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The transformative impact of Artificial Intelligence on overall firm's performance and the role of the Lean and Agile supply chain in mediating this relationship

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INTRODUCTION

The integration of artificial intelligence (AI) into business processes has revolutionized many industries by automating tasks, improving decision-making processes and customer relationship skills. This thesis examines the impact of AI in business areas, providing valuable insights into its current applications, present and future trends of this technology. The aim of this paper is to explore the advantages and benefits of integrating AI into business operations, offering new opportunities for growth, innovation and improved decision-making processes. As AI technology continues to evolve, it becomes increasingly important for companies to understand the opportunities and challenges associated with its implementation. This paper provides a comprehensive overview of the impact of AI in business areas and serves as a useful resource for understanding the opportunities and challenges associated with its strategic integration and application.

To excel in the competitive market and in a dynamic environment, companies need to continuously adapt to change by developing a flexible and agile organizational structure that can readily cope with obstacles and uncertainties. This adaptability enables companies to respond effectively to changing market conditions, technological innovations and customer expectations. In this context, the adoption of artificial intelligence plays a crucial role. Indeed, AI enables companies to develop and strengthen their dynamic capability to integrate, develop and reorganize internal and external resources and competencies to effectively respond to the rapidly changing business environment.

The present study seeks to contribute further empirical evidence to the current literature by examining the impact of AI technologies on firms' performance and focusing on the interaction between AI and the mediating variables represented by Lean and Agile supply chain practices. These are recognized for their ability to improve operational efficiency and flexibility and play a crucial role in determining the success of modern business strategies. Accordingly, the main objective of this study is to explore how the adoption of AI technologies can influence business performance and, more specifically, how lean and agile supply chain practices can mediate this impact.

Using advanced statistical models, this research aims to provide an in-depth understanding of the dynamics described, thus offering valuable insights into how organizations should implement strategies focused on the use of AI technologies to achieve better performance and thus be able to maintain a competitive edge in the target market.

Specifically, the organization of the study follows this scheme. *Chapter I* serves as an introductory section, providing an overview of the landscape of technological solutions in corporate environment.

This chapter discusses the increasingly central role that artificial intelligence technologies are taking in the context of industry 4.0. It describes how the integration of AI within corporate boundaries enables the development of business skills in crucial areas such as process automation, advanced data analysis and relationship building. As a result, this allows organizations to improve operational efficiency, make decisions based on more accurate insights and manage interactions with customers and partners more effectively. *Chapter II* entails a comprehensive literature review of the phenomenon. This section scrutinizes the importance of developing dynamic capabilities that allow for adaptation to the complexity of the environment in which organizations operate and provides an overview of the importance to adopt Lean and Agile supply chain practices. A significant focus of this chapter lies in investigating how the implementation of AI within companies is revolutionizing the way the supply chain is managed and how its use is boosting overall business efficiency. Finally, *Chapter III* is centered on the empirical investigation of the impact of AI technologies on firms' overall performance. It proposes the research questions addressed in the study, constructs a conceptual framework, outlines the methodology employed and the data collection process, delineates the variables incorporated into the analytical model, and discusses the primary findings derived from *Partial Least Square* (PLS) analysis.

The section *Conclusions* synthesizes the findings presented in the previous *Chapters*, presenting a complete framework for understanding the phenomenon analyzed.

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CHAPTER I: The evolving technological landscape in corporate environments

1.1 Industry 4.0 based technologies

The spread of technological innovations and digital advancement have laid the foundation for the introduction of a new model in the global economic landscape, culminating in what is now commonly referred to as Industry 4.0. Also recognized as the fourth industrial revolution, it fosters the modernization of manufacturing through greater connectivity between machines, tools and workers. Throughout history, four major industrial changes can be identified that have generated discontinuities compared to previous reference periods, among these Industry 4.0 is the latest and still ongoing.

In exploring a comprehensive overview of the succession of events that have characterized the modern and contemporary age within the global economic and industrial landscape, it is essential to consider the First Industrial Revolution. Located between 1760 and 1840, it marked a period of intense industrialization, distinguished by the use of the steam engine and the introduction of new textile and metallurgical technologies. This first wave of change was followed by the second Industrial Revolution, characterized by the introduction of electricity into industrial processes in the late 19th century. Finally, the third Industrial Revolution, which began in the 1960s, brought with it the use of information and communication technologies (ICT) and industrial automation, marking further points of discontinuity in the economic and technological development worldwide. These events paved the way for what is today known as Industry 4.0, which emerged in various developed countries and consolidated into actions aimed at creating smart factories through the integration of physical objects with digital technologies.

I4.0 is to be considered a far-reaching phenomenon that encompasses a series of developments such as the integration between systems, the distribution of decision-making power, instant data processing, as well as all the most advanced technologies that allow companies to put these models into practice (Kagermann & Wahlster, 2022). Analyzing the phenomenon, researchers highlight that Industry 4.0 promotes the implementation of activities and business logics that lead to significant development in logistics and supply chain management. In particular, the tangible effects of this strategic approach to digital innovation are evident in the way new technologies and process innovations aim to optimize production and business processes, resulting in reduced production costs and, consequently, positive effects on productivity.

There are two main categories into which Industry 4.0 technologies can be classified: front-end technologies and core technologies. The first category includes a series of developments related to advanced manufacturing, product offerings, horizontal integration, and human-machine interaction, specifically including technologies that enable users to interact with digital systems and industrial infrastructures. The technologies defined as core, which constitute the heart of the phenomenon and act as orchestrators for the various systems, include instead specific innovations such as cloud computing (CC), the Internet of Things (IoT), big data analytics (BDA), and artificial intelligence (AI). These emerging Industry 4.0 developments are essential because they bolster, offering business seamless connectivity and advanced analytical capabilities. The I4.0 core technologies facilitate the collection, storage, processing, and intelligent sharing of data, enabling operations to achieve high precision and efficiency, often with minimal or no human intervention.

These foundational technologies are crucial as they form the basis of processes essential to the development of Industry 4.0 principles and for the integration and connection of production systems. Each core technology of Industry 4.0 has unique characteristics that complement each other, creating a robust and integrated interconnection. In this environment, IoT tools enable the connection of devices and sensors, offering instantaneous data regarding the attributes and location of physical objects, while big data analytics (BDA) provides technological solutions for processing and analyzing data, identifying trends, and optimizing decision-making processes.

Industry 4.0 acts as a catalyst for innovation by increasing the availability of vast databases for companies through the use of intelligent algorithms. These databases support big data analytics, facilitating the creation of innovative products and services that promptly meet market demands. These benefits can be further enhanced when integrated holistically with systems that allow on-demand access to services from external providers, such as cloud computing (CC). Cloud computing promotes data sharing and analysis through continuous network access and substantial computational power, offering a robust and flexible system for supply chain (SC) integration. The synergy and integration of these technologies drive innovation, enabling companies to gain a substantial competitive edge. (de Oliveira-Dias *et al*., 2023). This principle is essentially encapsulated in the key concept of Industry 4.0, i.e. the digitalization of production through the interconnection of different information and communication technologies (ICT), which at the same time connect these systems with production facilities such as machines, products, and devices enabling autonomous actions. In this context, a crucial element is the introduction of artificial intelligence technologies in the automation of complex business and production processes, moving employees from active participation in these activities to monitoring roles with a focus on tasks characterized by high added value contributions. In the Industry 4.0 landscape, the interconnection of technologies and features

such as real-time capability, interoperability, and the horizontal and vertical integration of production structures through ICT systems represent key factors. When implemented correctly, these elements allow companies to achieve significant performance benefits through the reorganization and transformation of business processes. This leads to the creation of innovative products and services that better meet consumer needs, shifting the focus from standardized mass production to customized mass production in the manufacturing sector. Indeed, the interaction between machines and products enables the establishment of adaptable and flexible production lines, which can produce customized items even in small quantities. The idea of Industry 4.0 includes various technologies that can manifest in numerous forms. Especially, its key characteristic includes both the integration of Information and Communication Technologies (ICT) and their connection to all production infrastructures, including machines, products, and devices. The synergy of these elements is made possible by the adoption of Cyber-Physical Systems (CPS) in companies. These systems link physical operations with the digital infrastructure using sensors embedded in production facilities that, being connected via the Internet, have the ability to exchange information, communicate, initiate actions and monitor themselves autonomously. By introducing this new approach of designing the entire production process and adopting emerging technologies such as artificial intelligence, greater automation of production and business processes can be achieved. An increasingly relevant aspect is that employees are no longer directly involved in operational activities but rather take on a monitoring role, due to the increased automation of processes.

Following these considerations, it is possible to outline the salient features of industry 4.0 in four fundamental principles. These principles include interoperability, which refers to the seamless exchange of information between different technologies and systems; information transparency, which ensures that data is accessible and understandable in a clear and open way; technical assistance, which facilitates the transmission of technical knowledge and relevant data between the various parties involved in the production process; and finally, a decentralized decision-making process, which allows for greater flexibility and timeliness in decisions (Brettel *et al*., 2014).

Industry 4.0 is a way to achieve and sustain superior performance through the creation of competitive products and services, as well as the design of robust and adaptable logistics and production systems. The ability of companies to compete and thrive in their markets depends on their ability to adapt to ongoing changes, effectively addressing current and future challenges. Increasing product and process complexity, volatile markets, and shorter product, market, technology, and innovation cycles require companies to develop flexible infrastructures on which to innovate and create new products and services. This approach improves performance, thus obtaining a sustainable competitive advantage over time (Sarbu, 2022).

In this context, Industry 4.0 is today considered a new industrial era driven by increasing digitalization within companies, particularly in manufacturing processes, with the diffusion and adoption of production technologies as its foundation.

The integration of information and communication systems within industrial contexts has significantly enhanced companies' strategic and operational decision-making processes. The development of interconnected systems, aimed at monitoring and controlling equipment and products through the collection and use of large quantities of data, has made it possible to transform organizations into intelligent environments. This advancement has facilitated the development of adaptable manufacturing processes and real-time analysis of large datasets.

Considering the beginning of digital production, which has been widespread since 1980, several technologies have emerged in the industrial economic landscape. This has led to a series of significant evolutions that have radically transformed the way companies operate and compete in the global marketplace, including artificial intelligence. The latter, especially, has become increasingly integral, revolutionizing multiple aspects of production processes with its ability to optimize operations, predict maintenance needs and improve decision-making capabilities. Adopting an approach that reflects the concept of Industry 4.0 offers numerous advantages to companies. Especially, they will be better able to optimize the use of resources, improving overall operational efficiency. Furthermore, strengthening decision-making processes allows companies to quickly adapt to changes and unexpected events, ensuring greater flexibility and responsiveness in the face of uncertain situations. Industry 4.0 represents a fundamental transformation in the industrial sector, characterized by three main pillars: vertical, horizontal integration and end-to-end engineering. Vertical integration facilitates the joining of ICT systems between the various hierarchical levels of an organization, promoting synchronization between production and management within production structures. Horizontal integration, on the other hand, promotes collaboration between companies by allowing the immediate exchange of resources and data, thus optimizing efficiency and responsiveness to market dynamics. Finally, end-to-end engineering aims to integrate the design and manufacturing process along the entire product value chain, from concept through to distribution, ensuring greater consistency and quality of the final result (Erboz, 2017). Industry 4.0's service-oriented approach, combined with horizontal integration, fosters the development of new business models, opening up new avenues for delivering and extracting value from customers. Through strategic collaborations, companies share resources and smartly adapt to market changes, increasing the likelihood of overcoming difficult times and offering customers superior value through highly personalized offers that improve their perception (Dalenogare *et al.*, 2018).

1.2 Artificial intelligence at a corporate level

Within the framework of Industry 4.0, artificial intelligence (AI) technologies assume a pivotal role. AI encompasses systems capable of data interpretation, harnessing computers and machines to augment human decision-making, problem-solving prowess, and technology-driven innovation. The wave of technological innovation, coupled with information systems integration and industrialization, makes the adoption of AI technologies imperative for companies. In the current landscape, it is crucial to adapt to ongoing technological advancements to maintain a competitive position. Advanced artificial intelligence technologies such as machine learning (ML), sophisticated algorithms, the Internet of Things (IoT), automation, and intelligent robotics are profoundly revolutionizing and redefining both business contexts and processes.

In the contemporary landscape, corporate management and executives are employing AI-driven business process engineering, exerting a profound influence on their global innovation processes. Specifically, companies are integrating AI technologies into their innovation processes to bolster capabilities and gain competitive advantages. In this context, where digitalization plays a central role, organizations must make significant investments in their IT resources. The increasingly widespread use of data analysis and artificial intelligence (AI), defined as "the capability of machines to perform cognitive tasks similar to those of humans" (Benbya *et al.*, 2020), is pushing companies to reevaluate traditional structures and logics. This requires a reformulation of the management and planning approaches within organizational frameworks. The focus shifts towards consolidating an evolving system that integrates existing computational capabilities. The ability to quickly adapt to technological changes becomes crucial for maintaining competitiveness. Companies must therefore adopt a proactive approach in updating their IT infrastructure, implementing advanced solutions that include automation, machine learning, and cloud computing platforms. It is essential for businesses to understand how to address the challenges posed by the proliferation of these new technologies to capitalize on emerging opportunities. Hence, it is fundamental for today's leaders to grasp the paradigm shift in how IT innovation generates value. Being able to leverage the technological advancements brought by artificial intelligence is vital for organizations to manage changes and remain competitive in their respective sectors.

Artificial intelligence equips organizations with advanced capabilities to automate operations, process data, conduct complex analyses, and interact directly with people. This enables them to effectively respond to dynamic market changes, automate and optimize various operational processes, thereby enhancing organizational efficiency and responsiveness. Through predictive analysis based

on artificial intelligence, companies can more accurately forecast market dynamics and engage customers more effectively by anticipating their needs and preferences. By analyzing large amounts of historical and real-time data, businesses can identify patterns and behaviors, enabling them to adapt their strategies promptly. This enhances their ability to respond effectively and swiftly to market demands, offering tailored products and services that directly meet individual expectations and desires (Huang & Rust, 2021).

During the 1950s, Artificial Intelligence (AI) emerged as an academic discipline, spurred by the surge of big data and intricate computations. In particular, AI has made its way into human lives and the social and corporate landscape through the advent of machine learning algorithms. The narrative of AI's evolution unfolds across three pivotal phases: Phase I (1940–1979) marked the nascent phase of AI, characterized by its beginnings, an era brimming with boundless enthusiasm and often regarded as its golden age. It was a period when the very notion of artificial intelligence ignited profound curiosity and optimism, laying the groundwork for future advancements. Transitioning into Phase II (1980–2010), AI experienced a remarkable surge, often dubbed as a boom. This epoch was defined by significant technological breakthroughs, paving the way for the emergence of intelligent agents. As AI technologies have matured, they have begun to infiltrate various aspects of society, revolutionizing sectors and opening up new horizons of possibilities. Finally, Phase III brings us to the contemporary AI landscape (2011−2022). In this phase, AI has become synonymous with concepts like deep learning and big data. The advent of sophisticated algorithms and vast datasets has propelled artificial intelligence into new realms of capability and application, highlighting its indispensable role in modern society.

By tracing the evolution of AI, it is possible to delineate three primary developmental stages. Firstly, the so called artificial narrow intelligence (ANI), also known as weak AI. ANI is task-oriented, proficient at executing specific functions. Essentially, it concentrates on achieving predefined objectives without possessing the breadth of cognitive abilities inherent to human intelligence. It resembles a specialized tool, skilled at its designated task but lacking in broader comprehension or adaptability. Advancing forward, we encounter artificial general intelligence (AGI), or strong AI. AGI represents the subsequent phase in AI evolution, embodying a level of intelligence that mirrors human cognitive capabilities. Unlike ANI, AGI possesses the ability to emulate human behavior, learn from experiences, and apply its knowledge to solve diverse problems. Essentially, AGI aims to replicate the versatility and adaptability inherent in human intelligence. Looking further ahead, there is speculation surrounding the emergence of artificial superintelligence (ASI), denoting the theoretical third generation of AI. ASI transcends the confines of human intelligence, exhibiting self-awareness and surpassing human cognitive capacities. In this envisioned future, ASI is not merely

adept at problem-solving, but it embodies traits such as scientific creativity, intuition, and general wisdom, potentially reshaping the very fabric of our existence. These developmental stages provide a framework for comprehending the trajectory of AI development, from its rudimentary origins to its speculative future. They underscore the profound implications of advancing AI technologies, prompting contemplation on ethics, societal impact, and the economic ramifications of this transformative field. AI was initially characterized as the challenge of "creating a machine that exhibits behaviors deemed intelligent if performed by a human" (McCarthy *et al.*, 1955). Over time, it has become a predominant concept in business due to its pervasive integration into human activities and business operations. The terminology surrounding AI is widely employed and often loosely defined in academia, leading to varying interpretations among experts across multiple disciplines regarding its nature and standardization in tandem with technological advancements.

A prevalent approach to defining artificial intelligence is through the lens of human intelligence. Often, it is described as a technology that enables machines to perform tasks that would typically require human capacity, thus accurately interpreting external data, learning, and using these insights to achieve predefined goals (Bahoo *et al.*, 2023).

AI holds the promise of enhancing business operations and bolstering efficiency, leading to enhanced product quality and faster delivery times. Furthermore, AI aids businesses in comprehending customer needs and preferences more comprehensively, facilitating the customization of products and services to align more closely with those requirements. This increased level of customization often fosters greater customer retention. Artificial intelligence enables companies to discover new revenue opportunities, whether through enhanced marketing strategies or innovative product development. By curbing costs and augmenting revenue streams, enterprises can elevate their profitability and overall financial performance. Additionally, studies show that artificial intelligence enables businesses to enhance accuracy in forecasting future revenue streams and identifying potential risks, thereby empowering them to strengthen and optimize their overall financial position. (Sahoo *et al.*, 2024).

AI represents the cutting edge of computational progress, drawing on human intelligence to address increasingly intricate decision-making challenges. Widely regarded as the most pivotal and disruptive innovation for organizations, AI is reshaping managerial practices by enabling profound performance analysis and the development of novel insights.

Recognized as a foundational asset, organizations are keenly embracing AI to harness its potential and gain competitive advantages. Given its transformative potential, investments in IT are deemed essential for successful integration into organizational core functions. In this regard, Information Systems (IS) constitute a strategic pillar for organizations, playing a crucial role in aligning IT efforts

with business needs. This process promotes the development of essential global capabilities for seamless integration and coordination across business functions, thereby enhancing operational efficiency, supporting business growth, fostering innovation, and ensuring competitiveness in the global market. Through an AI-enabled lens, focus gravitates towards three key capabilities aligned with crucial business imperatives: process automation, insights generation, and customer engagement (Davenport & Ronanki, 2018). These capabilities include AI-powered automation, advanced analytics, and relational skills. While interconnected, each capability serves distinct business functions, with unique advantages: automation excels in standardization, analytics in personalization, and relational capability in fostering robust relationships. AI-enabled automation streamlines repetitive tasks, enhancing output consistency and reliability. AI-driven analytics employs machine learning to discern patterns and derive actionable insights, facilitating informed decision-making. Unlike traditional analytics, AI-enabled analytics learns systematically from data, processing both structured and unstructured information to refine or acquire knowledge.

In conclusion, AI-enhanced relational capability facilitates direct interaction with users through chatbots and intelligent agents, promoting an enhanced user experience. This AI iteration adapts and learns from human interactions, refining its behaviors over time (Sullivan & Wamba, 2024).

Artificial intelligence emerges as a crucial technology to enhance competitive advantage and improve overall business performance. Its capabilities, such as data analysis, business process automation, and stakeholder interaction, enable organizations to streamline operational workflows and facilitate strategic decisions, including product research and development.

Considering these aspects of significant centrality, organizations are increasingly adopting business models configured around the use of advanced technologies within the realm of intelligent automation. By effectively responding to market dynamics and facilitating the achievement of predefined goals, artificial intelligence enhances production systems by improving their learning capabilities through data acquisition and analysis, thereby helping maintain a sustainable competitive advantage in the long term (Yu *et al.*, 2024).

1.2.1 AI-enabled automation capability

By deeply examining the capabilities of AI-related technologies, with a focus on automation, several distinctive benefits emerge. These technologies allow company personnel to focus on higher-value strategic activities, standardizing the most repetitive operations to ensure consistency and minimize execution errors. This approach strengthens organizations' adaptive response capacity to

market fluctuations and increases the company's overall productivity. By allowing employees to focus on strategic core businesses, the most repetitive and mundane tasks are eliminated, minimizing redundancies and inefficiencies to respond effectively to market changes. (Huang & Rust, 2021). In this context, the adoption of AI-based automation emerges as a crucial strategy enabling organizations to swiftly adapt to market developments by automating labor-intensive processes, thereby reducing production costs and associated risks.

Consequently, AI-driven automation enhances scalability, enabling firms to reallocate resources towards activities that create and capture value more efficiently (Sullivan & Wamba, 2024).

AI applications have found widespread utilization across manufacturing operations, encompassing production, planning, and control to automate processes. In response to uncertainty and disruptions, manufacturers must leverage knowledge gained from data analysis to develop effective response strategies and ensure business continuity. The integration of process automation through artificial intelligence allows companies to optimize their operations, enhancing their resilience through improved information management capabilities (Yu *et al*, 2024).

The realm of AI-enabled automation encompasses technologies that support structured and semi-structured tasks, which are often repetitive and labor-intensive, encompassing both physical and cognitive domains. Traditionally, robots have been employed for physical tasks in settings like factory automation. In the current scenario, the introduction of AI-powered robots has the capability to perceive the surrounding environment, learn, and interact, assisting humans in various tasks. This enables the automation of routine administrative tasks and, through machine learning, the analysis of extensive datasets to detect anomalies and enhance the efficiency and productivity of the development process (Benbya *et al*., 2021).

1.2.2 AI-enabled analytics capability

AI capabilities, including predictive analysis, comprehensive customer data evaluation, and tailored content generation, offer organizations a spectrum of digital possibilities. These avenues augment operational efficiency, alternative knowledge acquisition, and swift adaptation to dynamic market conditions.

AI-based analytical capabilities enable the development of refined problem-solving aptitude through the ideation of accurate decision-making solutions, bypassing the limitations characterized by human information processing. These developments, in which artificial intelligence technologies permeate the organizational fabric of companies, enable them to develop new strategies and quickly evaluate

possible future scenarios, improving the ability to explore new markets, innovate and accelerate the product development process and services. As a result, this innovative approach enables to support companies in dealing with market changes and, by extrapolating models from the processed data, allows them to offer personalization benefits to the customer resulting in the extraction of greater value throughout the product supply chain (Huang & Rust, 2021).

Adopting a proactive strategy to prevent problems and hypothesize future event trends can allow organizations to identify and exploit market opportunities, increasing responsiveness and consequently performance. Leveraging machine learning enables firms to make predictions and evaluate their accuracy in real-world scenarios. Moreover, monitoring users' behaviors and feedback enables the delivery of precise recommendations that reflect users' evolving interests over time. Because AI analytics tools provide data-driven insights, they furnish accurate and reliable information, enabling companies to flexibly seize market opportunities that might escape human detection alone (Sullivan & Wamba, 2024).

The ability of an organization to process and leverage information from internal and external sources is crucial for its success, especially in contexts characterized by rapid changes and uncertainties. In a dynamic environment, where market conditions, consumer preferences, and technologies are constantly evolving, the capacity to effectively gather, analyze, and utilize information enables accurate and timely decision-making. This enables the identification and anticipation of opportunities, helping to detect potential threats before they can have a significant impact. AI technologies enhance the ability to process information at various stages of the product lifecycle, as well as to forecast demand and manage uncertainties more effectively. This leads to improved decision process, making the organization more agile and allowing it to maintain a stable competitive advantage.

The application of artificial intelligence techniques enhances the company's information processing capacity. Through the collection of relevant data, their analysis and the extraction of useful information for interested parties in managing decisions, it is possible to mitigate operational risks deriving from uncertainties, contributing to improving company performance.

In this way, companies that adopt artificial intelligence tools benefit from the double impact that these technologies are able to bring. In particular, both the ability to plan ahead for crisis situations and to respond quickly to sudden changes and market challenges are strengthened. (Yu *et al*, 2024).

1.2.3 AI-enabled relational capability

In the contemporary business landscape, it is critically important for companies to keep up with the continuous developments in modern technologies. In particular, implementing a strategy that places artificial intelligence tools at the center of business issues enables them to continuously enhance products and services, navigating through changes that are increasingly rapid and uncertain. Compared to those previously discussed, an additional functionality enabled by artificial intelligence tools concerns the possibility of enhancing the relational capacity of companies through the use and understanding of data to interact and offer support to users autonomously, without human intervention. Through technologies such as chatbots, deep learning, and machine learning, users have the opportunity to benefit from immediate and continuous assistance from the company. In particular, when these technologies are used for user interaction, they enable organizations to confer numerous benefits. These include the ability to make the process by which the company communicates with customers smoother and more effective, to handle a large number of interactions in a personalized manner, and to maintain a resistance to frustration that is not pressing in humans. These benefits enable firms to carefully listen to users and skillfully address their concerns (Sullivan & Wamba, 2024).

This type of artificial intelligence offers relational and message personalization advantages. Because of its ability to be able to recognize and respond to emotions, it is able to provide the most appropriate responses by making the user feel understood and followed with respect to the request made (Huang & Rust, 2021).

In manufacturing, the effective performance of AI, heavily relies on the expertise and talents of human capital, as AI alone cannot drive enterprises efficiently without leveraging human capabilities. Moreover, manufacturers have adopted artificial intelligence to engage the stakeholders they deal with such as consumers, suppliers and employees. Especially, the widespread utilization of AI by manufacturers is highlighted as a crucial factor in effectively engaging customers and enhancing overall satisfaction. Stakeholder involvement, particularly during the implementation of emergency response plans, has a significant impact on a producer's resilience to crises and its ability to recover quickly. (Yu *et al.*, 2024).

AI-enabled engagement encompasses the ability of computers to comprehend, respond to, and interact with people using human language. These engagements can occur through voice or text-based innovations, with the specific technology employed varying based on its capabilities, domain, and embodiment. While simpler AI engagement technologies can handle routine customer questions, more sophisticated technologies, are able to perform complex tasks involving deeper interaction and

even visualization of emotions, adapting responses accordingly in a more sensitive and personalized way. Despite ongoing advancements, current AI engagement technologies do not possess fully human-level language abilities, occasionally leading to misunderstandings and user dissatisfaction. In the described scenario, organizations face challenges related to managing interactions between humans and AI technologies. In order to provide conversational interfaces with an anthropomorphic character, it becomes central to introduce strategies that infuse conversational technologies with typical human characteristics, such as personality and empathy, in order to ensure an effective and enjoyable end-customer experience (Benbya *et al.*, 2021).

1.3 General trends and global states of the market

The current trajectory of AI in business is predominantly characterized by its capacity to enhance efficiency and productivity across various sectors. With the proliferation of AI technologies, companies are increasingly integrating machine learning capabilities into their operations, leveraging the potential of open AI models[1].

A recent survey by McKinsey highlights the rapid adoption of generative AI (gen AI) tools, with a significant portion of organizations incorporating this technology into their workflows. Notably, a considerable number of global executives personally utilize gen AI tools, indicating a widespread recognition of its value. Moreover, discussions around AI are becoming commonplace in boardroom agendas, underscoring its strategic importance. The survey reveals a growing commitment to AI investment, particularly driven by advancements in gen AI technology. However, despite the optimism surrounding gen AI, challenges remain, with organizations still grappling with issues such as inaccuracies. Commonly, gen AI finds application in core business functions like marketing, sales, product development, and service operations, reflecting its versatility and impact across diverse areas. Anticipations for AI's transformative potential are high, with many foreseeing significant disruptions in industry competition in the coming years. Especially, organizations that have successfully harnessed AI to drive value are at the forefront of adopting gen AI, extending its use across various functions such as risk management and supply chain optimization. Furthermore, these firms demonstrate a broader utilization of AI capabilities, encompassing traditional machine learning, robotic process automation, and chatbots, particularly in areas like product development and HR management. Overall, the integration of gen AI and traditional AI capabilities signals a strategic

[1] https://professional.dce.harvard.edu/blog/whats-the-future-of-ai-in-business

imperative for businesses to embrace AI-driven innovations and stay ahead in today's competitive landscape.

The anticipated disruption in the business landscape due to AI is poised to bring about significant changes in workforce dynamics, according to respondents. Forecasts suggest a considerable reshaping of talent needs, with expectations of both workforce reductions in certain areas and substantial reskilling efforts to meet evolving demands. Especially, the study indicates a prevailing sentiment among respondents that emphasizes reskilling over workforce separations. Nearly four in ten respondents anticipate that over 20% of their company's workforce will undergo reskilling initiatives, whereas a smaller proportion (8%) foresee workforce reductions exceeding 20%. A closer examination of AI's projected impact reveals service operations as the sole function where a majority of respondents anticipate workforce downsizing. This observation is consistent with recent research findings, which indicate that while gen AI may increase the automation potential of various tasks, it does not necessarily equate to the complete automation of roles. Current AI technologies, along with other advances, have the ability to automate tasks that currently occupy a significant portion of employee time (60/70%), having a significant impact on jobs associated with occupations requiring higher cognitive skills and higher wages. This is a change that is particularly relevant because it directly affects the nature of work and the skills required, pushing people to focus on higher value-added activities. Especially, these technologies excel in automating a diverse array of tasks involving intricate information processing, data analysis, and linguistic communication. Consequently, AI-generated automation holds the promise of liberating employees from repetitive or routine tasks, enabling them to redirect their focus towards activities demanding specialized skills and creativity. In light of this perspective, projections by Goldman Sachs suggest that AI-powered automation may impact up to two-thirds of U.S. occupations, yet it does not foresee widespread job displacement. Instead, the evolution of technology tends to complement existing roles, with job losses balanced by corresponding job growth driven by technological advancements. Historically, over 85% of employment growth has been attributed to the creation of new positions fueled by technological innovation[2].

Considering the degree to which artificial intelligence tools are adopted and the ways in which workers' time is allocated to other higher-value-added activities, these technologies could provide labor productivity growth of between 0.1 and 0.6 percent annually, until 2024. However, in order to make this scenario feasible, it is necessary to initiate operations to train workers who will be involved in different occupations that require the acquisition of new skills. Based on these considerations,

[2] https://www.mckinsey.com/capabilities/mckinsey-digital/our-insights/the-economic-potential-of-generative-ai-the-next-productivity-frontier#introduction

Effective management of these contingencies and associated risks becomes crucial for AI to provide a significant boost to economic growth. In general, given the scale of the phenomenon, the impact of AI on productivity is considered highly significant with estimates predicting increases contributed to the global economy that can reach the magnitude of trillions of dollars. Relevant to this scenario is the potential arising from the integration of artificial intelligence technologies into four main business areas which are customer operations, marketing and sales, software engineering, and research and development.

As part of the aforementioned survey, it emerged that 55% of respondents confirm that their organization has adopted AI tools, demonstrating the growing diffusion of these technologies. At the same time, an important data to analyze is the fact that less than a third of those interviewed reported having adopted AI in multiple company functions, suggesting the limited implementation of the phenomenon. While the relevance of these tools is evident, only 23% of respondents attribute at least 5% of the previous year's EBIT to the use of AI, indicating that there is significant untapped potential for value creation. Nonetheless, it clearly emerged that AI technologies allow for an increase in revenues in the areas and business functions in which they are used, with two thirds of respondents predicting an increase in their organizations' AI investments in next three years[3].

Benefits per function from AI adoption

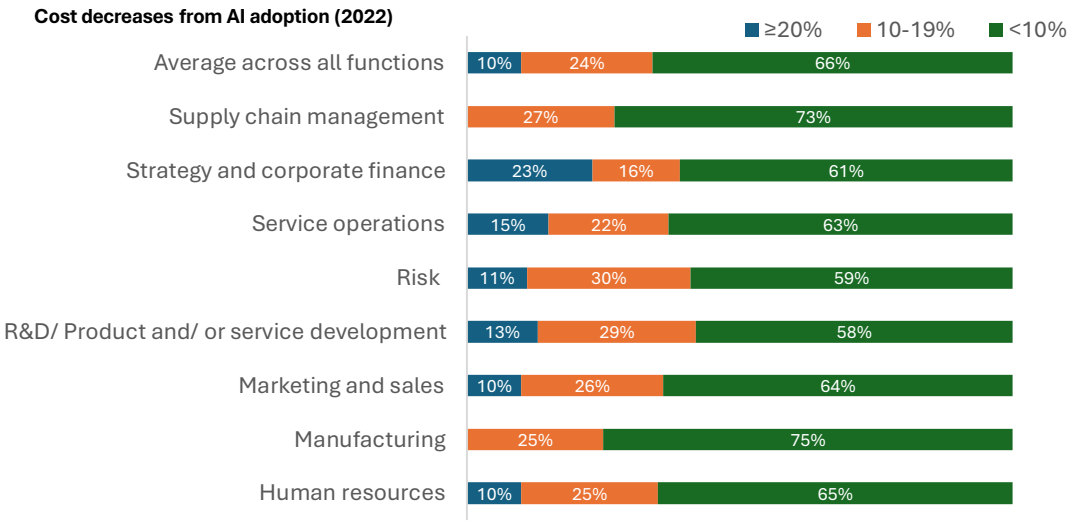

Figure 1

SOURCE: The state of AI in 2023: Generative AI's breakout year

[3] https://www.mckinsey.com/capabilities/quantumblack/our-insights/the-state-of-ai-in-2023-generative-ais-breakout-year#talent

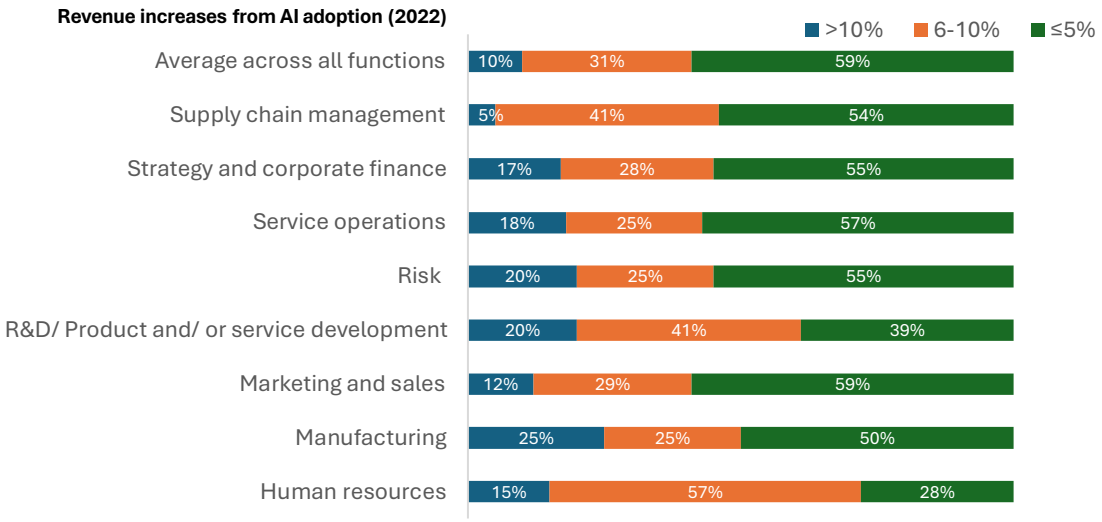

Figure 2

SOURCE: The state of AI in 2023: Generative AI's breakout year

There is an ongoing paradigm shift in the way companies conceive of AI, with a deep focus on the power this technology offers and the future opportunities it can generate. The recent development of generative AI has led companies to adopt new strategies and revise internal logic, with more and more organizations making these technologies a critical capability for conducting their business.

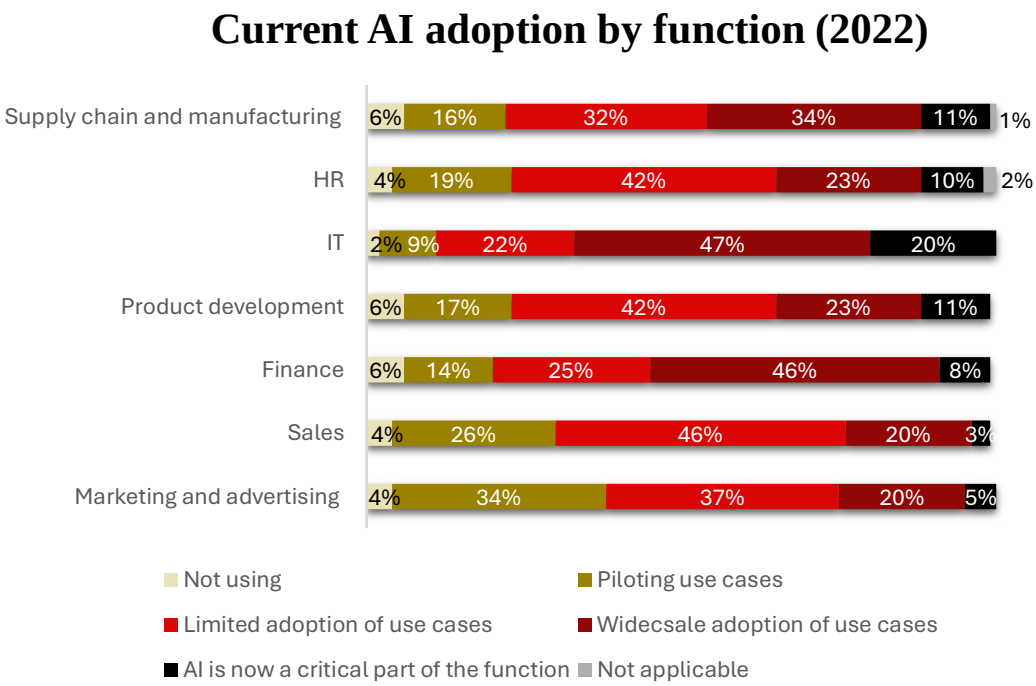

Figure 3

SOURCE: The great acceleration: CIO perspectives on generative AI

However, with AI now proving its utility across every business function, it is set to proliferate throughout entire enterprises. Additionally, AI is confidently expanding into creative applications, which were traditionally seen as uniquely human endeavors[4].

1.4 AI strategies in manufacturing firms

Artificial intelligence (AI) is a transformative force reshaping industries by automating tasks that traditionally relied on human intelligence.

Being able to exploit the advantages resulting from this change is crucial for companies if they want to avoid losing competitive ground. Artificial intelligence allows to create new opportunities for innovation and update the core operations of companies. This has the potential to impact and revolutionize most economic sectors and, without a comprehensive AI strategy, organizations risk not being ready to fully reap its benefits.

In the evolving landscape, every role holds the potential for transformation as humans collaborate with AI co-pilots, significantly amplifying human capabilities. As detailed in the previous paragraph, generative AI is set to revolutionize tasks rather than entire occupations. While some tasks will be automated, others will be enhanced through AI assistance, and some will remain unaffected. Additionally, it is possible to expect the emergence of numerous new tasks, such as ensuring the responsible use of generative AI systems. Therefore, companies that train their employees to work in synergy with generative AI will gain a significant advantage. To unlock the value of generative AI, companies must reinvent work by embracing job redesign, task restructuring, and employee reskilling. Ultimately, as today's jobs are deconstructed into automatable or AI-assisted tasks, every role within an enterprise holds the potential for reinvention.

An AI strategy makes it possible to monitor the progress of the company with respect to the adoption of AI tools, build the necessary capacity in terms of infrastructure to be configured and resources to be used, and finally ensure the strategic integration of AI into the framework of the organization. This is of paramount importance in order to address the challenges that this paradigm shift presents and to define clear objectives to be shared with the entire organizational structure, which is critical to extracting meaningful value and maximizing the impact generated by AI.

An AI strategy is central in order to effectively leverage AI technologies so as to achieve goals such as increasing efficiency, improving supply chain operations, increasing employee skills, and

[4] https://www.databricks.com/sites/default/files/2023-07/ebook_mit-cio-generative-ai-report.pdf

improving the customer-side experience. In today's fast-moving environment of new technologies, companies must be able to refine and adapt strategy to ongoing changes and technological advances. This allows organizations to keep up with the times and not lose the competitive edge needed to survive in the marketplace. The technology infrastructure that drives change within companies must be monitored, and it is the job of proper strategy to guide organizations in this regard, ensuring that they have the hardware, software and resource components necessary for effective AI implementation. The AI strategy enables to chart the course for the organization while contributing significantly to its success. This offers advantages in that it allows AI capabilities to be catalyzed in a way that is targeted to actual business needs and aligns AI initiatives with long-term business goals. Organizations that are able to adopt this approach have a greater likelihood of success, as this allows them to highlight in the eyes of stakeholders which projects can significantly improve productivity, decision making and overall financial performance[5].

It is essential to prepare an AI strategy aligned with what is the overall business strategy. This involves working closely with committed leaders in all business divisions and engaging employees at all levels. Ultimately, the IA strategy should act as a driving force for corporate strategy, aligning with the same key performance indicators (KPIs) designed to improve and maintain competitive advantage. Through the determination of the goals that need to be achieved, the strategy enables the identification of what are the opportunities and gaps to be filled within the various business divisions. Based on this evidence, ad hoc AI-based solutions can be implemented to fill these gaps, then going on to integrate the plans created locally with the central administration of the organization to ensure that the goals are aligned and unified with the overall business strategy. This step is crucial because only when AI is fully integrated and deployed across all levels of the enterprise can provide the combination of efficiency and value creation needed to sustain ongoing returns and ensure sustainable competitive advantage[6].

Crafting a successful strategy in this context involves several key aspects: firstly, adopting a business-driven mindset is crucial. Organizations should pursue a dual approach to experimentation, targeting both quick wins with readily available models and applications, and strategic reinvention using customized models tailored to the organization's data. Secondly, prioritizing a people-first approach is essential. Emphasis should be placed on investment in talent development to build both AI creation and utilization capabilities. This entails fostering technical competencies like AI engineering and enterprise architecture, alongside providing comprehensive AI training across the organization. Thirdly, preparing proprietary data is of utmost importance. Addressing the urgent need to curate vast

[5] https://www.ibm.com/blog/artificial-intelligence-strategy/
[6] https://www2.deloitte.com/us/en/pages/technology/articles/effective-ai-strategy.html

amounts of data required for foundational AI models is crucial. Organizations should adopt a strategic approach to acquire, refine, protect, and deploy data, ensuring the establishment of a robust cloud-based enterprise data infrastructure. Moreover, investing in sustainable technology infrastructure is essential. Evaluating infrastructure, architecture, operating models, and governance structures to support the integration of generative AI and foundational models, while maintaining cost-effectiveness and sustainable energy consumption, is critical for long-term success. Additionally, driving ecosystem innovation is paramount. Accessing resources and expertise from ecosystem partners, including major tech companies, startups, professional service firms, and academic institutions, can facilitate the development and scaling of AI applications. Lastly, prioritizing responsible AI is fundamental. Before scaling up generative AI applications, organizations must assess the adequacy of their responsible AI governance framework. Implementing controls to evaluate risks at the design stage and embedding responsible AI principles and practices across all business operations are essential steps in this regard[7].

[7] https://www.accenture.com/us-en/insights/technology/generative-ai

CHAPTER II: Literature review - a comprehensive overview of the phenomenon

2.1 Dynamic Capability View

To thrive in the competitive market and dynamic environment in which they operate, companies must continuously adapt to change by developing a flexible and agile organizational structure that can readily deal with obstacles and uncertainties. This adaptability enables companies to respond effectively to changing market conditions, technological innovations and changing customer expectations. Having made these considerations, it is critically important for companies to develop dynamic capability (DC), that is, to be able to integrate, develop and reorganize internal and external resources and skills to respond effectively to rapid changes in the business environment. In this context, the Dynamic Capability View has been proposed by several scholars as an extension of the Resource-Based View (RBV). Specifically, this theory seeks to explain how firms can gain and maintain a competitive advantage in markets characterized by volatility and highly dynamic and changing environments.

Dynamic Capabilities Theory is based on three main pillars. First, an organization's ability to identify emerging market opportunities and develop new technologies that meet customer needs and open up new business possibilities. Second, an organization's ability to activate and orchestrate key resources to meet customer needs and exploit market opportunities, thereby ensuring the creation of business value. Finally, the ability of an organization to constantly and consistently reconfigure its ordinary resources and capabilities in response to business dynamics. These capabilities enable the company to adapt to changes in the business environment and its target market, ensuring that internal resources are aligned with emerging needs and opportunities. Such organizational flexibility is critical to maintaining competitiveness and meeting challenges in an ever-changing economic environment.

In this context, it is essential for an organization to have a strong learning ability to grasp the proposals and opportunities offered by the surrounding environment. Companies that develop this aptitude demonstrate a particular ability to create the means and tools necessary to respond to market changes and opportunities. This includes not only innovation, but also the adoption and integration of new technologies. In practice, these organizations are able to turn challenges into opportunities by leveraging technological innovations to improve their processes and products, thus remaining competitive and relevant in an ever-changing business environment. The combination of these capabilities enables organizations to adapt their processes, innovate by creating new products, and

address changes promptly by absorbing new knowledge. This flexible approach focuses on the continuous alignment and reconfiguration of internal and external resources with business strategy, enabling effective response to market dynamics. Especially, this strategy enables companies to better understand customer needs, identify new market opportunities and leverage them to strengthen their competitive position. By implementing such capabilities, organizations can not only react quickly to market changes, but also anticipate them, thus ensuring greater resilience and economic sustainability in the long term (Dubey *et al*., 2020*).*

Consequently, based on these considerations, dynamic capabilities theory has received increasing attention in the field of operations management, focusing on the ways in which organizational resources and capabilities are deployed to gain an advantageous position in volatile markets. This approach analyzes how organizations can continuously develop, improve, and reconfigure their internal and external resources and capabilities to respond effectively to a rapidly changing competitive environment (de Oliveira-Dias *et al*., 2023).

Dynamic capabilities differ from common operational capabilities in that while the latter are used for the day-to-day activities of companies, dynamic capabilities improve the likelihood of survival in the marketplace by facilitating the creation of competitive advantage. The basis of dynamic capabilities lies in the organization's ability to constantly adapt its strategies to changing market conditions. This is done through innovation and the adoption of new technological opportunities, which enable the combination of corporate resources in ways that are unique and distinctive from competitors. With continuous adaptation of strategies, constant innovation, and effective resource management, companies are able to build and maintain a sustainable competitive advantage. In rapidly changing environments with a high degree of uncertainty, the ability to cope with distortions that affect the entire value creation chain is critical for a company. Therefore, the development of dynamic solutions does not occur in isolation but becomes relevant through coordinated and collaborative action with supply chain partners. This collaboration allows resources and expertise to be shared with the various players interacting with the organization at all stages of the supply chain, thereby enhancing the company's ability to adapt and thrive in a changing market environment. With the ability to identify and interpret opportunities and threats, organizations can respond proactively to such stimuli, avoiding the negative aspects of adverse tasks and capitalizing on opportunities. This approach promotes the prosperity of organizations in their operating environment. Through empowerment and innovative use of resources, both tangible and intangible, companies can quickly adapt to changing market conditions and maintain a competitive advantage. In a dynamic and uncertain market environment, the ability to perceive, shape, and proactively respond to opportunities and threats by leveraging resources in innovative ways is essential to organizational success. Through strategic

resource management and a culture focused on innovation, companies can not only survive, but also thrive and consolidate their position in the marketplace (Sullivan & Wamba, 2024).

A dynamic approach is critical to ensuring superior business performance in the long run, however, flexibility and adaptability of processes, structures, and decision rules to external changes pose a significant challenge to implement. Having dynamic capabilities enables companies not only to survive by adapting to changing business ecosystems, including new technological opportunities and changing customer needs, but also to shape and mold the market through innovation, new product development, and adoption of alternative business models. Underlying this approach is the ability to integrate and orchestrate diverse resources and expertise, enabling companies to adopt an innovation-driven mindset that consequently leads to value creation, generating innovative business solutions and improving financial performance. The ability to respond quickly and creatively to new market challenges, as well as to anticipate future needs, is essential to consolidating a competitive position and thriving in a dynamic and uncertain environment. Effective strategic resource management, coupled with a corporate culture that fosters continuous innovation and collaboration, enables organizations not only to adapt but also to drive change, thereby ensuring business growth and a robustness in the marketplace.

By studying the target market in depth, both domestically and internationally, it is possible to understand current dynamics and trends, thus enabling the organization to act consciously and anticipate future developments. To achieve this goal, it is essential for the company to adopt an approach geared toward investing in research and development, as well as actively listening to consumer needs and identifying emerging technological opportunities. To increase competitive advantage by exploiting the external environment, it is necessary to look beyond the company's boundaries, seeking to understand latent demand and outline possible developments in the sectors in which organizations operate in order to anticipate the moves of competitors and other market players. Adopting a strategic and innovative vision, makes it possible to seize opportunities and respond promptly to market challenges, thus ensuring a position of leadership and growth in the long term.

By capturing new opportunities in the embryonic stage and adopting a data-driven approach, managers must be able to interpret new economic phenomena and, as a result, identify the best technologies to use in order to respond promptly to changes and evolutions in the market, as well as to market players such as competitors, suppliers and customers. Company stakeholders play a crucial role in determining how market opportunities materialize, influencing the dynamics of the target ecosystem based on how they perceive and evaluate technological innovation. To thrive in environments of rapid change and global competition, with increasingly fluid corporate boundaries

and geographically dispersed sources of innovation and production, it is essential to develop unique and dynamic capabilities that are difficult to replicate.

These capabilities are fundamental for enabling organizations to evolve while simultaneously protecting their base of tangible and intangible assets from external threats. In this context, the ability to perceive and seize opportunities, shaping and targeting them strategically, enables the company to maintain its competitiveness. This is achieved through the continuous updating, protection and reconfiguration of hard-to-replicate capabilities and assets, which are the true source of value for the organization. As a result, the company can lead the market through the development of innovative products and services, realized through alternative business processes and models (Teece, 2007).

2.1.1 Lean and agile supply chain

The supply chain ecosystem is a complex system that can be considered the backbone of social, economic and environmental development. Its ability to adapt and respond to challenges and opportunities depends on the effective management of interrelationships among different supply chain entities and the adoption of dynamic and innovative practices and strategies. In this context addressing disruptions and improving resilience are key elements in ensuring the continuity and prosperity of the whole system. To achieve this and to gain a competitive advantage, companies need to devise strategies to achieve their long-term goals, thus ensuring their survival. With this in mind, supply chain management as a strategic tool enables the organization's operational activities to be carefully calibrated, producing products in the quantities, locations and times required by the market. This approach based on the concept of "supply chain strategy" allows for improved business performance through cost reduction and simultaneous increase in end-consumer satisfaction. Current literature points out that supply chain strategy must be closely integrated with overall business strategy to improve responsiveness and performance in the marketplace. This alignment not only increases the firm's ability to adapt to changing market conditions, but also helps to reduce costs, improve quality, and increase customer satisfaction, providing a lasting competitive advantage.

The supply chain is a system that includes all the stages involved in the production and distribution process of a given product, from its point of origin to the final consumer. Being able to manage these aspects is crucial to the success of the company, and therefore it is necessary to implement actions to monitor and develop the overall performance of the supply chain in order to respond promptly and effectively to customer demands. The strategy mentioned above, involves the comprehensive and coordinated integration of business processes throughout the value chain, with the goal of optimizing

each step in the process, increasing the quality of products and services offered and thus generating greater satisfaction for the end customer. Ultimately, the supply chain strategy aims to create an integrated and responsive system that delivers optimal value to the end customer through the efficient management of all activities along the value chain. In this context, companies that succeed in developing a lean and flexible end-to-end process have a greater likelihood of thriving and gaining a competitive advantage over competitors.

Supply chains (SCs) are under countless pressures to adapt to an increasingly volatile, uncertain and complex global business scenario. In order to improve supply chain performance, it is essential to adopt a Lean approach, which aims to eliminate activities that do not add value, and an Agile approach, which instead focuses on the ability to adapt quickly and respond effectively to customer needs. In line with dynamic capabilities theory, which emphasizes the ability of firms to continuously integrate, build and reconfigure their competencies to foster business growth, a lean supply chain strategy aims to create cost efficiencies in the supply chain through effective inventory management and continuous quality improvement.

The Lean Paradigm aligns with the principles of lean thinking, which focus on minimizing waste, reducing overall cost, improving product quality, ensuring quick delivery, removing non-value-added activities, maintaining minimal inventory, and fostering ongoing improvement. This approach allows for a lean architecture, free of structures that slow down the organization's operations, allowing processes to be optimized and to adapt quickly and efficiently to changes. Organizations that adopt this architecture are able to implement just-in-time strategies, coordinating production with the distribution of the final output, thus delivering the desired product according to customer requirements in terms of quantity, location and time of delivery. At the same time, organizations can implement careful supplier selection based on quality, which allows them to reduce the risk of defects and delays. This enables to establish long-term relationships and, thanks to better contractual conditions, makes it possible to realize a cost strategy without compromising quality. A Lean supply chain strategy takes a wait-and-see approach to market demand, keeping inventory low and planning production and logistics only when real demand occurs. This approach reduces the risks associated with excess inventory, which is a cost to the organization, and avoids the production of unsold goods. By acting only when demand is clear, companies can be more flexible and respond quickly to changes in customer needs and industry conditions. This predisposition allows them to operate in a market-oriented manner, strengthening the organization's ability to offer customized products and improve customer satisfaction and loyalty.

Another important characteristic that organizations must invest in if they are to continue to compete and achieve higher performance, concerns the propensity to build an agile structure. The agile

paradigm addresses the variability and variety of demand, consequently the agile supply chain emphasizes product customization to meet market sensitivity and respond quickly to customers in volatile environments to gain competitive advantage. This characteristic is necessary to improve the responsiveness of the supply chain, allowing it to respond quickly and flexibly to changes in customer demand. In particular, an agile supply chain strategy enables the supply chain to adapt promptly to short-term changes in demand and manage market uncertainty, while ensuring that the organization can take advantage of new and emerging opportunities through the integration of new technologies, processes, and business models (Agarwal *et al.*, 2006). To be Agile, the supply chain must develop the ability to analyze the environment, anticipate changes, and then use this market knowledge to quickly cope with demand volatility. A central aspect that characterizes a strategy based on an agile supply chain is that the organization can rely on resources such as flexible inventories, production and logistics capacities that are not fully saturated, and partnerships with suppliers that can quickly ramp up their production when needed. Having high-capacity buffer makes it possible to respond to market volatility and ensures that sudden fluctuations in demand can be met without delay. An agile supply chain enables companies to raise responsiveness by increasing their ability to respond effectively and timely to changes affecting customers. A key aspect of an agile approach, which confers flexibility, is generic inventory management, i.e., keeping standard and semi-finished products ready to be assembled when specific orders are received from customers. This approach, which requires a supply chain based on the principle of deferral, i.e., the ability to maintain materials and inventories of products that have not yet been finalized in a specific form, makes it possible to respond to changes in market demand, reducing the risks of excess inventory and improving the ability to deliver customized products quickly and efficiently. As a result, organizations that follow this approach are able to develop a supply chain that allows to reduce disruptions and lead times and speed up decision making (Qrunfleh & Tarafdar, 2013).

Therefore, Lean and Agile supply chain strategies can generate dynamic capabilities by leveraging existing resources and capabilities and developing new ones, which enables enterprises to achieve performance advantages. Organizations that decide to adopt lean and agile supply chain principles are able to improve their performance not only in the short term, but also lay the foundation for long-term economically sustainable growth. In this way, the ability to respond quickly to change and continuously innovate enables companies to maintain a competitive advantage over time. These strategies are a key aspect for companies operating in a dynamic and uncertain market. Especially, by integrating these principles, supply chains become more efficient and responsive, improving the company's ability to meet customer needs and take advantage of emerging opportunities (Sharma *et al.*, 2022).

2.2 Transformation of supply chain management through the power of AI

As covered extensively in the first chapter, Industry 4.0 is a concept that has introduced a new paradigm into the business environment, focusing on advanced automation of systems and processes, digitalization and data exchange in industries. Organizations that adopt a model based on this definition have the ability to develop structures that are able to respond in a timely manner to market demands and handle unforeseen events, while bringing improvements in overall efficiency and productivity. The focus of Industry 4.0 addresses the integration within corporate boundaries of modern, disruptive technologies such as the Internet of Things (IoT), advanced robotics, big data analytics, and last as an increasingly popular trend, artificial intelligence. These technologies can be implemented and involved in various business areas such as manufacturing, supply chain, and logistics, and through informed and timely decisions they enable greater control of the latter. In particular, supply chain management is an increasingly critical element as it enables organizations to anticipate and respond to changes in demand and to optimize operations, reducing costs and improving the quality of products and services offered, strengthening companies' competitiveness in the global market (Abdirad & Krishnan, 2021). Digitalization is an essential element for supply chain systems to thrive in today's competitive environment that is subject to constant change. Companies that adopt emerging technologies such as those related to artificial intelligence are able to have end-to-end visibility of the supply chain, thus improving the ability to monitor, analyze and predict the flows of goods and information. A further important aspect that this approach determines concerns the management of the growing flow of data in the value chain, becoming fundamental for the effective management of next generation digital supply chains. This shows how digitalization is not just a matter of operational efficiency, but also a key strategy for innovation and long-term sustainable growth.

Organizations that make use of a wide range of technologies have the ability to implement digital supply chain networks, thus developing systems that are not only efficient but also able to adapt and resist changes in the external environment. The impacts of using new technologies and an approach focused on the Industry 4.0 concept are manifested in multiple aspects of the supply chain, including new product development, manufacturing, procurement, planning, logistics and marketing. In this context, defining a supply chain management strategy enables a company's position in the market to be more stable by being able to optimize the entire flow of materials, information and resources, improving operational efficiency and reducing costs. Being able to share information in real time and synchronize with suppliers, as well as make forecasts and schedules, makes it possible to improve the

overall performance of the entire supply chain. Thanks to this innovation-driven approach, it is possible not only to be able to increase the supply chain's ability to respond to market variables, but also promotes the capacity to strengthen the competitiveness of companies at a global level. Adopting an integrated system that allows to connect supply chain stakeholders through smart solutions make it possible to optimize processes, improve the traceability of materials and products, and react more quickly and effectively to changes in demand and market conditions.

In summary, the use of these new technologies, which include advanced connection systems and continuous supervision of materials, equipment and supply chain parameters, not only optimize overall value chain efficiency, but also help reduce risk. The increased collaboration and transparency that these systems enable lead to the creation of stronger business relationships based on the trust of the various actors involved throughout the value chain, increasing its overall performance (Ghadge *et al*., 2020).

Supply chains represent fundamental pillars in the economic system as they ensure a constant flow of goods and services essential to markets and businesses. Market developments have led supply chains to become increasingly extended and complex, thus becoming imperative for companies to invest in order to support the constant coordination and collaboration of the various players involved, to ensure the continuity and quality of the services offered. The complexities of increasingly extended supply chain networks, together with the interconnections between different autonomous and globally distributed entities, have made supply chains susceptible to an uncertain and dynamic business environment. These challenges emerge in a highly competitive, vulnerable and risk-prone environment of ambiguity and volatility. Faced with such a scenario, SCs face a range of issues, such as supply chain disruption, sudden changes in international regulations, fluctuations in commodity prices, and geopolitical risks. Therefore, adaptability and resilience become crucial elements for organizations to develop flexible strategies and advanced technologies to effectively monitor and manage these complexities.

Traditional supply chain risk management approaches have proven inefficient given events that have demonstrated supply chains' unpreparedness for sudden disruptions that impact the entire value chain. However, the introduction of new technologies such as artificial intelligence are demonstrating a remarkable ability to enhance supply chian resilience. In particular, artificial intelligence can be used to predict and respond quickly to potential disruptions, improving the ability of supply chains to adapt and recover. Through sophisticated analysis of external data, organizations with the appropriate technologies and structures are able to learn from it and apply that knowledge to achieve predetermined goals through dynamic adaptation. In this context, AI therefore enables the creation of robust management strategies capable of dealing with unforeseen challenges and improving

operational efficiency on a global supply chain scale. In addition, the use of AI not only improves immediate responsiveness but also facilitates predictive analytics, enabling organizations to anticipate potential problems and take preventive measures. Thus, this technology is an essential tool for ensuring business continuity and resilience of supply chains by offering flexibility and accuracy that traditional information processing systems cannot provide (Kassa *et al.*, 2023). Organizations that are adopting new technologies within their business processes are able to acquire remarkable capabilities. By integrating these technological tools with human know-how, a proactive approach to managing operations becomes possible, creating intelligent supply chains that can predict and monitor the impact of almost any circumstance. This level of precision and control enables companies to consistently balance three key outcomes: cost efficiency, operational agility and customer satisfaction (Mohsen, 2023).

In this scenario, the integration of artificial intelligence with advanced Industry 4.0 technologies offers companies the opportunity to achieve unprecedented levels of efficiency. In the contemporary business environment, technologies aimed at creating a digital twin are becoming increasingly popular, which in the context of procurement systems represents a highly detailed virtual simulation of a company's supply chain, including all assets, warehouses, logistics flows, materials and inventory locations. This online, interactive representation acts as a replica of the company's operational structure, enabling real-time visualization and analysis of supply chain behavior and performance. Through this simulation, companies can explore the complexity of their operations and better understand the areas where value loss and risks occur. Especially, the ability of a digital twin to provide a detailed and dynamic overview of the supply chain allows to identify problems and inefficiencies that may not be evident through traditional methods. Having made these considerations, the companies that are truly able to reap the benefits of these innovative models are those that have the capability to integrate with advanced technologies such as artificial intelligence the digital systems mentioned, thus offering a unique capability for data processing and analysis. AI can monitor and interpret huge volumes of information, detect patterns and predict future problems enabling demand forecasts that can improve replenishment policies and appropriately modify inventory levels. This technological support helps improve supply chain resilience by identifying potential vulnerabilities and optimizing performance in real time. Companies can thus implement preventive strategies based on accurate simulations, reducing risk and improving responsiveness to unforeseen events. This approach helps to improve customer centricity by ensuring that the company has the products in stock that the customers want, when they want them, avoiding inventory while improving supply chain accountability, minimizing overall costs and the distances that inventory must travel to reach the end customer.

Another key aspect that enables companies to strengthen the supply chain and be competitive in the business, concerns the ability to understand demand and thus know the market in order to be able to meet the different needs of clients that are constantly changing. Integrating the available internal and external data related to the various processes and functions of an organization and being able to analyze them through the use of artificial intelligence, allows organizations to have a complete view of the context in which they operate. This approach applied to supply chain management enables organizations to gain an integrated view of demand throughout the supply chain, improving logistics efficiency and inventory accuracy. As a result, companies can optimally position themselves to meet client demand and avoid surprises caused by disruptions or sudden changes in market conditions. In particular, thanks to the increasing use of artificial intelligence-based solutions, organizations are able to capture a vast set of data, enabling them to understand what influences demand at increasingly detailed levels and to meet it effectively, even going so far as to predict customers' needs before they are expressed. With data-driven predictions, supply chain managers can make smarter and more proactive decisions about how to respond to and meet demand, determining the most appropriate actions to take in terms of production, pricing and promotions. Integrating AI and advanced analytics technologies into supply chain business processes not only improves customer satisfaction and loyalty, but also makes organizations more adaptable and resilient in the face of market changes. This approach enables companies to always be ready to seize new opportunities and overcome challenges, maintaining a strong position in an ever-changing competitive environment.

The complexity and distributed nature of global supply chains make it difficult to have a clear and comprehensive view of the entire procurement system. Consequently, a key aspect of maintaining the necessary stability and ensuring business continuity concerns the ability of organizations to monitor and then manage supply chain risk, to enable companies to understand the performance of their suppliers and assess their risks. Given the extension of the supply chain globally, the uncertainty and complexity of the supplier base is becoming increasingly high, and being able to manage it is a key issue for companies. In this context, it is becoming increasingly common for problems in the initial part of the supply chain, such as a delay in a shipment of raw materials, to spill over and amplify downstream along the supply chain, eventually creating an escalation that affects the end customer. This occurrence, which is commonly referred to as the “bullwhip effect,” in which small initial disruptions are amplified due to complexity and lack of visibility in the supply chain, can be overcome through the use of new technologies that enable companies to address and mitigate such challenges more effectively. Artificial intelligence is playing a major role in revolutionizing supply chain management, enabling organizations to monitor and react promptly to disruptions. AI provides data-driven recommendations, making better information available to companies about what is happening

throughout the supply chain, which helps managers make more informed decisions about purchasing, inventory management and resource planning. Companies that integrate these technologies into their business model are able to collect data from the supply chain and process it through the application of artificial intelligence systems. With this data, companies are able to gain a comprehensive view of the state of the entire supply chain, and the use of AI allows them to identify patterns, predict future events, and detect anomalies. In particular, companies can identify risks such as supplier financial problems or raw material shortages that could cause their bankruptcy or a disruption in operations resulting in supply shortfalls. Being able to view possible alternative future scenarios and assess their impacts on the supply chain, enables companies to develop detailed contingency plans to handle unforeseen events or emergency situations that could disrupt an organization's business operations. This allows companies to be prepared and have a broad view of the situation of the various players operating in the supply chain and thus to take alternative measures by anticipating the negative impact that would result from these circumstances. In conclusion, the use of advanced tools such as artificial intelligence not only help companies identify and mitigate supply chain risks, but also improve operational efficiency and the ability to make strategic decisions that direct the organization toward superior performance and the achievement of a sustainable long-term competitive advantage[8].

2.3 The impact of AI technologies on operational performance

Artificial intelligence is revolutionizing traditional processes and reshaping the landscape of work and productivity. Riding the resulting wave of innovation, organizations are able to fully harness the power of data and algorithms, thereby being able to gain valuable insights, automate repetitive tasks with little added value, and consistently increase productivity thresholds. The use of these innovative technologies enables organizations to leverage new information streams that can be used as inputs to improve the performance of production processes. Once data are gathered, AI allows for enhanced analytical processes and real-time insights that can identify inefficiencies and uncover hidden patterns and trends that can guide strategic and operational decisions.

Information technology (IT) is becoming increasingly common in professional activities, presenting itself as indispensable elements capable of reconfiguring core processes and operations according to the new rules of innovation. The integration of these systems within business logics improves the consistency and speed of operations, reducing response times and increasing flexibility by playing a

[8] https://www.accenture.com/us-en/insights/artificial-intelligence/supply-chain-analytics-ai

central role in the way companies' processes and operations evolve. Information technologies can improve the relationship between the company and its customers by increasing the personalization of offerings and the effectiveness of marketing strategies, as well as by fostering greater collaboration with partners along the supply chain, increasing transparency and responsiveness.

Within this scenario, AI has emerged in recent years as the most cutting-edge IT application, offering potential for development and growth that cannot be matched by other technologies. The impact of artificial intelligence is pervasive and represents a strategic lever that offers numerous benefits, improving performance at various levels, both organizational and process. This technology enables positive feedback in various business areas. From a financial point of view, it offers the possibility of identifying new market opportunities, improving strategies by reducing operational costs, and enhancing the use of corporate resources. As for marketing activities, advanced data analysis and real-time campaign optimization increase effectiveness and return on investment. Finally, AI can also bring benefits in the administrative area by automating activities such as human resource management, accounting, and logistics, reducing workloads and improving efficiency.

Because of these attributes and the ability to automate repetitive processes, reducing the time it takes to complete tasks, AI enables improving overall operational efficiency and therefore, enhance the organization business value (Chen & Wang, 2022).

One of the central aspects to be leveraged in order to fully exploit the potential of this technology concerns the ability of artificial intelligence-based systems to collect, store, process and disseminate information within and between organizations. This, commonly known as the information effect, is a key element in improving business performance. The use of data analyzed through algorithms and AI technologies, feed pools of information that is extremely rich, reliable and diverse. Therefore, the ability to efficiently collect, process, and disseminate information enables organizations to make more informed and high-quality decisions, improving control and coordination of resources and increasing overall responsiveness. This feature of AI has a significant impact on how companies manage and use information, directly affecting the quality of decisions and, consequently, the financial and managerial stability of organizations. In addition to AI's ability to improve the quality and effectiveness of business decisions, the transformational effect that these technologies produce should also be considered, which refers to the value that emerges from AI's capacity to facilitate and enable process innovation and transformation. Transformational effects play a major role in improving customer relationships and creating new products and services, and are related to AI's ability to promote service transformation through innovation and process redesign (Wamba, S. F. 2022).

Both the informational and transformational effects operate synergistically and enable the enhancement of business operations through redesigning processes and organizational structures,

supporting competitiveness and building trust, and thus creating new market opportunities. This stimulates innovation and consequently promotes the organization's competitiveness in the market.
The use of AI enables business structures to be streamlined and agile by offering a wide range of opportunities to steer organizations toward success by improving business performance. Thanks to the reconfiguration of processes resulting from the deployment of this technology, there has been a shift from a manual logic, requiring significant expenditure of resources, to an intelligent one based on optimization, efficiency and automation with the elimination of obsolete practices.
AI offers several potentials for organizations that can be attributed to various areas. In particular, this technology can increase the efficiency of business operations, including supply chain maintenance; optimize the end-customer experience by improving it through the implementation of new, customized capabilities; readily adapt to changing market conditions by creating business models that are able to respond quickly and effectively to new challenges and opportunities; improve forecasting and planning, enabling companies to better manage the relationship between supplies and requirements; automate monitoring and information systems by providing timely and accurate information to make informed decisions; and finally reduce errors and improve the quality of products and services offered (Wamba-Taguimdje *et al*., 2020). In this context, AI enables organizations to adopt a dynamic framework that allows for the agile reconfiguration of the companies' set of resources and capabilities. This approach facilitates optimal adaptation to changing conditions in the target environment, thereby enhancing the company's ability to respond quickly to emerging challenges and opportunities. This underscores AI's ability to enable organizations to modify their processes to adapt to a changing environment thereby contributing significantly to improved organizational performance in all areas of the business (Wamba-Taguimdje *et al*., 2020).

2.3.1 The influence of AI in boosting efficiency and delivery performance

The current economic-industrial environment can be summarized as extremely challenging and competitive, characterized by highly variable and uncertain market demand, requiring greater flexibility in production. Manufacturing companies must be able to adapt to an increasingly dynamic market, that requires customized work orders to meet the needs of customers who demand tailored solutions rather than standardized products. This paradigm shift implies the need to optimize all production processes in order to make them flexible, to avoid compromising operational effectiveness, while ensuring the adaptation and efficient use of production lines. In this context, critical elements that enable improved efficiency and responsiveness are digitization and hyper

connection, which offer tools that enable companies to adapt quickly to new challenges and remain competitive over the long term. In this highly dynamic and ever-changing environment, artificial intelligence offers organizations a wide range of powerful tools to create development alternatives and address the complexities of the modern business environment. Its innumerable capabilities enable it to catalyze innovation, enhancing the activities performed by human resources and simplifying business processes. AI systems are able to discover potentially actionable insights, predict trends and optimize resource allocation, thereby improving efficiency and competitiveness. The increasingly strategic role played by AI encourages organizations to create a global communication network and share collected data among different parts of the organization and with external partners. This enables companies to operate more efficiently by making optimal use of resources, streamlining processes and improving overall operations.

The application of AI enables operational efficiency and productivity benefits on multiple fronts. For example, predictive maintenance systems powered by AI technologies enable the anticipation of maintenance needs of production facilities, allowing intervention before failures occur, thus reducing production interruptions. At the same time, predictive analysis of sales data and market trends enable more accurate inventory management, avoiding overfull inventories or product shortages, ensuring greater responsiveness to customer demands and better resource allocation. In this context, companies that are able to integrate AI technologies into workflows and business processes experience tangible benefits in terms of efficiency, quality, and responsiveness, enabling better operational performance and increasing business competitiveness.

Artificial intelligence-based solutions can provide a competitive advantage in today's manufacturing paradigm, redefined by the Industry 4.0 revolution and the huge amount of data available through virtual sensors and IoT devices. The application of artificial intelligence enables real-time monitoring and analysis of data from equipment, quickly identifying any problems and suggesting corrective action. This not only reduces unplanned downtime, but also improves the quality of the finished product and optimizes the entire production process. In addition, the predictive capabilities of AI enable the anticipation of maintenance needs, further reducing operating costs and increasing equipment longevity. In this context, the use of data available through AI and machine learning solutions have a significant impact on overall operational efficiency, which is a critical aspect of a manufacturing plant's productivity. Having the foresight to introduce AI systems within the corporate fabric represents an invaluable resource for manufacturing companies seeking to improve operational efficiency, thereby radically transforming the way they operate, leading to significant improvements in productivity and quality[9].

[9] https://library.oapen.org/bitstream/handle/20.500.12657/43835/1/external_content.pdf#page=93

In general, according to findings in the literature, higher levels of AI integration are associated with improvements in production efficiency, defect reduction and supply chain responsiveness. This suggests that companies that invest in AI technologies experience tangible benefits in terms of increased efficiency, cost savings and improved quality, helping to strengthen business competitiveness, making firms more agile, responsive and able to sustain growth over the long term (Usman & Moinuddin, 2024).

In addition to improving aspects related to operational efficiency for organizations, artificial intelligence can bring significant performance gains in delivery operations by going on to increase the logistical productivity of organizations. Specifically, AI enables shipping operations to be streamlined and made more efficient through automated processing and real-time analytics that enable risk prediction and mitigation, as well as bringing greater personalization to customer service. The integration of this advanced technology enables improved inventory management through the automation of low-value-added tasks such as shipment planning and order administration, while at the same time improving shipment monitoring through advanced data analytics, tracking deliveries accurately in real time. Therefore, organizations that adopt these tools are able to optimize their operations and maintain a competitive advantage through more accurate and informed decision making. Advanced analytics also enable them to optimize inventory levels and identify inefficiencies by implementing continuous and ad hoc improvements. In particular, integrating AI technologies into an increasingly digital business environment characterized by the deployment of sensors and IoT technologies that constantly communicate with each other, can yield cost reduction benefits and faster delivery times. Going specific, the introduction of AI into business operations enables significant benefits and improvements in efficiency, cost reduction and resource optimization, promoting positive business performance.

Thanks to predictive maintenance, it is possible to carefully monitor machinery parameters that allow anticipating failures, thus intervening before the problem occurs and reducing unplanned downtime. In this context, warehouses are becoming increasingly smart by relying on machine learning algorithms that allow optimizing operations by automating picking and storage processes, thus enabling streamlined inventory management. Artificial intelligence also makes it possible to adapt and respond to logistics needs due to its ability to analyze large amounts of data, which enables it to handle sudden changes in orders or expand the shipping network without compromising operational efficiency. By combining predictive maintenance, process optimization, and efficient resource allocation, AI enables significant reductions in operational costs. These aspects show how integrating AI into business operations can lead to significant improvements in efficiency, cost reduction, and

resource optimization by enabling organizations to thrive in their environment and maintain high competitiveness (Sarker, 2022).

2.3.2 Leveraging AI to drive profitability

Being able to ensure that all parts of the organization are working together consistently to achieve the same goals, maximizing overall effectiveness and improving business performance is of paramount importance in ensuring business profitability and success. In today's rapidly changing marketplace based on the use of new technological tools, AI systems play a crucial role in reinforcing and achieving this strategic alignment by providing models that improve operational efficiency, reducing costs and optimizing business processes. With its enormous analytical capabilities, it can provide decision makers with information that allows them to identify the specific workflows from which inefficiencies arise enable targeted interventions. By increasing monitoring, improving quality, and increasing resource productivity, the use of AI enables higher profit margins and maintains a competitive advantage in the rapidly changing marketplace. The effectiveness of AI in the context of market forecasting, whose estimates far exceed those obtained with traditional models, enables companies to make predictions about product adoption, thereby improving marketing strategies and reducing the risks associated with new product launches. Using this technology helps organizations obtain data and make clearer limited and information in the testing phase of a new product before mass production. This approach allows for strategic alignment between marketing activities and IT expertise that enables risk reduction, resource optimization, and responsiveness to critical business phases, improving business profitability (Al-Surmi et al., 2022). Further underscoring the importance of this technology in increasing the performance of organizations, concerns its ability to bring about improved decision-making. Indeed, one of the main ways through which AI increases corporate profitability concerns the paradigm shift from a decision-making model based on human intuition and experience, which are subjective and often biased, to data-driven approaches. These in particular rely on the objective analysis of data to provide accurate insights that humans might overlook, identifying patterns and trends that drive the company toward greater profitability. AI offers companies powerful tools to optimize operations and reduce costs through machine learning algorithms that, by analyzing large volumes of data, can identify patterns and trends that can help companies optimize processes. In addition, AI can automate repetitive and time-consuming business processes, which improves the accuracy and speed of these operations and also frees up employee time by giving them the ability to focus on more strategic and value-added activities. Thus, through

optimization and automation of operational activities, AI not only improves productivity but also reduces labor costs by decreasing the need for labor for repetitive tasks. AI systems play an important role in analyzing customer data, leveraging algorithms that enable companies to personalize their offerings based on market needs and thus improve the end customer experience. This personalized approach not only improves customer satisfaction, but also increases the likelihood of repeat purchases and loyalty, ultimately driving profitability. As a result, the benefits from AI enable companies to operate more efficiently, respond quickly to market changes, and deliver greater value to their customers, thus contributing to an increase in overall profitability.

In summary, as shown by studies in the literature, artificial intelligence has a significant impact on the profitability of companies by improving decision making, optimizing operations, reducing costs and personalizing offerings. The channels through which this technology helps companies increase revenue concerns AI's ability to identify weak signals from the market, that is, small changes from data that are difficult for humans to detect. These weak signals can provide valuable insights into future trends and help companies develop, refine and generate numerous forecasts in diverse areas related to demand, supply, inventory, pricing and logistics. Another distinguishing aspect of AI concerns the speed of processing data to make informed, real-time decisions. This enables companies to monitor their environment and react quickly to market changes through timely decisions. The continuous improvement of business processes ensured by these systems and the responsiveness of action allows companies to prevent losses and seize opportunities that would otherwise be missed thus leading to the generation of more revenues.

CHAPTER III: Data and methodology

3.1 Research questions development and hypothesis framework

Nowadays, keeping up with the technological advances that are increasingly emerging in the economic and social landscape allows companies not only to secure their position in the market, and therefore survive, but also to achieve unprecedented improvements in terms of performance and operational efficiency. In this context, artificial intelligence technologies are emerging as a transformative force in improving business performance, with Lean and Agile supply chain (SC) strategies acting as crucial mediators in this relationship. While traditional supply chain management (SCM) strategies have long been recognized for their ability to increase operational efficiency, the advent of AI offers new opportunities to elevate performance to unprecedented levels, opening up new avenues for companies to seize. In particular, this study focuses on the direct impact of AI on business performance, examining how Lean and Agile practices, which are themselves influenced by the advent of this highly disruptive innovation, mediate this relationship. In today's highly competitive global market, companies are becoming increasingly interconnected and, in order to gain an advantage, they must be able to integrate their internal processes with external stakeholders, including customers and suppliers, to stay ahead of the curve. AI technologies play a key role in this integration, improving collaboration along the supply chain and driving superior performance by enhancing automation capabilities and optimizing companies' analytical and relational skills, as described in the previous chapters. In this context, artificial intelligence is an essential resource that can amplify the strategies of Lean SC, which focus on maximizing operational efficiency by eliminating waste, and Agile SC, which provide the flexibility needed to respond quickly to unpredictable market demands. This allows companies to obtain advantages in terms of efficiency by increasing their flexibility and thus offering a new dimension of performance improvement (Raji *et al.,* 2021).

This thesis provides a study that fills a gap in the literature, exploring how AI technologies are able to influence the overall performance of the company considering Lean and Agile SC practices as mediating variables, which interact in this relationship. In particular, it investigates the extent to which AI enables and improves the implementation of these SC strategies and evaluates the consequent impact on company performance. Based on these reflections, three Research Questions have been formulated that allow to guide the entire research process by delimiting the field of study:

RQ1. **What effect do AI base technologies have on the Lean and Agile SC strategies?**

RQ2. **What effect do AI base technologies have on firm's operational performance?**

RQ3. **What effect does the Lean and Agile SC strategy have on the firm's operational performance?**

With the purpose of answering the previous research questions, the present thesis follows a conceptual scheme that is based on a series of hypotheses outlining the relationships among key variables. These hypotheses, which I report next, were formulated to test the interactions among the variables with the intention of testing the theoretical constructs and gaining insight into the research context.
According to studies in the recent literature, the combined use of AI technologies and strategies aimed at the development of Lean practices promotes positive results. It is assumed that AI technologies can enable more efficient decision-making in organizations through improved data and information transmission and optimal management of physical assets, with positive effects on operational and logistical efficiency. The creation of an infrastructure that leverages AI resources makes it possible to foster knowledge sharing across facilities and collaboration among the actors that make up the supply chain. This can have a positive effect on Lean supply chain management, allowing resources and capabilities within the supply chain to be transformed, making them increasingly efficient. AI can be used in order to monitor products along the path of the entire supply chain and thus optimize tracking that allows production and inventory plans to be adapted to market needs. This reduces inefficiencies and errors by improving the flow of information and assets, making the supply chain more accurate and integrated. Given the ability of AI technologies to support the integration, development and reconfiguration of skills, these can be employed to improve LSC strategies by increasing flexibility and the efficiency needed to thrive in a dynamic environment. Hence the formulation of the first hypothesis:

- H1: **AI base technologies have a direct and positive influence on LSC implementation**

The use of AI systems integrated within business processes is a useful resource for organizations to ensure better management of aspects of the supply chain. According to recent literature reports, organizations that adopt such technologies are able to cope more readily with market shifts, identifying trends and anticipating changes. Through the development of improved demand response and planning capabilities, studies indicate that this technology plays an important role in determining

supply chain agility by enabling the entire value creation apparatus to continuously adapt and reconfigure its resources. By enabling efficient information management and rapid data sharing, this technology makes it possible to create new knowledge within the organization and to optimally reconfigure internal and external resources, thus enabling the implementation of Agile supply chain management in dynamic and uncertain environments. Based on these aspects, the second hypothesis arises, which I report below:

- H2: **AI base technologies have a direct and positive influence on ASC implementation**

According to current literature Lean and Agile are approaches that can be considered complementary and influence performance. Companies that adopt Agile strategies integrate management paradigms based on the concept of Lean within their structures, which is not only a complement but a key component to the success of an Agile approach. Through the implementation of the Lean supply chain, organizations are able to minimize the use of resources while minimizing waste, thus laying the foundation for greater flexibility. Based on these considerations, studies show that flexibility is a relevant element that precedes and enables an approach aimed at agility. In particular, flexibility understood as the ability of an organization to adapt quickly to changes in market conditions is closely related to Lean practices, which consequently can be considered precursors to an Agile strategy. Based on these arguments, the following hypothesis is formulated:

- H3: **LSC has a direct and positive influence on ASC implementation**

Through the implementation of Lean and Agile strategies, higher supply chain performance can be achieved. By acting on cost reduction and cutting activities that do not add value, LSC strategies enable continuous improvement throughout the supply chain and thus achieve better performance. These results are achieved by increasing company efficiency, reducing operating costs and optimizing the time needed to produce and deliver goods or services, as well as keeping inventory levels low by minimizing the risk of surpluses or shortages. At the same time, ASC strategies also play an important role in improving a company's competitiveness and operational performance by increasing its ability to respond promptly to market needs, delivering products and services in the manner and timeframe desired by customers. Through an agile approach, organizations develop flexibility and adaptability by helping to develop dynamic capabilities that contribute positively to the achievement of improved business performance. Therefore, based on these considerations, it is assumed that the

implementation of these two strategies leads to the development of dynamic capabilities that enable companies to achieve high levels of performance, hence the rise of the following two hypotheses:

- H4: **LSC has a direct and positive influence on the firm's operational performance**
- H5: **ASC has a direct and positive influence on the firm's operational performance**

Artificial intelligence technologies enable the coordination of activities within companies and the automated production of goods and services, allowing for faster decision making, better demand forecasting, and the production of customized products at scale. Organizations that employ these technologies by integrating them within corporate boundaries should be able to achieve better operational performance, taking advantage of the opportunities generated through faster production processes, resource optimization and the implementation of new business models. The adoption of AI systems makes it possible to accurately capture data from the company's internal and external environment, process it and share the information with members of the organization, enabling the identification of new market opportunities. Recent studies attest to the ability of AI technologies to generate greater integration between suppliers and customers, increased overall productivity, reduced operating costs and superior product quality. Accordingly, the formulation of the last hypothesis of this study is as follows:

- H6: **There is a positive relationship between AI base technologies and the firm's operational performance**

Finally, we go on to hypothesize a final relationship between operational and business performance, assuming that the former has an impact on the overall performance of organizations. Specifically, improvements in operational performance are assumed to have a positive impact about the company's ability to achieve its strategic goals and maintain long-term competitiveness. From these considerations, the following formulation emerges:

- H7: **Operational performance has a positive and direct impact on firm performance**

Figure 4 shows from a conceptual standpoint the relationships among the variables based on the assumptions defined earlier. These were the focus of the study and guided subsequent statistical analyses to test their validity.

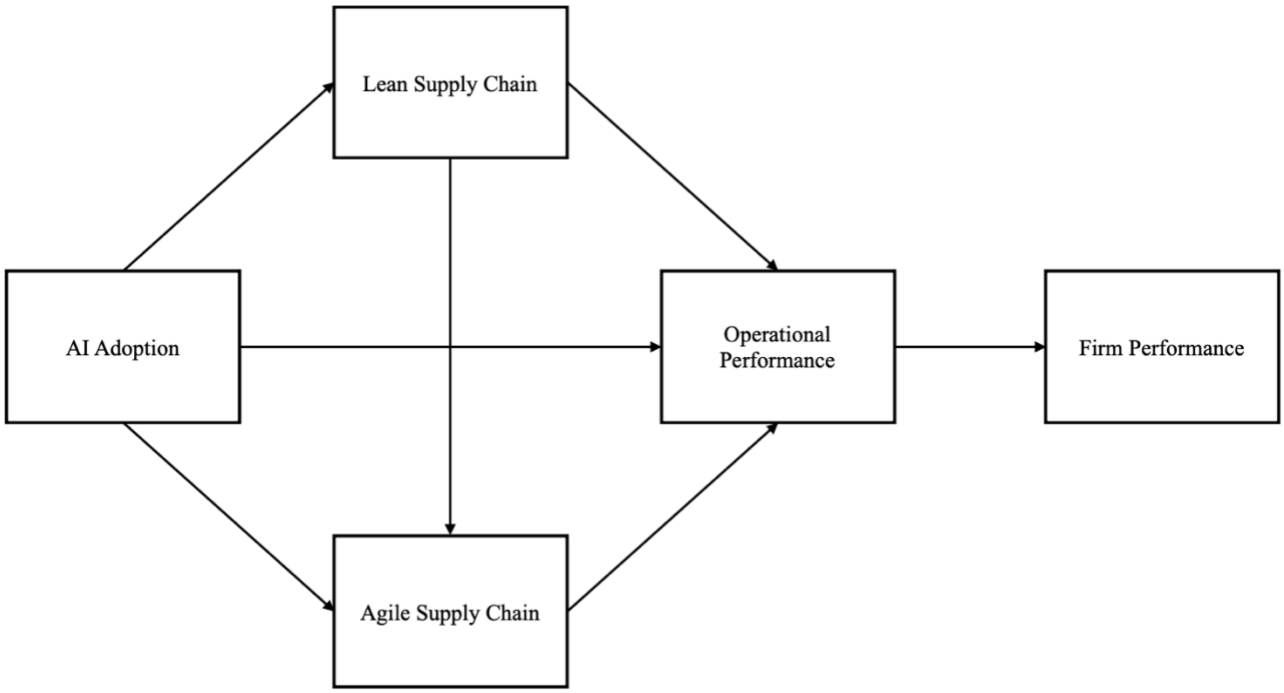

Figure 4

3.2 Research methodology

3.2.1 Sample design and data collection

The intent of the following thesis is to study the relationship that exists between the implementation of AI technologies and business performance. In order to proceed with an empirical analysis and thus examine from a statistical point of view the subsistence and actual significance of the study, a questionnaire was designed for employees of service and manufacturing companies. Specifically, in the present research, participants were recruited through Prolific software, an online survey platform, which allowed, through a careful screening carried out according to the criteria considered suitable for the research, to reach a total of 206 respondents. All questionnaires received were returned completed, which resulted in no exclusion from the data set, and adherence to the defined criteria resulted in a sample consistent with the purpose of the research. The survey consists of a first part regarding the demographic details of the respondents, including gender, education level, and geographic location, which are summarized in Table 1. This provide an overall picture of the respondents, allowing the results to be interpreted and the context in which the information was collected to be understood. In particular, it is possible to note that most of the feedback came from male respondents which reflects an imbalance with respect to gender distribution in the organizations

from which the sample came. Regarding the level of education, it is possible to state that the sample is generally well educated. In fact, 44 % have a Bachelor's degree and an additional 19.40% have a Master's degree, while only 34.50% have an education of high school diploma or less, indicating that most respondents are characterized by a high level of skills and knowledge. Most of the replies are from Europe and North America while the other geographical areas are underrepresented, indicating that the study results are more indicative of European and North American perceptions and conditions. A positive aspect concerns the high seniority of respondents, with nearly half of the participants in the survey (48.50%) having more than 10 years of work experience. This data is consistent with that for job position, which shows that most respondents occupy mid-level or supervisory positions (48.10%), followed by senior managers or department heads (30.60%). This indicates that the sample is mainly composed of people with significant responsibility and decision-making power within their organizations. Finally, it is possible to note that a large proportion of participants work in service-oriented companies (59.70%), followed by product-centered companies (37.40%), and only a small proportion (2.90%) are employed in platform-based companies.

Variables	Categories	N	%
Gender	Male	150	72.80%
	Female	56	27.20%
Education	High school or below	71	34.50%
	Bachelor’s degree	91	44.20%
	Master’s degree	40	19.40%
	Ph.D.	4	1.90%
Geographical area	Europe	134	64,10%
	North America	52	25.20%
	South America	1	0.50%
	Asia	9	4.40%
	Australia	12	5.80%
Job tenure	Less than 1 year	4	1.90%
	1-3 years	30	14.60%
	4-6 years	42	20.40%
	7-10 years	30	14.60%
	More than 10 years	100	48.50%
Job position	Entry-level/Junior staff	22	10.70%
	Mid-level/Supervisor	99	48.10%

	Senior manager/Department head	63	30.60%
	Executive/C-level	22	10.70%
Company type	Service-oriented	123	59.70%
	Product-centric	77	37.40%
	Platform-based	6	2.90%

Table 1

The survey was structured with specifically defined items to gather detailed information and accurately measure the key variables involved. Specifically, the variables considered refer to firm and operational performance, the degree of implementation of Lean and Agile supply chain strategies, and the adoption of AI technologies. Since these are latent variables and therefore not directly measurable, they were inferred through items in the survey in order to obtain quantitative data to allow for an in-depth analysis of the interaction between these variables and their possible impact on operational performance.

3.2.2 Variables

The research methodology employes in this study centers around a key independent variable related to the adoption of AI technologies. This is considered the factor that is expected to directly influence the other variables in the model. The implementation of Lean and Agile supply chain strategies is considered within the study as mediating variables, that is, elements that have the ability to influence the relationship between AI adoption and dependent variables. The latter are the operational and firm performance, respectively, which represent the final outcomes of the realized model.

Especially, the adoption of AI is hypothesized to improve the company's operational performance, increasing efficiency and responsiveness through the integration of advanced data, automation, and process optimization. Lean and Agile SC practices, which are strategies already known for their effectiveness in reducing waste and improving flexibility, are assumed to mediate this relationship. Accordingly, this research hypothesizes that the adoption of AI, supported and mediated by Lean and Agile SC strategies, leads to an increase in operational and business performance, improving not only internal efficiency but also the company's overall competitiveness in the global market.

The variables under study can be categorized as latent variables that cannot be measured directly but are inferred through a series of observable indicators, which in this study are the items that make up

the survey. In order to measure the adoption of AI within the relevant organization, three categories defined on the basis of the capabilities made possible by the implementation of this technology were used. The first refers to AI-enabled automation capabilities, measured through 3 items that assess the use of AI tools for automating basic and repetitive tasks, allowing employees to focus on higher value-added activities. The second category refers to AI-enabled analytical capabilities, in which three items measure the ability of the use of AI technologies to respond quickly to changes in inventory levels, predict changes in demand, and test various scenarios before making a decision. Finally, the relational capabilities enabled by AI are considered. The three items representing this category refer to the extent to which the use of AI tools are employed to manage customer relationships, including chatbots and data analysis tools for managing customer interactions.

The LSC scale consists of three dimensions each defined by specific items. The first characterized by 2 items refers to the use of tools to eliminate waste in the LSC. The second dimension refers to the operationalization of the LSC strategy as measured by 2 items that assess high inventory turnover, minimization of inventories, and standardization of processes and products. The last dimension, on the other hand, refers to LSC strategy planning, represented by 2 items related to forecasting activities and uncertainty management strategy.

The ASC scale was measured using 5 items in order to capture aspects of the SC's ability to make changes according to specific customer requirements, plan production in response to changing market needs, increase capacity in the short term, adjust delivery times, and respond to customer demand.

The fourth variable referring to the operational performance is measured, instead, through indicators of efficiency and delivery. The first dimension is represented by two items that measure the level of inventory turnover and the time taken from raw materials to delivery. The second dimension similarly refers to two items that assess punctuality and speed of delivery.

Finally, corporate performance was evaluated by considering 5 items and asking for information compared to the situation of competitors. Specifically, the items considered cover such aspects as profitability, sales growth, revenue growth, market share growth, and an overall assessment of performance relative to competitors

Each variable is then defined through a set of specific items to measure various aspects of the theoretical construct considered, using a 7-point Likert scale for evaluation.

3.3 Data Analysis

To carry out the following study, data analysis methods were used to ensure the reliability and validity of the results, addressing problems such as common method variance and multicollinearity. Using tools such as SPSS and SmartPLS, both descriptive statistics and structural equation models (SEM) were conducted to accurately evaluate the relationships between latent and observed variables. Common method variance is defined as variance in systematic error arising from a common method used to measure study constructs, which could compromise the reliability and validity of the research results. To mitigate the risk of common method variance inherent in studies using self-reported questionnaires for both dependent and independent variables (Podsakoff et al., 2003), this study employed multiple strategies. First, respondents were granted anonymity to minimize response bias, resulting in greater sincerity and responses consistent with interviewees' true opinion. Next, variance inflation factors (VIFs) were examined for values above 3.3, as suggested by Kock (2015). The Variance Inflation Factor (VIF) is a measure used in statistics to identify the severity of multicollinearity in regression analysis. It is a statistical concept that indicates the increase in the variance of a regression coefficient as a result of collinearity. Especially, multicollinearity exists when two or more of the independent variables demonstrate a linear relationship between them, causing problems in the analysis, reducing the precision of coefficient estimates and making it difficult to interpret the results. In order to verify the absence of this issue, an analysis was conducted that confirmed that no V'ìF exceeded the threshold defined by Kock, thus indicating the absence of multicollinearity and supporting the reliability of the study's predictions.

In this research, data analysis, including descriptive statistics and construct reliability assessment, was conducted with SPSS version 27.0. This enabled a baseline assessment of the information obtained, providing a general overview of the sample data as well as the consistency of the measurement scales and constructs used in the study. For the analysis of the research model, *partial least squares* (PLS) analysis was employed through SmartPLS 3.0 software. This statistical technique allows the construction of models involving latent variables, i.e., theoretical constructs that cannot be measured directly, and observed variables. Specifically, the two-stage procedure recommended by Hair and colleagues (2013) for structural equation modeling (SEM), a statistical technique used to analyze relationships between latent and observed variables, was followed. In the first stage, the measurement model was tested, a key step to ensure that the latent variables are measured correctly and reliably from the observed variables, while in the second stage, the structural model was examined, assessing whether the hypothesized relationships between the latent variables are supported by the data.

3.3.1 Measurement model

A measurement model describes how latent constructs are measured through observable indicators. In this context, convergent validity is a fundamental concept that refers to the extent to which items of a latent construct are correlated with each other, thus assessing how well items that are designed to measure the theoretical concept actually do so and are consistent with each other. Initially, the convergent validity of the measurement model was assessed by examining factorial loadings, composite reliability (CR), average variance extracted (AVE), and Cronbach's alpha (α), the results of which are presented in Table 3.

Specifically, the following information can be extrapolated from the results obtained: standardized factor loadings indicate how well an item represents the latent construct with which it is associated, and consequently measure the strength of the relationship between an observable indicator and the latent construct the indicator is supposed to measure. In the study under review, standardized factor loadings for all items considered exceeded the threshold of 0.5, as recommended by Hair and colleagues (2009), indicating strong indicator reliability. Composite reliability values, on the other hand, is an indicator similar to Cronbach's alpha (α) and, both measure the internal consistency of items representing a latent construct, thus serving as an indicative measure of how well items work together to measure a latent construct. Specifically, in all cases considered, both of these indicators exceeded the benchmark of 0.7, further demonstrating the consistency of the items used in the measurement model. Ultimately, even referring to the AVE values, which assesses the amount of variance a latent construct explains in its indicators relative to the total variance, were above the 0.5 threshold, suggesting adequate convergent validity (Hair et al., 2013).

Further to the reported analyses, Table 2 shows both z-values and p-values for each standardized factor loadings, providing additional information on the statistical significance and reliability of the model constructs. Applied to factor loadings in a measurement model, the z-value indicates how significantly different an indicator's factor loadings is from zero. Specifically, a high z-value indicates that the factor loadings are significantly different from zero, suggesting that the indicator has a strong and significant relationship with the latent construct. The analysis performed shows a high z-value, indicating that each indicator is a good representative of the construct. Looking at the p-value, meanwhile, it can be seen that for all indicators in the measurement model, the value is less than 0.001 demonstrating that the standardized loading factors for these indicators are highly significant.

Ultimately, these analyses testify the robustness of the model considered, supporting its reliability and validity.

Factor	Indicator	z-value	p-value	Std. Est.
FIRMPER	FIRMPERF_1	15.530	< .001	0.866
	FIRMPERF_2	17.629	< .001	0.932
	FIRMPERF_3	17.879	< .001	0.940
	FIRMPERF_4	14.577	< .001	0.832
	FIRMPERF_5	15.283	< .001	0.858
OPERPER	OPERATPERFO_1	8.990	< .001	0.598
	OPERATPERFO_2	13.543	< .001	0.810
	OPERATPERFO_3	14.952	< .001	0.863
	OPERATPERFO_4	14.939	< .001	0.862
LSC	LSC_1	10.348	< .001	0.672
	LSC_2	11.374	< .001	0.721
	LSC_3	8.703	< .001	0.588
	LSC_4	10.118	< .001	0.660
	LSC_5	11.603	< .001	0.731
	LSC_6	13.343	< .001	0.807
ASC	ASC_1	12.990	< .001	0.782
	ASC_2	14.620	< .001	0.845
	ASC_3	13.083	< .001	0.786
	ASC_4	13.083	< .001	0.786
	ASC_5	13.946	< .001	0.819
AIADOPT	AIADOPT_1	17.096	< .001	0.914
	AIADOPT_2	16.710	< .001	0.902
	AIADOPT_3	16.835	< .001	0.906
	AIADOPT_4	17.094	< .001	0.914
	AIADOPT_5	16.469	< .001	0.894
	AIADOPT_6	16.154	< .001	0.884
	AIADOPT_7	16.610	< .001	0.899
	AIADOPT_8	14.482	< .001	0.825
	AIADOPT_9	16.177	< .001	0.885

Table 2

	Cronbach's Alpha	Composite Reliability	Average Variance Extracted (AVE)
AIADOPT	0.972	0.976	0.818
ASC	0.901	0.927	0.716
FIRMPERF	0.948	0.960	0.827
LSC	0.848	0.888	0.569
OPERPERF	0.860	0.906	0.708

Table 3

Subsequently, discriminant validity was assessed to determine the extent to which constructs were distinct from one another. Especially, it indicates whether a construct is truly unique and not too similar to other constructs that might be confused with it. Following the approach recommended by Henseler et colleagues (2015), the Heterotrait-monotrait (HTMT) ratio of correlations was analyzed. The HTMT values, as shown in Table 4, did not exceed the 0.85 threshold set by Henseler and colleagues (2015), affirming the discriminant validity of the measures. This ensures the theoretical clarity as well as the validity of the conclusions based on the study under consideration.

	AIADOPT	ASC	FIRMPERF	LSC	OPERPERF
AIADOPT					
ASC	0.479				
FIRMPERF	0.316	0.363			
LSC	0.645	0.682	0.526		
OPERPERF	0.458	0.625	0.518	0.593	

Table 4

To ascertain the model's overall fit, several model-fit measures were employed, including, CFI, GFI, TFI, SRMR and RMSEA, indicators that provide insight into how well the model fits the observed data. Specifically, the CFI and TFI indicators are similar to each other and assess the fit compared to a null model that assumes no relationship between variables, with higher values indicating a better fit. The GFI Measures the proportion of variance-covariance explained by the model relative to the observed data. The last two indicators considered, instead, are SRMR and RMSEA. The former measures the mean difference between observed and model-predicted values, standardized to account for variance; the latter assesses how well the model fits the observed data, penalizing model complexity. In addition to these analyses, the CMIN/df, a fit ratio used to assess how well a model fits the observed data, was also evaluated. Specifically, with this ratio, we compare the chi-square value with the number of degrees of freedom, allowing us to identify the goodness of fit and the

degree of complexity of the model. All these indicators, reported in Table 5 fell within the widely accepted thresholds as established in prior research (Bentler 1990; Hair *et al*., 2009; Hu & Bentler, 1998; Schumacker & Lomax, 2016; Ullman, 2001), affirming the robustness of the model and its good representation of the data.

Fit Indices	Recommended Value	Obtained Value
CMIN/df	2-5	2.053
CFI	>.90	.928
GFI	>.90	.940
TFI	>.90	.920
SRMR	<.08	.051
RMSEA	<.08	.071

Table 5

3.3.3 Structural model

In evaluating the structural model, Hair et colleagues (2013) recommended assessing R^2 values, beta coefficients, and corresponding t-values through a bootstrapping procedure with 5,000 resamples which resulted in more robust and reliable estimates of the model parameters and to assess the uncertainty associated with the estimates. Specifically, the coefficient of determination R^2 measures how much of the variance in the dependent variables is explained by the independent variables in the model. A high R^2 indicates that the model explains the variability in the data well and can predict the latent dependent variables. The R^2 values for the dependent variables, as reported in Figure 5, exceeded the 0.26 benchmark suggested by Cohen (1988), with the only exception of firm performance, which, however, is very close to the threshold value and can therefore be considered negligible, indicating a substantial model fit.

Beta coefficients represent the strength and direction of relationships between latent variables in the model, indicating the impact one variable has on another, while, t-values are used to test the statistical significance of beta coefficients, indicating whether the observed effect is statistically significant.

Additionally, the predictive relevance (Q^2) and effect sizes (f^2) should be reported. Predictive relevance (Q^2), assessed through the blindfolding procedure and cross-validated redundancy, indicates the model's empirical data reconstruction capability using the model and PLS parameters. This indicator measures how well the model is able to predict the observed data for the dependent

variables, and tests whether the model has significant predictive ability or whether its predictive ability is weak or nonexistent. A Q^2 greater than 0 suggests the model has predictive relevance, whereas a Q^2 less than 0 indicates a lack of predictive relevance. Results showed positive Q^2 values for all endogenous variables, demonstrating good predictive relevance, as illustrated in Figure 5.

Effect sizes f^2 were also evaluated, using Cohen's (1988) benchmarks of 0.02 for small, 0.15 for medium, and 0.35 for large effects, as significance levels (p-values) indicate the presence of an effect but not its magnitude. In this way it is possible to quantify the magnitude of a relationship between variables, providing an indication of how large or important the effect is in practical terms. Especially, it was found that the relationships exhibited different values from small to large effects, as detailed in Table 6.

Description	Beta	t-value	f^2	Decision
AIADOPT → ASC	0.149+	1.864	0.023	Not supported
AIADOPT → LSC	0.588***	11.073	0.528	Supported
AIADOPT → OPERPERF	0.131+	1.681	0.017	Not supported
ASC → OPERPERF	0.367***	5.338	0.131	Supported
LSC → ASC	0.515***	6.881	0.280	Supported
LSC → OPERPERF	0.209*	2.395	0.035	Supported
OPERPERF → FIRMPERF	0.473***	8.327	0.288	Supported

Notes. * p< 0.05; **p<0.01; ***p<0.001

Table 6

The analysis began by examining the relationships between variables. Regarding the implementation of an Agile supply chain strategy, it was found that the adoption of AI technologies exerts a positive but not significant influence (b=0.149, p>0.05). This suggests that while the effect tends to be positive, the impact of AI technologies on Agile supply chain strategy is not strong enough to be considered statistically significant. Similarly, AI adoption has a positive but not significant effect on the operational performance (b=0.131, p<0.05), showing that there is no direct and significant relationship between these variables thereby refuting hypotheses H2 and H6.

In the analysis of factors influencing operational performance, the effect due to the implementation of Agile and Lean supply chain strategies was also observed. Specifically, the implementation of Agile supply chain strategy was found to have a positive and significant impact on operational performance, (b=0.367, p<0.001). Likewise, Lean supply chain significantly and positively influence performance, despite a lower level of significance (b=0.209, p<0.05). This highlights that although

the effect of Lean supply chain is less pronounced or evident, it is still statistically significant and relevant, which allows us to confirm both hypotheses H4 and H5 of the present study.

Regarding the implementation of Lean supply chain strategies, the study reports that the adoption of AI technologies has a positive and significant influence on it (b= 0.588, p< 0.001), showing that the H1 hypothesis is supported by the data and confirmed. The relationship between Lean supply chain and Agile supply chain was also confirmed as hypothesized. Specifically, the analysis showed that the Lean supply chain strategy has a positive and significant impact on the Agile strategy (b=0.515, p<0.001), thus confirming the hypothesis that was originally formulated.

Finally, the analysis confirmed a positive and significant relationship between operational performance and firm performance (b= 0.473, p<0.001) as supposed in hypothesis H7. This indicates that improvements in operational efficiency contribute directly to the overall success of the company, underscoring the importance of optimizing internal processes to achieve better financial and strategic results.

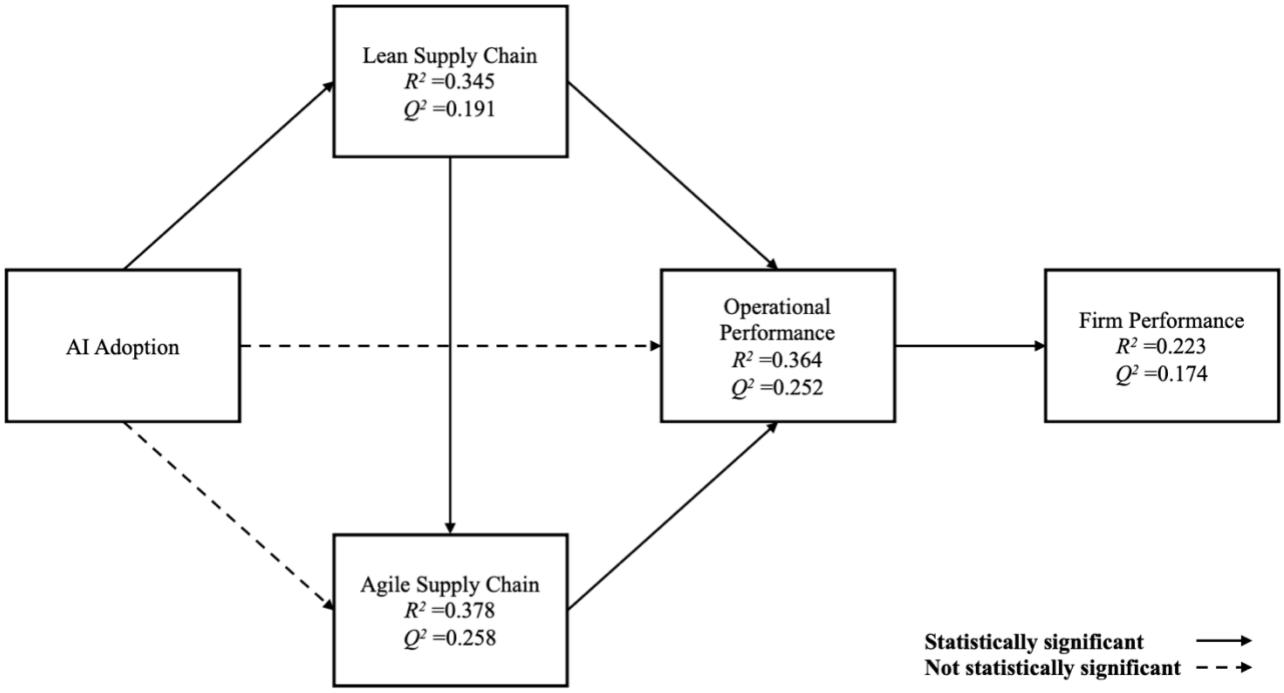

Figure 5

3.3.4 Mediation analysis

In addition, mediation analysis was conducted, a statistical technique used to understand the process by which an independent variable influences a dependent variable through one or more intermediate factors, called mediating variables. Mediation analysis was performed to assess the

following mediating roles: 1) Lean supply chain in the relationship between AI adoption and operational performance; 2) Agile supply chain in the relationship between AI adoption and operational performance; 3) Agile supply chain in the relationship between Lean supply chain and operational performance.

For the first mediation analysis, the results revealed a significant indirect effect of AI adoption on OP through LSC (b=0.123, p<0.020). The direct effect of AI adoption on OP was not significant, but with the inclusion of LSC as a mediating variable, the effect of AI adoption on OP became significant. This shows a full mediating role of LSC in the relationship between AI adoption and operational performance, emphasizing the importance of developing LSC strategies to maximize the benefits of AI adoption.

For the second mediation analysis, the results revealed a not significant indirect effect of AI adoption on OP through ASC. This means that ASC does not significantly mediate the relationship between AI adoption and operational performance, indicating that AI adoption impacts OP through other factors, such as LSC, rather than ASC.

Finally, the third mediation analysis, the results revealed a significant indirect effect of LSC on OP through ASC (b=0.189, p<0.000). The total effect of LSC on OP was significant (b=0.398, p< 0.000), with the inclusion of the mediator (ASC) the effect of LSC on OP was still significant (b=0.209, p<0.017). This shows a partial mediating role of ASC in the relationship between LSC and OP, meaning that part of the effect of LSC on OP is mediated by ASC, while part of the effect of LSC on OP is direct. LSC improves OP performance partly directly, and partly through the implementation of ASC strategies.

In summary, it can be deduced from these analyses that organizations adopting AI technologies should focus on implementing LSC strategies to translate AI adoption into significant improvements in operational performance, whereas they should consider the role of ASC strategies as an additional, but not sufficient support on their own to optimize operational performance.

3.4 Discussion of results

This study provides valuable insights into the synergistic effects of AI and SCM practices on business performance. Despite what has been reported in recent literature and the initial expectations that the adoption of AI technologies can revolutionize supply chain strategies and business performance, the study revealed that their direct impact on Agile supply chain and operational performance is not significant.

In response to RQ1, it is possible to state that although the adoption of AI technologies has a positive and significant impact on the implementation of Lean SC strategies, with regard to the Agile approach, the adoption of AI exerts a positive influence, but this effect is less pronounced and not statistically significant. Consequently, it is possible to say that AI is a technology for improving operational efficiency, reducing waste, and optimizing processes from a Lean perspective, but it is not a key determinant for the success of Agile strategies.

Addressing RQ2, which is the focus of this elaborate, the result shows that, AI integration may require further combination and optimization with other technologies or business strategies to have a tangible impact. Although it is a promising technology with high growth potential, using this innovation in isolation may not be sufficient to achieve significant improvements in performance. This indicates that organizations must be able not only to invest in AI but also to manage this technology so that it can be integrated consistently with business operations.

The analysis conducted confirmed the positive impact that Lean and Agile supply chain strategies have on business performance, responding to RQ3. Going into specifics, the study shows that a strategy related to the Lean supply chain approach has a positive and significant impact not only directly but also indirectly through the role played by the Agile supply chain. This shows that even in a modern context of digitization and automation, organizations must be able to maintain and enhance supply chain management strategies, which play a central role in maintaining a sustainable competitive advantage.

Among the most significant findings to emerge from the research is the centrality played by the LSC as a mediator in the relationship between AI adoption and operational performance. This suggests that although AI does not have a direct effect as a stand-alone technology, its impact can be triggered through the combined effect of Lean strategies. These can be viewed as a framework through which technological innovations such as AI can be best leveraged to achieve greater efficiency and thus obtain improvements in business performance.

As a final result of the analysis, moreover, the positive and significant relationship between operational and overall company performance emerges. Consequently, the mediating effect played by Lean supply between the adoption of AI technologies and operational performance also reverberates on overall financial and strategic performance, thus posing itself as a key determinant of long-term business success.

Given these considerations, it is possible to argue that modern advanced technologies such as AI are revolutionary and powerful tools, yet they only fulfill their potential when integrated into an appropriate business and strategic context. Organizations should be able to adopt a coherent approach that can combine AI and established supply chain strategies in order to create synergies that allow the

full benefits of technological innovation to be harnessed and consequently achieve significant improvements in both operational and overall business performance.

3.4.1 Limitations

Some limitations related to this study can be highlighted. As a first consideration, the research conducted is based on variables that are by their nature latent and therefore not directly observable, the use of which may lead to the emergence of certain biases. In particular, ambiguities related to the correct definition of variables and subjectivity in the selection of indicators may arise.

Second, this study makes particular reference to two supply chain management strategies. Considering other approaches, such as the resilient and green SC strategies, may reveal additional elements that have significant impact in the relationship between AI technology adoption and operational performance.

Another aspect that may represent a weakness of the study conducted concerns the limited scope of individuals who can be reached through surveys and who represent the research sample. While 206 respondents represent a sample that allows for meaningful results, increasing the scope of those involved would increase the statistical power of the study and the generalizability of the results, thus being able to rely on more robust and reliable analyses.

Finally, a final aspect that needs attention concerns the limited geographic scope of the study. Although results were collected from respondents from various parts of the world, most of them are from European countries (about 64 percent) and North America (about 25 percent). Regions such as Asia, Australia and South America account for a smaller proportion reflecting an unbalanced geographical distribution of respondents, which may affect the generalizability of the study results.

CONCLUSIONS

The purpose of this study is to conduct an empirical investigation into the impact of artificial intelligence on firm and operational performance. While the academic literature has begun to explore in depth topics related to the benefits of Industry 4.0 technologies for the organizations that adopt them, the area related to the effect of the implementation of artificial intelligence on business performance still seems to have limited coverage, as it is an absolutely current and expanding topic. The current study aims to extend the scope of the analysis by examining whether the use of artificial intelligence within organizational boundaries has a direct and positive impact on performance.

The empirical model employed in this study produced interesting results by going to fill gaps in the current literature on the topic under analysis. For the analysis of the research model, partial least squares (PLS) analysis was particularly suitable for this study, which included a large number of latent variables, such as the impact of AI technologies, business performance, and lean and agile supply chains. A PLS analysis also allowed the mediating effects of the latter two variables to be assessed in a clear and significant manner.

Given the objective of the research, which is to explore the impact of AI technologies on business performance in relation to supply chain practices, PLS is shown to be particularly effective in providing valid predictive models by maximizing the variance explained in the dependent variables. In particular, this is indicated by the Q^2 value, which was positive in all the relationships examined in the study. In addition, the R^2 value, which was above the threshold of 0.26, demonstrated the effectiveness of the model in explaining the variance in business performance, taking into account the use of AI technologies and the mediating variables in the supply chain.

By going to analyze the strength and direction of the relationships between the latent variables involved and the statistical significance of these relationships the results yielded interesting evidence about the synergistic behaviors between AI technology adoption and supply chain management practices and their impact on business performance. Among the most interesting aspects that emerged from the study is the fact that, contrary to initial expectations, the direct impact of AI technologies on operational performance is not significant. The centrality of the lean supply chain as a mediator in the relationship between AI adoption and operational performance is the most significant finding of the research leading to the conclusion that while advanced technologies such as AI are revolutionary and powerful tools, they can only realize their potential when integrated into an appropriate business and strategic context. Organizations need to adopt a coherent approach that combines AI with established supply chain strategies to create synergies that will enable them to reap the full benefits

of technological innovation and, as a result, achieve significant improvements in both operational and overall business performance.

LUISS

Appendix. Survey items

Dependent variables

Firm performance

Source: Queiroz, M., Tallon, P. P., Sharma, R., & Coltman, T. (2018). The role of IT application orchestration capability in improving agility and performance. *The Journal of Strategic Information Systems*, *27*(1), 4-21.

To what extent do the following statements reflect your firm's current situation in the last 12 months? (1 = strongly disagree to 7 = strongly agree)

- We are more profitable than our competitors.
- Our sales growth exceeds that of our competitors.
- Our revenue growth exceeds that of our competitors.
- Our market share growth exceeds that of our competitors.
- Overall, our performance is better than our competitors.

Operational performance

Sources:

Liu, G., McKone-Sweet, K., & Shah, R. (2009). Assessing the performance impact of supply chain planning in net-enhanced organizations. *Operations Management Research*, 2, 33-43.

Danese, P., Romano, P., & Bortolotti, T. (2012). JIT production, JIT supply and performance: investigating the moderating effects. *Industrial Management & Data Systems*, *112*(3), 441-465.

Please, indicate on a scale of 1–7 your firm's position in the following operational performance indicators compared to your competitors (1 = very poor; 2 = poor; 3 = below average; 4 = average; 5 = above average; 6 = good; 7 = excellent):

Efficiency

- Inventory turnover
- Cycle time (from raw materials to delivery)

Delivery

- On-time delivery performance

  Fast delivery

Mediation variables

Lean Supply Chain

Source: Moyano-Fuentes, J., Bruque-Cámara, S., & Maqueira-Marín, J. M. (2019). Development and validation of a lean supply chain management measurement instrument. *Production Planning & Control*, *30*(1), 20-32.

To what extent do you agree with the following aspects related to the LSC? (1 = strongly disagree to 7 = strongly agree)

Tools to eliminate waste in the SC:

- Value stream mapping is used to identify and eliminate waste throughout our supply chain.
- Our supply chain uses lean manufacturing techniques (such as pull flow, Kanban systems, and setup time reduction).

LSC operationalization:

- Our supply chain generates high stock turnover and minimizes inventory.
- Process and product standardization is a common practice in our supply chain.

LSC planning:

- Our supply chain does long-term forecasting of customer demands and only focuses on the current market segments.
- In our supply chain, the strategy for handling uncertainty consists of using queues and buffers to protect subprocesses.

Agile Supply Chain

Sources:

- Gligor, D. M., Holcomb, M. C., & Stank, T. P. (2013). A multidisciplinary approach to supply chain agility: Conceptualization and scale development. *Journal of business logistics*, *34*(2), 94-108.
- Qi, Y., Zhao, X., & Sheu, C. (2011). The impact of competitive strategy and supply chain strategy on business performance: the role of environmental uncertainty. *Decision Sciences*, *42*(2), 371-389.
- Tachizawa, E. M., & Gimenez, C. (2010). Supply flexibility strategies in Spanish firms: Results from a survey. *International Journal of Production Economics*, *124*(1), 214-224.

To what extent do you agree with the following aspects related to the ASC? (1 = strongly disagree to 7 = strongly agree)

- Our supply chain can make the adjustments to order specifications requested by our customers.
- Production planning has the ability to respond quickly to varying customer needs.
- Our supply chain can increase short-term capacity as needed.
- Our supply chain can adjust/expedite its delivery lead times.
- Our supply chain responds to customer demand.

Independent variable

Artificial Intelligence

Source: Sullivan, Y., & Wamba, S. F. (2024). Artificial intelligence and adaptive response to market changes: A strategy to enhance firm performance and innovation. *Journal of Business Research*, *174*, 114500.

To what extent do you agree with the following aspects related to the adoption of AI technologies in your company? (1 = strongly disagree to 7 = strongly agree)

AI-Enabled Automatic Capability:

- In our firm, AI tools and applications are used to automate time-consuming activities, including claim processing, basic customer-service interaction, and inventory tracking.
- In our firm, AI tools and applications are used to save staff time by allowing them to focus on higher-value activities.
- In our firm, AI tools and applications are used to automate routine as well as back-office tasks.

AI-Enabled Analytics Capability:

- In our organization, AI tools and applications allow us to respond more quickly to changing stock or inventory levels.
- In our organization, AI tools and applications allow us to test nearly all potential scenarios before making a decision and asses the efficiency of different decisions under different conditions.

- In our organization, AI tools and applications allow us to enhance market prediction capabilities (e.g., next-best product or service a customer is likely to buy or the traffic in our stores/websites)

AI-Enabled Relational Capability:

- Our AI-based system offers various decision-making tools that enable us to manage our relationship with our customers.
- Our AI-based system offers various tools, such as chatbots, that enable us to support our interactions with our customers and enable us to promptly address their queries.
- Our AI-based system offers various tools that enable us to examine trends in the data for managing our interaction with our customers.

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