9.2 Levels of education

Portuguese education system has experienced progress in the last decade, but there are still important changes to address.

Portuguese population still has a high share of people with low education attainment. Half of the population has no more than lower secondary education, with adult's participation rate in education and training being only around 10%.

In the last decade, there has been some positive improvements regarding the decrease in low education labor rate while medium skilled workers rate is growing (Pordata, 2019; EU, 2019).

2.9.3 Employees productivity

Despite marginal improvement in labor productivity in the last years, Portugal still has a low productivity rate. According to EU this fact is affecting competitiveness of the industries and economy, contributing among other factors to the maintenance of low salaries.

Productivity performance levels changes across types of companies and sectors of economy. Manufacturing, wholesale and retail trade are the sectors with lowest productivity in Portugal.

There are a number of measures designed to help productivity and competitivity in areas of research and innovation, competition in services, among others. Despite these measures to increase knowledge and competitiveness Portugal still has a low number of PhDs graduates which translates in low levels of scientific investigation and research comparing to other European countries.

The connection between academic and scientific research, and companies is of key importance for the advances on innovation, which will contribute to the competitiveness of firms.

Another prevailing obstacle is the digital skills deficit, which remains a major problem in Portugal. In 2019, 48% of the Portuguese population lacked basic digital skills, including 26% with no digital skills at all.

Productivity growth remains slow, but net private investment is increasing, remaining a major contributor to the growth in upcoming years. There has been a weak investment in the industrial sector, with the upcoming EU funds displaying an important support to companies.

Regarding competitiveness, Lisbon metropolitan area is the most competitive region. North and center regions show similar performance.

EU cohesion policy has contributed to transform Portuguese economy providing support for around 14500 companies in 2019

2.9.4 Clusters of innovation

In the contemporary literature positive economic benefits for firms due to organized agglomeration were first mentioned by Marshall in 1890 and popularized by Michael Porter in the 1900s and 2000s. Studies suggest that firms that are closely located and share resources and knowledge spillover become more productive. Therefore, the study of clusters has become a crucial research tool among investigators and police makers in Europe when measuring companies' productivity and growth.

European Union has been studying and attributed importance to the organized cooperation in networking areas of companies as a strategy to leverage innovation and competitiveness.

According to European Commission (2020), which analyzed 2950 regional industry clusters across European countries, concluded that productivity in clusters is much higher than average productivity and increase with clusters strength, with basic performance clusters productivity being 15% above the average, whereas in high performance clusters the average productivity can be 140% higher than companies not organized in clusters.

Its last publications reflect the concernment about improving the framework conditions for collaborations and there are being designed measures to increase cooperation among companies.

2.9.5 Regulations

Overall, Portugal markets and companies remain among the most heavily regulated.

Regulatory restrictions limit ability of companies to effectively compete in the markets, either as sellers or buyers.

Steps are being taken to lighten the administrative burden and judicial efficiency. But the structural problem of regulatory barriers and the slow pace at which processes unfold continues to restrict competition for business services, where excessive recourse to authorization schemes prevail with long decision deadlines (European Commission, 2020).

Regarding the retail sector, it is growing and becoming more competitive but burdensome administrative and taxation also remain a problem that creates obstacles to companies.

Also, there are many persistent barriers associated to licensing and patenting in Portugal, with company owners and administrators complaining about the slow and bureaucratic process of registering a patent, especially in some business sectors.

This reality generates constraints in the overall implementation of innovation processes within companies, slowing down competitiveness.

Portugal is one of the countries in Europe where companies spend more time paying taxes, thus the burden of complying taxes in this country is still a reality. A greater simplification could make the country a tax system more business friendly (European Commission, 2020).

2.9.6 Innovation funds

Portugal 2020 is a partnership between Portugal and European Commission, responsible for the distribution and application of five European funds that have the purpose to support through financial incentives, projects, and companies of different sectors. These European funds display a very important role for companies to leverage their innovation performance and business growth.

Portugal 2030 aims to promote the economic growth and the creation of qualified jobs, through the promotion of markets related to space technology namely satellite signals, and data exploration applied to several business sectors.

Portugal is also addressing the issue of companies' digitalization by developing measures to help firms integrate digital technology into businesses.

Another important plan towards innovation is the strategy on "*Artificial intelligence Portugal 2030.*" With the country aiming to be at the vanguard of education on Artificial Intelligence. There is also the plan of expanding advanced cyberinfrastructures until 2030.

The National Innovation agency, (ANI) has in course a strategy to speed up innovation in Portugal in the next decade with the creation of the "*technological and business innovation strategy*" approved in 2018. Being the flowing objectives:

1. Increase the investment and development in innovation
2. Entrepreneurship
3. Valorization and transference of technology
4. Internationalization strategy
5. Improve the application of European funds for Innovation
6. Promoting innovation
7. Monitorization

Published in 2020, the OCDE *Innovation Indicators* is a compendium of indicators on business innovation of the 39 country members and partner economies.

Some of the indicators of innovation performance within companies are:

- Implementation of new or improved products and business processes
- The degree of novelty and economic significance
- The level of investment and collaboration activities incurred as part of the innovation efforts
- The role of markets and government support (OECD, 2020).

Chapter 3 - Research Methodology

3.1 Qualitative research

The author chose the qualitative research method to analyze the subject of the impact of AI on innovation management within companies' sphere, using a convenience sample of five companies based in the region of Aveiro. The companies were contacted through the network of contacts of the author.

As approached before, Innovation management is a very broad and subjective matter that involves different processes.

Nowadays, despite the volume of studies that attempt to quantify innovation and the increasing attention given to innovation capability, the truth is that the perception of the concept varies according to business sectors, leaders and managers.

Academic and policy makers usually prefer quantitative data for research purposes. But when answering surveys, people find it challenging and difficult to report quantitative, interval data regarding innovation activities such as gross profit generated by innovation; collaborations; intellectual property such as patents, among others. In addition, many innovation concepts are difficult to quantify. Therefore, using statistics of qualitative information that cannot be collected on interval level can be obtained through questionnaires that ask nominal or ordinal information.

Among those questions are organizations most relevant innovations, innovation strategies targeting processes or cultural organization reports and what are the sources of information and how frequently they are accessed. The present research focus on that type of information. This qualitative data can be used in econometric analysis and to construct indicators (OECD, 2018, p. 57).

Today, there is some common agreement about the characteristics that define qualitative research (Cressel, 2017; Hatch, 2003). Talking to individuals directly in their environment, seeing them behave within their context is a major characteristic of this type of research. In this work, the author has spoken to company leaders and managers and also analyzed documents on innovation, provided by companies.

The inductive process of building patterns from concrete to more abstract units of information, working the information until establishing a set of themes. Then deductively, the data was analyzed to determine if evidence can support each theme (Cresswell, 2014).

As mentioned in the first chapter, the author aims to find answers to the following research questions:

- Are companies using innovation from the perspective of management capability?

- What is the impact of Artificial intelligence in the innovation management of companies?

- What are the main challenges and implications for companies regarding the implementation of AI systems and Innovation?

Chapter 4 - Case Study

4.1 Research design

The research method adopted was the case study, using an interview that aimed to answer the research questions through the analyze of a sample of 5 companies all based in the Aveiro district: Vista Alegre; Gres Panaria; Primagera; Oli and Bresimar.

The author resorted to semi-structured interviews, and the questionnaire was designed based on interviews of different research and scientific papers used as a reference.

 Before the interviews took place, the author conducted some interview tests in order to test the clarity of the questionnaire. The length of the interviews was 50-60 minutes, conducted through the support of a questionary with some close-ended and open-ended questions that aimed to achieve a level of depth in the answers. Besides, while doing the official interviews the author clarified every possible doubt raised by the interviewees. The interviews targeted company leaders and Innovation managers, and the interviewees were: Two CEOs and 3 Directors (Innovation, Marketing and Industrial Director) of each company. After, the interviews were transcribed, and the content analyzed.

4.2 Description of the companies

The factors that determined the choice of the companies were first and foremost, the goal of analyzing well-stablished and successful firms that have a considerable dimension since according to European Union (2020) report on business innovation, larger firms tend to be more innovative. This way, not only the degrees of AI systems and innovation management within companies can be more easily detected and analyzed in the context of interview, but also the perception and opinions that managers and leaders have about those concepts, since large companies' innovation strategies are more methodical and organized.

    The author found some limitations regarding the amount of literature available on innovation in Aveiro industry, therefore the data analyzed regarding innovation is more focused on Portuguese industry as a whole.

According to Pordata (2018) database, medium companies represent 0,5% of Portuguese business structure, whereas regarding large sized enterprises they represent less than 1% of the total number of businesses.

Aveiro has a significant industrial activity, especially in ceramics. Three of the five companies analyzed are in the ceramics sector, other operates in automation and one produces cisterns and bath solutions.

Presentation of Company 1 - Vista Alegre group

Founded in 1883, it was the first industrial unit dedicated to the production of porcelain in Portugal and is the oldest in Iberian Peninsula. Vista Alegre is a well renowned large company, having a determinant role in Aveiro economy and culture. The brand is present in 80 countries and is involved in international big scale projects, contributing to the projection and promotion of Portuguese industry in the world.

Presentation of Company 2 -Primagera

Founded in 1972, is a familiar company constituted by private capitals, which produces utilitarian and decorative earthenware ceramics.

The company has a long-lasting reputation in the region, being one of Vista Alegre competitors and collaborators. Originally it was a family-owned business with 25 employees that grew throughout the years. Nowdays Primagera has 260 workers.

Presentation of Company 3 - Gres Panaria

Founded in 1990 in Aveiro as Novagres, is dedicated to the production of high-quality ceramic materials for paving and coatings.

In 2008, the company was acquired by one of the main Italian Groups in ceramics, Panaria. Using the vast know-how that already existed the brand was restructured with a new image and communication, based on "emotional marketing".

Presentation of Company 4 -Bresimar

Bresimar Automation, S.A. was founded in 1982, beginning its activity with the commercialization of electronics materials for industry. Nowdays is specialized in equipment, systems and solutions for industrial automation with a strategy focused on innovation. In 2010 Bresimar created two electronics brands (Asatek and Tekon eletronics). It is a medium sized company with a strong reputation in innovation and good workplace practices and environment.

Presentation of Company 5 - Oli

Oli - Sistemas Sanitários, S.A. was created in 1954. The company is the largest cistern producer in Southern Europe, and exports around 90% of its production. A global bath solutions brand that is present in 80 countries on five continents. Over the years, Oli has created innovative products for the bathroom, using patent technology and high-quality manufacturing.

4.3 Analysis of the Interviews

4.3.1 Interview synthesis structure

The questionnaire for the companies which is in the appendix, was organized in three main groups: The characteristics of the company, Innovation and Artificial Intelligence.

Due to the length of the interviews, which lasted approximately 60 minutes, the author resorted to tables to present the interview contents, in order to synthetize the information collected.

Below each table is referent to one main group, followed by ab analysis about each table.

The Company	Bresimar	Gres Panaria	Oli	Primagera	Vista Alegre
1.Business area	Equipment, systems and solutions for industrial automation	Ceramic materials for paving and coatings.	Bath solutions	Utilitarian and decorative ceramics	Utilitarian and decorative porcelain, crystal, glass
2. Year the company was founded	1982	Novagres - 1990 Gres Panaria integrated in Panaria group -2006	1954 1982- first industrial unit	1973	1824
3. Enterprise category	Medium sized company	Large	Large	Large	Large
4. Sales turnover in 2019 and Business growth (%)	13 million euros	73 million and 261 thousand euros. Decrease of 3,13% in 2019	60 million euros (growth of 5%)	10.5 million euros growth of 6% in 2020 Best years growth of 10%-12%	120 million (double digit growth)
5. Number of employees (in the beginning and now)	Started with 3 employees. Currently there are 66	Currently 558 employees	Started with 3 employees Currently there are 420 employees	Started with 25 workers. Today there are 260	Currently 2300 employees
6. Employees educational attainment levels	27% high school diploma 36% Bachelor's degree 34% Master's degree 1% PhDs	30 with some college or associate degree 55 with bachelor's degree, 26 with Master's	38% less than high school graduates 32% high school graduates 16% with bachelor's degree 13% with master's degree	93%-94% with 9th grade.	10% with bachelor's degrees
7. Best-selling products	Automatons and programable controllers, sensors and servo motors	"Marble" collection and 3D products.	Toilet flushing systems and related components.	60% tableware, 30% oven ceramics and 10% garden ceramics	A great variety of porcelain, crystals and glass. From tableware to decorations.
8. Percentage of exports	45% of exports in 2019 To Lithuania, UK, Italy, Australia, Brazil, etc	50% to France, Germany, Italy, UK among others	80% to Europe. Germany is the first market	90% (mostly to European countries)	Above 75% for 80 countries.
9. Main competitors **Competitors in the past.**	Internal: F. Fonseca, ABB, etc. External: sensorization companies such as Emerson, Testo, Danfoss, Omron	Internationally is Porcelanosa The competitors haven't altered much since the beginning.	Geberit is the main competitor. We are leaders in Portugal. Competitors of the past no longer exist.	Grestel, Matceramica nowdays. The competitors of the past no longer exist because of globalization of the last 20 years. Asian prices more competitive.	No internal competitors apart from Costa Verde. Biggest competitors are international

Table 2 - Characteristics of the Companies
Elaborated by the author based on the interviews

Most of the companies have no more than 15% of workers with higher degrees.

Bresimar, a technological company specialized in automation equipment is the firm with the highest percentage of employees with higher educational attainment, with 70% of their employees having at least a bachelor´s degree.

The majority of the companies interviewed stated that one of the obstacles to the firm growth has to do with the limitations of the internal market, such as its small dimension and the weak purchasing power of Portuguese people. Therefore, all the companies interviewed export more than 50% of their production with some of them exporting 90% of their products especially to European countries. Internationalization and export capacity strategies are of crucial importance to the Portuguese business growth.

In 2010 Bresimar created two electronic brands, Tekon and Asatek. While Asatek is more present in the internal market, Tekon target international markets, being its direct competitors' some world-renowned electronic brands. And so, the Portuguese electronics brand is having a hard time in conquering external markets. Internationalization is a catalyst to innovation, since to compete with established worldwide brands, Portuguese companies need to continuously invest on innovation.

Primagera mentioned a characteristic of internal costumers, that look for highly customized products, delivered in timely fashion. This can be a challenge but also an opportunity, since the implementation of 3D printing and product design innovations, will allow to create more customized products in a shorter period of time. Gres Panaria have acquired one machine that creates singular and unrepeatable products.

The Company	Bresimar	Gres Panaria	Oli	Primagera	Vista Alegre
10. Obstacles to the business growth in the present and past	In the 80s, a new industry appeared in Portugal that lacked technologies and specialized technicians	Small internal market	Small internal market, lack of knowledge share and cooperation	In the past, the firm worked for brands as a subcontractor. Small internal market	Since year 2000 consumer spending patterns changed, and new competitors
11. Obstacles to business growth	Tekon competitors are renowned worldwide brands. Bresimar has been in the market for 38 years, proving its quality. The firm is growing.	Huge investment necessary to approach new markets	Small internal market and the low purchasing power of the Portuguese are always an obstacle.	Challenges to position our new brand- Aveiro tableware

China princes, Bangladesh and India are strong competitors. Markets changes | Portugal has a limited market. Internationally, the challenge is to create a global brand. It takes a huge investment. |
| 12. Most important awards and recognitions | -PME leader 8 times and PME Excelência 7

-Ranking of best firms to work for.
-1st place of happiest companies in Portugal

-Recognition in organizational climate and human capital study | (Not mentioned) | -Kaizen awards Millennium horizons Award in innovation Design Award in 2019
first control plate in the market, wins four international awards. | Awards in trade shows and trade fairs | In 2019 V.A. received 38 international awards in design, product, marketing and communication |
| 13. Company greatest achievement in the last years | Company's internationalization project and conquest of the international market | A well-defined strategy and its successful implementation | Recognition as a strong player in the sector. We are the suppliers of 8 of the 10 best brands in the world in sanitary ware. | Keep growing each year 6% -10% despite the challenges. | The internationalization, worldwide recognition and financial solidity |
| 14. Company practices that motivate employees | Employees gatherings and team building
-Freedom to choose professional training subjects
-Free sports and physiotherapy, etc | Employees receive much information regarding sales, objectives. We want them to share our mission. | Employees are motivated. The questionnaires about organizational environment were positive. There are aspects that can improve. | From the beginning we give all workers information about the strategy and goals.
We try to give workers conditions to feel well and included in the team. | Continuous improvement mindset of all workers, practiced every day. |
| 15. Employees' freedom and autonomy to contribute with ideas. | Continuous stimulation of the disruptive thinking and creative freedom. Methodology for innovation, Creative room, Awards for innovative ideas, etc | We launched an innovative project to all employees: they can give ideas to improve processes and products and receive rewards. This stimulate creativity | Ideas management system is implemented. With strong incentives that reward employees that present innovative ideas. | There is a box where people can leave anonymous suggestions to improve the workplace. | Employees have freedom to give ideas, which is something that motivates them. |
| 16. The Future of the company. Biggest challenges | Promising future in several business areas

Biggest challenge is the ability to keep up with the fast changes | To improve our strategy and achieve the 100 million euros turnover goal | Improving, becoming better, not bigger. | Our biggest competitors are in Portugal. Our challenge is in creating differentiated products with price-quality relationship | Increase turnover and continue the expansion plan to new markets |

Table 3 - Company Achievements and Practices
Elaborated by the author based on the interviews

Regarding employee's productivity, we can conclude that managers are putting more effort in employee's well-being with some stating that there is space to improvements.

Some companies put a great focus on employees' creativity and freedom to contribute with ideas and solutions. For instance, Bresimar an automation medium sized company that started with 3 employees and has currently 66, has been considered one of the happiest companies to work in Portugal being award consecutively best SME. The company has several practices implemented that focus on the well-being and creative freedom of the employees such as: The creation of a platform where all employees can develop ideas and share them. Also, in the beginning of each working year each individual can decide which subjects want to learn about and have professional teaching. Besides, the company gives autonomy to choose break-times, and has physiotherapy available for all workers.

The Head of Innovation department underlines the importance of creating the right atmosphere where people feel well and integrated, an environment that stimulates creativity and innovation strike within teams.

Innovation	Bresimar	Gres Panaria	Oli	Primagera	Vista Alegre
17. The Porter report in 1994 reaction.	*There were many changes in the 90s. The company defined a new strategy, focused on the commercialization of automated systems. Focus on new markets, and the necessity to create new departments.*	*(Cannot answer)*	*No impact. The ADM was very reluctant to those benefits.*	*There were no significant incentives to ceramics industry*	*Vista Alegre was well established on that time. There was no impact.*
18. Innovation Department: creation and nº of employees	*The IDT department was created in 2007, with the support of investment projects. On that time, it was constituted by 4 people. Today we are 14.*	*Created in 2011, with 7 people. Focused on product, design innovation and sustainability.*	*The innovation department has 1 worker that coordinates innovation with other departments*	*It was created in the year 2000 with 5 employees. 4 have a bachelor's degree*	*Marketing and design department is responsible for product innovation. 15 people.*
19. Annual investment in innovation.	*Around 5% of the financial budget.*	*PT 2020 investment of 9 million*	*Certified by NP4457 Around 2 million euros*	*not answered*	*The budget for innovation oscillates each year.*
20. The company's role on innovation	*The company is a follower in innovation, given the high risk associated to the sector (automation).*	*Our focus is on incremental innovation*	*Our goal is to be leaders in innovation despite the obstacles*	*Incremental innovations. We have our own way of innovating.*	*Leaders in the sector in Portugal* *Innovation leader in products and processes.*
21. Types of innovations	*The rebranding, the creation of an innovation department, the commercialization of new products, the creation of two brands in 2010, and the internationalization.*	*The company is Pioneers in the Marketing strategy In the sector "emotional marketing"*	*new product- moon black, control plate*	*No relevant innovations (just improved processes)*	*In design, functionality, quality and product sustainability Process innovation that aims energy efficiency and sustainability*
22. Incremental or disruptive innovation	*The innovations are incremental*	*Focus on incremental innovations but some innovative products*	*Incremental and disruptive*	*Incremental*	*V.A. created new products and the most innovative and competitive factory at global scale.*
23. Factors that contributed to company's innovations	*The rebranding process created a new brand identity. The 2008 crisis decreased the sales, so the company had to find new opportunities. That triggered the investment in innovation and new partnerships. In 2000s, it was created a technological department, possible due to knowledge acquired from the contact with prestigious brands throughout 20 years.*	*Brand restructuring that allowed the conception of an emotional marketing* *The company had the know-how, but Italian group helped to improve brand communication.* *-3D printing is a game- changing tech. In ceramics*	*Knowledge of the market, right interpretation of costumer's needs. Courage to do things differently*	*No relevant innovations so far.*	*To win projects, we had to become the most competitive players. We created the most innovative factory at global scale, and it worked.*

Table 4 – Innovation Management
Elaborated by the author based on the interviews

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Some of the companies interviewed consider themselves leaders in innovation in some areas, but most of them have a focus on continuous and incremental innovations rather than disruptive, with concern on product development and design improvement.

According to some companies, innovation is being more systematically implemented in a continuous way, especially since the beginning of 2000s. Due to technological advancement factors such as the digital revolution which is a continues process (with some mangers stressing the game change that was the introduction of 3D printing in ceramics sector).

Managers also mention the role of investment on innovation with European funds materialized in the industry 4.0 and Portugal 2020 as important catalysts of innovation growth.

Despite some incentives on innovation, company leaders stress the barrier in the legislation that does not favor the patenting of inventions thus, innovative processes are sometimes slowed down. This is due to the heavy bureaucratic system in Portugal that creates constraints in the implementation of innovation.

Companies are relying more on innovation not only to achieve differentiation, but also to decrease energy consumption and environment impact.

Most interviewed companies such as Vista Alegre, have a design department totally focused on product and design innovations.

Also, in a ceramics company one manager mention that the innovation department was created only in 2011 and before that, innovation was merged with marketing into one department. Since the creation of the innovation department with a team dedicated solely to the continuous investigation on product and processes development, some important innovations were created such as: products that use less raw materials without compromising the quality thus less energy consumption. In the case of

Primagera, the firm mention their goal and priority to improve product design and quality while including all production wastes in product composition. Therefore, investment in R&D has a key role in achieving sustainability goals.

Bresimar has shift its innovation model from a more linear and closed one to an open innovation model, which will benefit from external sources such as scientific and technological investigations, business partnerships, etc.

Another manager underlines the importance of technology tools such as the augmented reality for the marketing strategy of the company, especially during the coronavirus pandemic restrictions. Despite the presence of isolated applications of augmented reality have been around for decades, only recently technologies required to unleash its potential, have become available. Many companies base their marketing strategy in tradeshows and physical events with costumers. Primagera has a particular marketing campaign and communication that organize exciting experiences for costumers every year,

such as race cars, etc. Those events demand a considerable investment in different countries creating some obstacles, so augmented reality becomes an important tool that allows companies to take advantage of the big data they possess designing virtual environments and creating costumers' interactive experiences without the limitations of the physical world.

Innovation	Bresimar	Gres Panaria	Oli	Primagera	Vista Alegre
24. Current innovation model	*The open innovation models.* Interactions and knowledge share. The current model was an evolution of the linear and closed model where "secret Is the soul of business"	Continuous Technological innovation + Improving Sustainable processes and products	Innovation model where some projects are developed outside the company, in partnerships with consultants or subcontracts with the coordination of our innovation department.	Technological innovation. Investigation to improve materials and use all the residues created. Lab with 5 ceramic engineers	Strategy of Internationalization and innovation. Product innovation was the fast way to gain competitive advantage. But organizational innovation is our goal as well.
25. Challenges to the implementation of innovation management	The speed of technology development and product cycle challenges.	The lockdown has increased the necessity to innovate.	People management	The number of orders (high volumes of IKEA) and Internal costumers demand very customized and creative products in short- time	Weak innovation financing. Creativity to develop ideas is also a challenge.
26. Biggest opportunities	To create the right environment that favors creativity. There is some resistance of employees to strategic changes. Opportunities of 4.0 industry, such as process automation, etc	-The amount of data available, -Digital tools that allow interaction and better insight of costumers -Augmented reality	To become leaders in solutions we are developing to attract powerful partnerships and costumers.	Product differentiation through design-creativity is key. The proximity to costumers.	We are present in 80 countries, there are more markets to enter.
27. Possibility of a cluster?	There is not much cooperation among companies of the same sector.	There is know-how for a cluster creation in Aveiro, but there's no cooperative culture, not only in ceramics sector.	There is no organized cooperation. Aveiro could be a rich region with a powerful cluster but organizations and the university are against each other.	We have a good relationship with other firms. Partnership with Vista Alegre in big commercial projects.	Vista Alegre has helped to create a collaborative chain with other companies such as Primagera. This way Portugal can have large scale projects.
28. National and European incentives for innovation	There are several European and national programs, that help to leverage innovation activity.	They focus more on SME. We try to apply to the ones available to leverage the competitivity	The problem is not in the incentives and legislation, it is in firms and people	Incentives target more SMEs But there are some EU, specific for innovation.	There are some EU incentives and PT 2020, which has helped to leverage the business at a global scale.
29. The influence of Legislation and regulations on innovation	There is space to improvements. Much bureaucracy.	We subcontract consulting firms to deal with the bureaucracy. The RGPD has created obstacles	(check answer 20.)	Our certification hasn't changed from PME to large firm. (slow processes)	The legislation has been an obstacle. It is very difficult to create new units and patents. Much bureaucracy.
30. Company's innovation strategy for the future	Automation of processes, so that in the long-term allow the creation of disruptive products, with the goal to reach new markets and industries.	-Continue to create innovative events that offer different experiences and impact costumers. -Continuous innovation and high-quality products	Inclusion, sustainability, connectivity, digitalization and AI	Continue with Technological innovation. And digital investment in 2021	Increase internationalization, sustained on product and processes innovation

Table 5 – Innovation Management
Elaborated by the author based on the interviews

The know-how gathered throughout many years, helps to explain why these companies excel in their activity, and have survived and adapted well to the economy fluctuations and society changes.

Despite the incredible source of technical and human capital expertise companies possess, managers and directors express their opinion regarding the lack of cooperation among firms of the same sector. Most Directors agree that Aveiro could have a powerful cluster where knowledge-based companies would implement some characteristics of an open innovation model communication, benefiting from a level of mutual help. However, firms and institutions are not established within an organized cooperation, therefore the creation of a cluster becomes difficult. In the interviews one Director stresses that not only companies "*are against each other, but also academic institutions and other organizations.*"

Gres Panaria manager mentions that in 2006 when the Portuguese company was acquired by the Italian Panaria group, Portuguese workers were surprised by the relationships that the Italians stablished with other companies of the same sector and the knowledge and information they shared. That was a significant change in the mindset of managers that the external influence brought.

Primagera mentioned their goal and priority to improve product design and quality, while including all production wastes in product composition. Therefore, investment in R&D has a key role in achieving sustainability goals.

Bresimar has shift its innovation model from a more linear and closed one to an open innovation model, which will benefit from external sources such as scientific and technological investigations, business partnerships, etc.

Artificial Inteligence	Bresimar	Gres Panaria	Oli	Primagera	Vista Alegre
31. Presence of AI in the company past and present	In the 80s there were some automated systems, but only a few companies had access to them. Nowadays, we have several AI systems	Automated AGVs

Quality control in assembling lines,

Predictive analytics for marketing (identify trends and costumer preferences) | 20 years ago, there were some simulation programs that allowed virtual prototyping. | In 72, clay was hand built. Nowadays assembling lines are automated. | Intelligent sensors, predictive algorithms, 3D printing, |
| 32. AI systems implemented in the value chain | *HR*- Hiring algorithms *Technological development*- data analysis and predictive maintenance *Sales*- supplier performance system *Logistics*- intelligent warehouse *Marketing*- content personalization | 3D printing

Robots are empowered by Machine Learning, and computer vision algorithms | The company is still giving the first steps in artificial intelligence | Human resources employee's recognition AS400 for orders. | R.S. factory is 100% Automated. Sensors in cameras, scales, etc, collect data in real- time. Big data allow to monitor operational indicators that help in decision making. Algorithms help us to improve processes. |
| 33. AI systems that have contributed to the growth of the company. Future acquisitions | It hasn't been implemented yet, but the CRM with AI to create costumer profile. | -2008 marks a turning point with 3D printing -Automated process monitoring in 3D printing using machine learning | Machine learning algorithms implementation soon. | -We want to Implement 3D printing with AI -Deepening automation | Predictive analytics, AI in voice of the costumer, 3D printing. |
| 34. Impact of AI in the innovation management processes | AI is still in its early stages in Bresimar. The company aims to implement CRM and robots to perform tasks in costumer's reception. | -AI allows to get a deeper understanding of clients -The way we communicate with clients. | Still not perceptible, but the potential is huge. | All information shared through the digital system improves communication among people and departments | Online tools improve customer information, and the efficiency of operations. |
| 35. Main changes in the organizational structure | Organizational culture focus on innovation. implementation of methodologies in all structures of the company. All workers have access to company's knowledge and information so that innovation can come from everywhere. | Processes are changing.

Helps eliminate the "guess" work

AI is making big data actionable | No significant changes. | Nowadays we invest more in academically qualified people. There have been some changes in the structure. | We try to innovate in all activities and departments. |
| 36. Influences of AI in the marketing strategy | -Business intelligence tools that will impact marketing strategy | - Data analysis - Augmented reality has been an important tool to interact with clients. Allows for more creativity. | -Apps and YouTube advertisement. Some projects in mind. | We plan on introducing more marketing tools. Our strategy is based on tradeshows and newsletters | Predictive analytics to serve personalized recommendations Our online product selling has tripled in the last months |
| 37. How AI is changing the business | In this changing phase, it is still not very noticeable, although there is an increasing interest in AI systems. AI will soon change processes and business models. | -AI is creating a better understanding of the costumer, improving marketing strategy. -Automated factories. | If we can achieve our current objectives, changes will be big and fast | From the moment we change to digital creation and 3D printing, AI will have more impact in the company | |

Table 6 – Artificial Intelligence
Elaborated by the author based on the interviews

The automation in assembly lines has been introduced in the ceramics sectors for some time. Vista Alegre developed a 100% automated factory in which the technical equipment structures such as sensors, cameras, scales, among others are equipped and rely on sensorial based machine learning applications, to monitor the main operational indicators such as: quality control and efficiency of equipment on real-time. This information provided on real-time is crucial in the support of decision-making in order to anticipate and avoid problems. The collection of this incredible amount of Big data also allows managers to make statistical inference and creating predictive algorithms, continuously improving the operational efficiency.

One company mentioned the automation shift that took place in the last 20-30 years in production with some assembly lines nearly 100% automated. Automation is also being applied in the quality control, with robots being now responsible for the entire quality control process, a job that used to be done by humans.

In the quality control process, there is a system that takes a lot of images of the product while on the assembly line. Then, it makes those images searchable and comparable, and for last it applies learning and reacting to the assembly line data so that engineers can prevent future product issues. These systems process automatically hundreds of units and identify the most interesting issues in seconds. In the near future, the company will alert engineers directly when discovers anomalous units.

The author believes that technology and AI systems are being a catalyst for companies to rethink their innovation models as many AI systems required large volumes of data to improve. Therefore, information needs to be available and AI might have a key role in unleashing more cooperation among companies and organizations.

Besides manufacturing the author concludes that one of the main areas where creativity and innovation is being influenced by AI is the marketing department, with managers disposing of amounts of data like never before, as well as predictive analytics that allow them to know costumers' preferences more accurately.

Some managers think that AI will continue to change the way companies advertise as most digital advertising strategies would be almost impossible without a rudimentary AI system nowdays. Not long ago, marketing strategies relied on creativity, nowdays is about knowing the data.

Chapter 5 – Conclusions, Limitations and Contributions

5.1 Conclusions

As it was presented in chapter 1, three research questions were formulated with the aim to answer the research objectives, being the main research goal of this work to understand the influence of Artificial Intelligence in the Innovation Management processes of companies. To support the research, a sample of five Portuguese companies were analyzed.

In this chapter the conclusions of each research question are presented.

1st Research Question

- Are companies using innovation as a management capability?

One of the objectives of the research is to understand if Portuguese companies are innovating. And if yes, if they are investing in innovation not only as a technological capability but from the management perspective, embedded in all activities of the company and having the contribution of not only internal but external agents. According to the results innovation is indeed a non- linear, continuous and mutable process influenced by many internal and external factors. This idea is also presented in the literature (see e.g., Trott, 2017).

Some of the companies interviewed in this research such as Bresimar, state that there was an evolution and a shift in the paradigm specially since the 2000s regarding innovation models.

The company has implemented an open innovation model, with the manager saying that" it contradicts the Portuguese saying that" the secret is the soul of business."

This conclusion is corroborated by the same author Trott (2017) and European Union (2020)

that claim companies can no longer innovate on their own.

Nowdays all companies have an Innovation department with most firms mentioning that it was created only in the years 2000s.

Some firms refer that their perspective of innovation changed from a more technological capability to a managerial one, transversal to all activities.

All companies invest a considerable percentage of their budget on innovation each year.

Chesbrough and Bogers (2014) corroborate this idea by stating that recently many innovation models have been developed, but what all of them have in common is the open innovation concept. Chesbrough (2003) opened the way for the open innovation model with many scholars considering that his contribution created a new paradigm for the analysis of the innovation process. Open innovation encourages companies to open up their innovation process, giving up their closed and hierarchically rigid processes.

There was one company (Oli) that despite not having an innovation department has one innovation manager responsible for the control of innovation processes, being the linkage among the departments that contribute to the process. As approached in the chapter about innovation literature, Yasini (2015) refers the strategy of connecting all the departments through one innovation manager, as being one important component of innovation management.

According to European Union (2018) larger companies (the target of this research are medium and large companies) tend to be more innovative. From the analysis of the interviews, we can conclude that companies in this case study are indeed innovative. All companies mentioned that the majority of their innovations are incremental, but according to Aseev and Katsumoto (2020) small incremental innovations can have a smaller outcome than a radical one, but often their cumulative outcome is bigger.

The author also concludes that there are some obstacles that companies analyzed in this work have pointed that influence negatively firms' capacity to innovate and therefore must be addressed. These constraints are corroborated by the European Commission Report (2020) on Innovation Performance of Portugal as it was approached before in this work.

Such constraints are as follows:

• The lack of an organized cooperation among firms and other organizations.

According to European Union (2020) cooperation among companies that are organized in clusters increase significantly company's innovation actions, outputs and productivity.

In the interviews, some Directors mentioned that Portuguese companies have not embedded in their culture a cooperative policy, with one Director stating that "companies and other organizations are against each other".

Bresimar Innovation Director mentions the secrecy that prevails among companies of the same sector. In the case of this medium size firm which operates in the technological sector, not being involved in a cooperative and technological environment creates some limitations. For instance, Bresimar electronics brand Tekon is having a hard time penetrating in the external market due to its competitors being worldwide leading brands.

Despite that, there are some examples of mutual cooperation, such as Vista Alegre case that due to its great logistic operations capacity have established partnerships with other Aveiro companies such as Primagera. These partnerships are of key importance since otherwise, Portuguese enterprises would not possess enough production capacity to be involved in some global scale projects.

The second constraint to innovation management is:

• The bureaucracy burden and patent registration problematic.

Most of the managers interviewed complain about the excessive bureaucracy in Portugal that creates constraints in the innovation processes. According to European Commission (2020) which

corroborates the analysis that patent registration is a slow process in Portugal and can delay the implementation of innovation. This can have other negative effect of jeopardizing the cooperation among companies. If companies have the support of government in registering their innovations, then they can more easily cooperate with each other. As supported by Gallaud and Nayaradou (2012) using various means of legal protection strengthen, when firms cooperate with various partners. Failing to address these issues will compromise the innovation performance of Portuguese companies.

The third constraint to the innovation capacity of Portuguese companies is:

- Workers resistance to the implementation of innovation.

The European Commission (2020) mention that Portugal still has a high percentage of low educational attainment comparing to other European Union countries.

Two managers mentioned that there is sometimes resistance of workers towards the implementation of some ideas and processes. Companies should have a proactive role in decreasing that resistance, by investing continuously in workers technical skills and education on different subjects such as AI. Firms must have as a main priority the human capital investment as it is supported by European Union reports (2020).

2ⁿᵈ Research Question

The second research question is:

- What is the impact of Artificial intelligence in the innovation management of companies?

According to Haefnar et al. (2020) the main potential of Artificial intelligence lies in deep learning subfield algorithms that have the capacity to" train" and improve their performance only possible through the use of large datasets. By processing multiple layers of complex data, creating insights and unlocking the potential of data that humans could not process on their own.

This skill allows researchers to conclude that a new general method of innovation was created: deep learning.

Cockburn, Henderson and Stern (2018) corroborate this idea that the learning capacity of deep learning allows AI to be used as a transversal innovation tool in the support of R&D and other stages of innovation management, influencing how innovation is indeed practiced.

According to the interview results, companies such as Vista Alegre are taking advantage of this general method of innovation by implementing AI systems in components and devices to control the manufacturing process and spot malfunctions. By detecting product defects managers can give accurate and fast feedback to other departments such as Research & Development. This way, Artificial Intelligence systems help to improve the efficiency of product and design innovation processes.

AI systems are impacting product and process quality, decreasing de-routinization of jobs and allowing managers to be more focus on creativity and conceptual related tasks.

In this research it was also possible to conclude that artificial intelligence is being progressively included in companies' activities. But there are many challenges businesses face.

3rd Research Question

- What are the main challenges and implications for companies regarding the implementation of AI systems and Innovation?

According to the results, the three companies of the same sector were consensus about the strong market competition, specially the external one and the necessity to continue innovating.

All companies agree on the transition that is taking place regarding AI systems, and they are aware about its potential that can improve operations namely in the marketing department, R&D, etc. Companies recognize the game changing nature of AI and have started to include these systems in their operations.

Authors such as Cockburn et al. (2018) stress that Artificial Intelligence systems need to be seen and adopted from the perspective of business capability as a general method of innovation. But for AI potential not be missed, companies will need to invest more on employees' skills and improve their capabilities of key employees like data scientists, who have statistical and big data skills (European Commission, 2018).

For last and establishing the linkage between the two main subjects of this research which are Innovation Management and Artificial Intelligent concepts, European leaders have put Artificial Intelligence on top of their agendas, with the European Commission (2018) encouraging countries and companies to step up investment on innovation and research on Artificial Intelligence. Alerting for the risks of losing out on the opportunities offered by AI which can have consequences for Europe, by becoming a consumer of solutions created elsewhere. Therefore, the EU should become a research powerhouse applying innovations in the market.

5.2 Limitations and contributions

There are some limitations in this research, due to the case study being limited to only 5 companies with three of them belonging to the same sector of ceramics and other two of other sectors.

The interviews were conducted only to one person representing the firm (being these people in leading positions in the company). Therefore, the author is aware that the results might be biased by the interviewees personal opinions and so, the results might not be used as representative example of the Portuguese reality.

However, if we consider the contributions of this research, we can find relevant contributions namely regarding the influence that Artificial Intelligence systems are having in the innovation models in Portuguese companies. Also, this research contributes to some knowledge of three companies that operate in the same sector, ceramics, that is indeed very relevant to the overall Portuguese exports.

This work opens the path to a more detailed research that considers a more comprehensive number of Portuguese companies in the analysis, also including SMEs.

Chapter 6 – References

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Annex A

Interview Script Directed to the Companies of Aveiro Region

The following interview is integrated in a research work developed in the context of the Master thesis in Business Administration of ISCTE-IUL. <u>The data collected is confidential and will be exclusively used for the purpose of the research.</u>

Interview Script

Introduction

The primary data will be collected through semi-structured interviews, that aim to gather information from companies' CEO's and managers responsible for the innovation processes and departments.

Objectives

The objective of the present interview is to collect information regarding the impact that Artificial Intelligence systems have in the innovation management models, in the context of companies that operate in Portugal.

Interview plan

<u>Interview location</u>: Through video call (recorded) by zoom or as suits the interviewee better.

<u>Time:</u> The interview should take between 50 to 60 minutes

Interview Questions

<u>Characteristics of the Company</u>

1. The business area of the company.

2. Year of foundation.

3. What is the company size category? Small, medium, or large.

4. What was the business turnover in 2019? Percentage of company growth in the last years (%)?

5. What is the current number of employees? What was the number of employees when the company was founded?

6. What are the educational qualifications of the employees? Percentage or number of people with higher education degrees (bachelor, masters, PhD, and other levels)

7. What are the best-selling products?

8. What is the percentage of exports?

9. What are the main competitors in the present and past? (Internal and External)

10. What were the main obstacles and challenges for the business growth of the company in the past? What are the main challenges in the present?

11. What are the main obstacles to the company's growth in Portugal and worldwide?

12. About awards and recognitions, what are the most important ones that the company achieved?

13. If you could select one, what was the company's greatest achievement in the last years?

14. How is it to work in the company? What are the company policies and practices implemented that aim to motivate and engage the employees? Do those practices involve all the workers?

15. Do employees have any freedom and autonomy within the teams to contribute with ideas? Is that a subject that the company look to develop and promote, as being of key importance to the success of the firm? (The role of each employee in the goals and mission of the company)

16. Where do you see the company going? What do you think will be the biggest challenges in the future?

Innovation

17. In 1994 the Porter report defined the most important clusters in the Portuguese economy. On that time, financial incentives were created to promote innovation and investigation industrially oriented. Did the company benefit from any of those incentives or plans? Were there any changes?

18. Does the company have any innovation department? If so, when was it created? How many people take part in it?

19. What is the annual investment in innovation?

20. Is the company a leader on innovation or just a follower?

21. What are the types of innovations that the company has implemented? (Regarding process, product, marketing, or organizational)
    Did the company create a new product or process?

22. Are those innovations incremental (small improvements), or disruptive (completely new and challenging incumbent firms with better prices)?

23. What factors contributed to that innovation, regarding technological innovation, or innovation management processes?

24. What is the current innovation model?

25. What are the main challenges to innovation management?

26. What are the biggest opportunities?

27. Is there a possibility of a cluster creation?

28. Is there any kind of national incentive for innovation? What about incentives from the EU?

29. Regarding legislation, do you consider that the country facilitates and promotes innovation plans of companies?

30. What is the company's innovation strategy for the future?

Artificial Intelligence

31. When the company was founded Artificial Intelligence had no expression. What changed since that time?

32. Examples of AI systems implemented in the value chain.

33. Is there any AI system that the company defines as being determinant to the company's success/growth? Any future acquisitions in mind?

34. Establishing a comparison with the past, can you explain (with concrete examples) the impact and the way how some AI systems are affecting and influencing the innovation management processes in the company?

35. What are the main changes in the organizational structure, (in leadership, creative processes, interdepartmental communication, human resources, knowledge management, etc.)?

36. In the marketing department, how are AI systems influencing the marketing strategy of the company?

37. How is Artificial Intelligence changing the business?

Is there anything else you would like to add to the interview?