Entrepreneurship 4.0 and Success Factors in the Context of Industry 4.0: A literature review.

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Abstract

Throughout the ages, industry has undergone profound transformations, evolving from mechanization (Industry 1.0) to electrification (Industry 2.0), and subsequently to digitalization (Industry 3.0). Today, we stand at the dawn of Industry 4.0, an era that integrates advanced digital technologies such as artificial intelligence, the Internet of Things, and cyber-physical systems. This article examines the essential features of this new era, employing a methodological approach grounded in a comprehensive literature review. Marked by intelligent production, accelerated decision-making, and optimal resource utilization, Industry 4.0 places particular emphasis on sustainability and social responsibility. The associated challenges include adapting organizational structures and managing cybersecurity.

The article also explores entrepreneurial dynamics in response to these advancements, thereby redefining business strategies and structures with a focus on technological innovation, enhanced product and service customization, and the development of interdisciplinary skills among employees. It is further emphasized that ecological sustainability plays a central role in both contemporary and future entrepreneurial contexts, with optimized resource management and significant waste reduction. Drawing on a rigorous literature review, we have identified several key dimensions critical to the success of entrepreneurship in the era of Industry 4.0, including organizational structure, human resources, innovation processes, personalized production, customer relationship management, technological advancements, and sustainability. Within this framework, we have formulated hypotheses and developed a conceptual model demonstrating that, to maintain their competitiveness, companies must adopt strategies encompassing these six dimensions.

Keywords: Industry 4.0, Entrepreneurship 4.0, Internet of Things, Artificial Intelligence.

Résumé

À travers les âges, l'industrie a connu des transformations profondes, passant de la mécanisation (Industrie 1.0) à l'électrification (Industrie 2.0), puis à la numérisation (Industrie 3.0). Aujourd'hui, nous nous trouvons à l'aube de l'Industrie 4.0, une ère caractérisée par l'intégration de technologies numériques avancées telles que l'intelligence artificielle, l'Internet des objets et les systèmes cyber-physiques. Cet article se propose d'examiner les caractéristiques essentielles de cette nouvelle ère, en adoptant une approche méthodologique fondée sur une revue de la littérature. Marquée par une production intelligente, une prise de décision accélérée, et une utilisation optimale des ressources, l'Industrie 4.0 met un accent particulier sur la durabilité et la responsabilité sociétale. Les défis associés incluent l'adaptation des structures organisationnelles et la gestion de la cybersécurité.

L'article explore également les dynamiques de l'entrepreneuriat en réponse à ces avancées, redéfinissant ainsi les stratégies et structures des entreprises, avec un accent sur l'innovation technologique, la personnalisation accrue des produits et services, et le développement de compétences interdisciplinaires chez les collaborateurs. Il est également souligné que la durabilité écologique joue un rôle central dans le contexte entrepreneurial contemporain et futur, avec une gestion optimisée des ressources et une réduction significative des déchets. S'appuyant sur une revue rigoureuse de la littérature, nous avons identifié diverses dimensions clés déterminant la réussite de l'entrepreneuriat à l'ère de l'Industrie 4.0, telles que la structure organisationnelle, les ressources humaines, les processus d'innovation et de production personnalisée, la gestion de la relation client, les avancées technologiques, ainsi que la durabilité. Dans ce cadre, nous avons formulé des hypothèses et conçu un modèle conceptuel démontrant que, pour préserver leur compétitivité, les entreprises doivent adopter des stratégies englobant ces six dimensions.

Mots clés : Industrie 4.0, Entrepreneuriat 4.0, Internet des Objets, Intelligence Artificielle.

Introduction

Since the dawn of the industrial revolutions, the evolution of production methods has been marked by several phases of radical transformation, each redefining the industrial landscape. Industry 1.0 introduced the mechanization of processes, followed by Industry 2.0, which saw the advent of electrification, and Industry 3.0, which defined the era of widespread digitization. Today, we stand on the threshold of Industry 4.0, characterized by an advanced integration of digital technologies, the Internet of Things (IoT), Artificial Intelligence (AI), and cyber-physical systems (Buła & Niedzielski, 2021). This era emphasizes high innovation capabilities, flexible and customized production, decentralized organizations that facilitate rapid decision-making and resource efficiency, autonomous units capable of solving problems automatically, smart digitalized factories, and a skilled workforce integrated into intelligent systems (Bello et al., 2024).

Industry 4.0 extends beyond mere automation of industrial processes; it represents a fundamental shift in how businesses design, manufacture, distribute their products, and deliver their services (Ibarra et al., 2018; Machkour & Abriane, 2020b). Companies are now incorporating intelligent systems that enable highly flexible and customized production, leading to resource optimization and waste minimization (Bibri et al., 2023). Moreover, advanced digitization provides entrepreneurs with real-time product customization in response to consumer preferences while transforming supply chains into intelligent networks capable of swiftly reacting to market fluctuations (Karmaker et al., 2023). Consequently, value creation, presentation, and sustainability are critical success factors in business processes (Hanelt et al., 2021). Thus, the importance of entrepreneurship in this context remains crucial as entrepreneurs are often the first to adopt and integrate these new technologies, thereby creating innovative and sustainable business models (Diez-Olivan et al., 2019; Jabbour et al., 2018).

Alongside the emergence of this new era, the role of the entrepreneur has also evolved. Entrepreneurs are expected to adopt advanced technologies to transform traditional business processes. They are encouraged to use digital tools to enhance decision-making, optimize operations, and tailor offerings to customer needs. Focused on technological innovation and sustainability, this era directs entrepreneurship to play a vital role in building a more resilient and inclusive industrial future (Ibarra et al., 2018). This new entrepreneur is called to navigate a complex environment, leveraging the capabilities of Artificial Intelligence, big data analytics,

and autonomous systems to create agile and innovative business models (Bal & Erkan, 2019), leading to the emergence of Entrepreneur 4.0.

Moreover, the requirements for Entrepreneur 4.0 extend well beyond mere technological adoption; Industry 4.0 has introduced an innovative entrepreneurial approach centered on agile and integrated production systems, allowing for rapid production and accelerated market entry. This necessitates a comprehensive revision of business strategies by integrating new technologies. Entrepreneurs must focus more on real-time communication with clients, flexibility, quality enhancement, differentiation, logistics process efficiency, and agile organizational structures (Mrugalska & Ahmed, 2021). They are also called upon to foster continuous innovation, strengthen team collaboration, and manage organizational changes with agility (Mrugalska & Ahmed, 2021). The impact of industrial transformation also alters the working methods of entrepreneurs while emphasizing waste prevention, accelerated design and production cycles, environmentally friendly production systems, and employee integration into new work processes (Kumar et al., 2023). Consequently, there are numerous opportunities and challenges related to this new era.

This analysis establishes a comprehensive structure for grasping how Entrepreneur 4.0 addresses societal and environmental challenges by developing sustainable and ethical solutions that contribute to inclusive and responsible economic development. Integrating these practices into entrepreneurial strategies is essential to ensure sustainable economic growth in the age of Industry 4.0. Adopting this new form of entrepreneurship also fosters the emergence of agile startups and companies capable of quickly adapting to technological changes and consumer needs. By leveraging real-time data and automating processes, Entrepreneur 4.0 can reduce operational costs, enhance efficiency, and create highly personalized products and services.

To achieve our research objectives, we have developed a conceptual framework by identifying key variables and exploring concepts such as Entrepreneurship, Industry 4.0, the Internet of Things, and Artificial Intelligence using databases such as JSTOR, ScienceDirect, Scopus, Google Scholar, and Semantic Scholar. After combining these keywords, we focused our search on scientific articles before broadening our investigation by applying the chain research method (Boote & Beile, 2005).

In this article, we first explore Industry 4.0, highlighting the impact of integrating advanced technologies and automation on production and the importance of customization, sustainability,

and cybersecurity. We will also demonstrate the significance of Entrepreneur 4.0, which plays a crucial role in the era of Industry 4.0 as both a catalyst for innovation and an engine of economic transformation, enabling the development of new business models that meet the demands of customization, flexibility, and speed inherent in Industry 4.0. We will then focus on Entrepreneur 4.0 as a response to the challenges of this industrial revolution, emphasizing its specifics across various aspects, namely organizational structure, human resources, innovation and customized production processes, customer experience and personalization, technological aspects, and sustainability dimensions.

1. Literature Review

1.1. Industry 4.0 and Its Characteristics

Recognized as the fourth industrial revolution, Industry 4.0 relies on integrating advanced technologies and is characterized by automated production systems, cloud computing, the Internet of Things, cyber-physical systems, smart factories, and machine-to-machine communication. According to Jiang et al. (2020), embedding cyber-physical systems into production processes significantly enhances the efficiency and flexibility of modern factories, allowing for smoother interaction between physical and digital components.

Similarly, Mittal et al. (2019) emphasize that intelligent factories, the essence of the Industry 4.0 concept, refer to spaces equipped with digital technologies where manufacturing is entirely carried out by sensors and autonomous systems, leveraging connectivity and automation to provide more adaptable and responsive production. Additionally, García de Soto et al. (2022) underscore the importance of virtualization and decentralization in transforming manufacturing environments, reflecting the principles of Industry 4.0 and their impact on optimizing industrial processes.

Furthermore, open innovation and customization principles are crucial role in Industry 4.0. Kipper et al. (2021) explore how open innovation practices and self-organization facilitate the integration of new ideas and technologies into production processes, enabling a quicker response to market needs. Concurrently, Machkour & Abriane (2019b) underline the increasing importance of product and process customization in response to specific consumer demands within an ultra-dynamic industrial environment. These enhanced perspectives also constitute increased product and service personalization through better data management and manufacturing process fabrication (Wang et al., 2017).

Moreover, corporate social responsibility and sustainability are essential dimensions within the framework of Industry 4.0. Karmaker et al. (2023) examine how waste reduction and resource efficiency can improve sustainable management practices in supply chains. Simultaneously, Sanchez (2019) emphasizes the importance of integrating social responsibility and sustainability principles into modern production strategies, arguing that this inclusion will balance economic performance and environmental responsibility. In the context of Industry 4.0, strategic alliances and cross-sector collaboration can optimize resource management and foster innovation while addressing sustainability challenges (Kumar et al., 2023).

Thus, for Industry 4.0 applications to succeed, certain critical factors must be present, such as committed top management and a well-defined organizational strategy. For an effective transition to automation, these factors remain essential. Additionally, Fettig et al. (2018) demonstrate that organizational structure must be integrated, extending beyond the four walls and covering a broad range of areas and processes, from procurement to delivery, to maximize the benefits of digitization and automation of production processes. This holistic approach remains crucial for value creation and performance optimization. Similarly, considering economic, environmental, and social dimensions is fundamental to ensure the success of Industry 4.0 projects. Karmaker et al. (2023) highlight that entrepreneurs must manage environmental and social impacts alongside economic aspects to ensure sustainable adoption. Effective human resource management and engagement also determine successful transformation (Jafari, 2024).

Furthermore, cybersecurity and system security are significant concerns, on the one hand, in implementing complex digital technologies associated with Industry 4.0 and, on the other hand, for protecting automated processes from potential threats (Clim, 2019). Consequently, Entrepreneur 4.0 emerges as a response to the challenges of Industry 4.0, requiring advanced skills in artificial intelligence and digital technologies. Concurrently, Gupta et al. (2024) argue that entrepreneurial practices must adapt to integrate automation and innovation, leading to the redefinition of strategies and structures necessary to succeed in the dynamic environment of Industry 4.0.

1.2. Entrepreneur 4.0 and Its Characteristics

In the era of Industry 4.0, the entrepreneur is pivotal to a profound transformation in business practices, distinguished by the adoption of sophisticated digital technologies and the increasing interconnection of production systems. This entrepreneur, often referred to as a "digital

entrepreneur" or "technology entrepreneur," leverages innovations not only to create new business opportunities but also to transform traditional business models (Hastuti et al., 2023). Indeed, Entrepreneur 4.0 represents a significant shift in how businesses reorganize their structures, production systems, interactions with customers and employees, and relationships with other stakeholders in their professional environment. The ability of these entrepreneurs to innovate rapidly, utilize big data for strategic decision-making, and leverage digital platforms to reach a global market position them as key players in the contemporary economic ecosystem (Dwiastanti & Mustapa, 2020).

Moreover, Entrepreneur 4.0 goes beyond merely adopting new technologies; it plays a crucial role in redefining industrial value chains. These entrepreneurs act as change agents by introducing disruptive solutions that reshape production processes, optimize operational efficiency, and promote product innovation (Hanelt et al., 2021). This requires mastery of technological skills and the capacity to manage the inherent risks of adopting new technologies and anticipate associated economic and societal challenges. Additionally, the societal impact of Entrepreneur 4.0 is an area of growing concern. Entrepreneurs of this new era are not just technological innovators but also leaders in promoting sustainability and social responsibility.

1.2.1. Organizational Structure Aspect

The new organizational structures and production processes shaped by Industry 4.0 must also evolve to align with its principles, fostering greater autonomy and enhanced company collaboration. Organizations are adopting more flexible and decentralized models by leveraging cutting-edge digital technologies, such as cyber-physical systems and digital communication platforms. This transformation reduces bureaucratic processes and improves cross-functional cooperation, enhancing employee efficiency and engagement. Indeed, simplifying hierarchies and promoting autonomy allows for better adaptability to changing market needs (Margherita & Bua, 2021).

To align with the demands of Industry 4.0, organizations need to rethink their structures by integrating automated systems and digitized production processes. This evolution reduces hierarchical levels, promoting more horizontal and agile structures (Huang et al., 2021). Processes become less rigid and more diverse regarding tasks, encouraging increased collaboration (Huang et al., 2021). Consequently, managing this increased complexity requires thoroughly revising organizational processes to effectively integrate new technologies while harmonizing interactions between functions and human requirements. Companies are,

therefore, encouraged to adopt structures that enable smooth coordination and rapid adaptation to technological advancements and market demands (Mrugalska & Ahmed, 2021).

Managing this complexity becomes crucial for success in an advanced and complex production environment requiring a greater diversity of tasks. Organizational structures must thus integrate automated systems to facilitate communication and collaboration between teams to succeed in an increasingly sophisticated production environment (Ghobakhloo, 2020). Organizations have moved from traditional hierarchies to more interactive structures by eliminating intermediate management levels and promoting employee autonomy. Automation systems accelerate production processes and also alter their supervision. Moreover, organizational design now focuses on speed, flexibility, simplicity, and agility (Hanelt et al., 2021). Indeed, it is more crucial than ever to have structures capable of responding quickly and effectively managing change processes efficiently.

1.2.2. Human Resources Aspect

With the advent of Industry 4.0, the required human resources skills landscape has significantly evolved. Work processes have been transformed by integrating automation and cyber-physical systems, thus altering the qualifications needed to operate effectively in increasingly complex production environments. Indeed, the rise of intelligent technologies necessitates employees who can work interdisciplinarily with information technologies, adapt quickly to technological changes, and actively engage in collaborative processes while pursuing continuous learning (Li, 2022).

In parallel, training programs must evolve to meet the new demands of the labor market. García de Soto et al. (2022) emphasize the critical and enhanced importance of continuous training to enable employees to master new technologies and adapt to automated systems. Managing digital technologies and teamwork skills becomes essential, as employees must coordinate effectively and demonstrate autonomy in managing complex tasks (Miah et al., 2024). Consequently, the interconnected nature of modern production systems further accentuates the need for effective communication and high professional engagement.

Moreover, robotics' impact on the labor market remains significant. This is evidenced by performance improvements and new job opportunities in sectors related to maintenance, programming, and management of automated systems (Maisiri & Van Dyk, 2021). Kipper et al. (2021) show that despite the increase in digitization, human skills such as creativity, complex problem-solving, and managing interactions with machines remain indispensable.

Companies must, therefore, invest in developing their employees' skills to maintain competitiveness in this new industrial era. The evolution of work processes demands a reassessment of sought-after characteristics, emphasizing the ability to adapt to advanced technological environments and collaborate effectively with automated systems. As a result, the employability of employees with advanced technology skills is rising sharply, creating a dynamic labor market where companies actively seek to recruit talent suited to Industry 4.0 requirements (Whysall et al., 2019). Effective human resources management thus becomes essential for ensuring a smooth integration of new technologies and maintaining high levels of engagement. Ejsmont (2021) supports this approach and demonstrates that collaboration between employees and innovative technologies enhances productivity and job satisfaction.

1.2.3. Customer Aspect and Personalization of Customer Experiences

Entrepreneurship 4.0 places the customer at the heart of the strategy, integrating their preferences from the beginning of the production and commercialization process. Companies must evolve to offer personalized services tailored to the specific needs of customers, which requires integrated management of various service channels (Machkour & Abriane, 2020c). Customers now expect rapid responses and seamless interactions, and any delay or issue in service can lead to significant customer loss. Whysall et al. (2019) argue that data collection and analysis systems must be continuously optimized to enable companies to adapt quickly to changing preferences.

Analyzing data collected through information technologies and using obtained insights allow for determining customer preferences and expectations, thereby avoiding dissatisfaction and enhancing the quality of interactions. Intelligent systems manage customer relationships much more quickly, allowing for proactive handling of complaints or even preventing potential complaints before they arise. Ameen et al. (2021) reinforce this perspective, demonstrating that the integration of predictive analytics technologies enables adequate understanding and response to customer expectations. Additionally, forecasts indicate that by 2025, 95% of customer interactions will be managed online, with future behavior predictions facilitated by artificial intelligence and extensive data analysis (CloudTalk, 2023)[1]. Machine learning systems enable advanced service personalization, meeting changing customer expectations without constant human intervention.

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[1] https://www.cloudtalk.io/blog/95-of-your-customer-interactions-may-be-ai-powered-by-2025-heres-how-to-make-the-most-of-it/ (Last accessed 20/06/2024)

It has become imperative to ascertain customers' increasingly volatile and diverse desires and adapt production, distribution, and communication processes accordingly. The entrepreneur must possess a comprehensive system that continually collects and processes data and makes calculated decisions to enhance customer satisfaction (Machkour & Abriane, 2020a).

Similarly, personalizing customer experiences has become an essential dimension in Entrepreneurship 4.0. This dimension, supported by technological advancements such as digital platforms, Artificial Intelligence, and data analytics systems, allows companies to design more relevant interactions tailored to individual consumer needs. Artificial Intelligence offers advanced personalization by scrutinizing large volumes of data to identify specific customer trends and preferences (Hoyer et al., 2020). This approach remains crucial for meeting customer expectations for personalized services and meaningful interactions.

Indeed, recommendation systems based on AI algorithms can suggest products or services that precisely match individual preferences, thereby increasing customer satisfaction and loyalty (Lemon & Verhoef, 2016). Furthermore, digital platforms and Customer Relationship Management (CRM) tools enhance this dimension by facilitating continuous personalized communication. These tools enable companies to track real-time customer interactions and adjust offers and messages based on behaviors and purchase histories (Hassine & Youssef, 2023). This proactive approach contributes to more effective management of customer relationships and significantly improves overall experience (Ijomah et al., 2024).

Thus, advanced manufacturing technologies such as on-demand production and 3D printing support the integration of personalization into customer experiences. These technologies enable creating custom products that address unique customer needs while minimizing waste associated with overproduction (Pal & Jayarathne, 2022). Similarly, Srivastava et al. (2021) reveal that companies integrating personalization strategies into their offerings can significantly increase profitability and market share. Entrepreneurs capable of delivering highly personalized customer experiences can meet high consumer expectations and create substantial competitive differentiation.

1.2.4. Innovation and Personalized Production Aspect

With the advent of intelligent systems, production processes have been profoundly altered from the design phase. Entrepreneurs must adapt production processes to meet personalized customer demands, aiming for rapid and high-quality production (Kulkarni et al., 2020). Achieving this requires systematic data collection and processing and continuous business environment

analysis. Indeed, using big data helps improve efficiency throughout the value chain, from design and production to inventory management and logistics (Huang et al., 2021).

To achieve these objectives within the context of Entrepreneurship 4.0, entrepreneurs must ensure the effectiveness of processes such as the production of intelligent products, agile collaborations, connected value creation, and decentralized, data-driven production control. Modern production environments, which utilize machine-to-machine communication and the Internet of Things, significantly simplify production control while keeping costs under control (Mittal et al., 2019). Moreover, cost management challenges while meeting increasing customer expectations for customization and speed require effective integration of digital technologies (Kulkarni et al., 2020). This approach optimizes production process performance and allows for rapid responses to changing market demands (Grassi et al., 2020).

In this vein, recent advancements in robotics, automation, and artificial intelligence have also altered the dynamics of production processes. Collaborative robots and autonomous systems increase flexibility and precision in production operations, reducing human errors and improving workplace safety. Companies must, therefore, adapt their processes and infrastructures to leverage these technological innovations and maintain their competitiveness in the global market (Ghobakhloo, 2020).

In the context of Industry 4.0, innovation and personalized production become essential pillars for entrepreneurs. Highly innovative products and personalized production allow companies to stand out in an increasingly competitive market. Indeed, to meet diverse customer needs and adapt to customization demands, entrepreneurs must focus on integrating advanced technologies and implementing flexible and adaptive systems (Lasi et al., 2014). Smart factories, equipped with cutting-edge technologies, play a vital role in this process by enabling seamless interaction between machines and humans, optimizing resource use, and controlling costs (Huang et al., 2021).

Thus, adopting open innovation practices and digital collaboration reinforces the emphasis on production flexibility and personalization. Companies must create environments where ideas can flow freely, and partnerships among different stakeholders are encouraged to foster co-creation and knowledge sharing. Consequently, shared innovation, combined with effective resource management and dynamic value creation, enables companies to design unique products tailored to specific customer preferences while maintaining high levels of performance and efficiency (Ghobakhloo, 2020).

1.2.5. Technological Aspect

1.2.5.1. Internet of Things

The Internet of Things has emerged as a significant driver of digital transformation, profoundly reshaping how businesses operate and interact with their environment. Since its introduction in the early 2000s, the concept of "IoT" has established itself as a pivotal technology, linking physical objects and devices to the Internet to support real-time interactions and data transmission (Machkour & Abriane, 2019a). This interconnection has paved the way for profound innovations across various sectors, including industry, energy, healthcare, agriculture, and, more recently, education (Bibri et al., 2023).

IoT plays a crucial role in creating new business models based on service personalization and advanced data analytics. These capabilities enable entrepreneurs to enhance operational efficiency, optimize processes, and provide products and services that more precisely meet customer expectations (Ali et al., 2021; Mishra & Salunkhe, 2023). Another area where IoT shows considerable potential is in energy management. Devices such as smart meters allow more efficient resource management, reducing costs and improving sustainability (Al-Turjman & Altrjman, 2019). Similarly, in agriculture, the use of IoT sensors to monitor environmental conditions and optimize irrigation has made agricultural practices more productive and sustainable (Hassebo & Tealab, 2023). These examples demonstrate that IoT facilitates more informed decision-making and efficient operations, which is essential for addressing current business challenges.

Additionally, integrating IoT into innovative environments offers numerous benefits, including improved career management, enhanced resource management, and increased security (Vaya & Hadpawat, 2020). For instance, IoT devices can monitor employees' physical activity, track environmental conditions, and manage energy consumption within company premises.

Thus, IoT is a transformative technology capable of redefining operational processes across various sectors while revolutionizing how businesses and institutions interact with their environment. Its impact on entrepreneurship is particularly significant, as it enables the emergence of new business models based on technological innovation and object connectivity. As IoT continues to develop and become more widespread, its role in enhancing efficiency, productivity, and sustainability will only grow, confirming its importance in the new digital era (Ali et al., 2021).

1.2.5.2. Artificial Intelligence

Artificial Intelligence (AI) is profoundly transforming the industrial landscape, marking a significant milestone in the fourth industrial revolution. Recent advancements in AI have shown notable progress in perception, creativity, and complex strategic execution. While some fear that the widespread adoption of AI may lead to massive job reductions and wealth inequality, historical trends from previous industrial revolutions show a contrary tendency: reduced unemployment rates and increased productivity (Majekodunmi, 2021). Debates about AI's future impact vary among optimists, pessimists, pragmatists, and skeptics. AI technologies, such as deep learning and machine learning, play a crucial role in this transformation (Batin et al., 2017).

Since the early days of AI with Ada Lovelace and Alan Turing, AI systems have evolved, notably with convolutional neural networks in 1989 and recent advancements in deep learning (Majekodunmi, 2021). These developments have enabled innovative applications such as image and speech recognition and the creation of generative models capable of producing creative works (Keune et al., 2024).

In the context of Entrepreneurship 4.0, AI is perceived as the "new electricity" of the emerging industrial revolution. Current trends include supervised learning for recommendation systems, deep reinforcement learning with agents, and computational creativity (Ferrara, 2024). These technologies improve decision-making processes and service personalization and introduce challenges related to ethics, security, and privacy (Nadimpalli, 2017). Indeed, the potential benefits of AI include solving complex problems, though associated risks require stringent regulation and international collaboration (Pariente et al., 2023). International and national strategies focused on competitiveness, ethical collaboration, and economic growth are expected to find a consensus to ensure transparency and security (Huang et al., 2023).

Indeed, Artificial Intelligence, with its growing capabilities and diverse applications, represents a crucial opportunity for entrepreneurship in the era of Industry 4.0, and organizations that strategically adopt AI will gain a significant competitive advantage. However, challenges related to ethics, regulation, and the implementation of global collaborative projects must be addressed to maximize benefits while minimizing associated risks (Majekodunmi, 2021).

1.2.6. Sustainability Aspect

1.2.6.1. Ecology and Environmental Responsibility

Ecological sustainability has become a crucial priority for entrepreneurship in the fourth industrial revolution era. Integrating automation, advanced technologies, and data analytics has radically transformed how businesses manage resources and minimize their ecological footprint. These technologies enable real-time operations tracking and optimize energy use to reduce waste.

Indeed, IoT sensors play a vital role by providing accurate and synchronized data on energy consumption and greenhouse gas emissions, allowing for dynamic adjustments to improve energy efficiency (Lee et al., 2014). For example, using intelligent systems to regulate energy consumption in the manufacturing industry can significantly reduce losses and operational costs while decreasing environmental impact (Varlamis et al., 2023). Integrating such solutions promotes more effective waste management. Advanced technologies facilitate sorting and recycling of materials, contributing to a circular economy that minimizes waste (Su et al., 2023). This approach aligns with a broader trend toward reducing dependence on natural resources and limiting the environmental impacts of industrial activities (Bocken et al., 2016).

Moreover, the benefits of an ecological strategy extend beyond environmental advantages. Embracing eco-friendly methods can also improve a company's reputation and attract investors concerned with corporate social responsibility (Oluwasikemi Janet & Babatunde Ayodeji, 2019). Indeed, consumers and regulators are increasingly sensitive to efforts to protect the environment, encouraging companies to adopt planet-friendly practices.

Thus, ecological sustainability becomes a fundamental pillar of Entrepreneurship 4.0. Using advanced technologies to improve energy efficiency and reduce waste allows businesses to meet environmental requirements while gaining significant competitive advantages.

1.2.6.2. Circular Economy

The emergence of the circular economy is also a crucial dimension of sustainability within the context of Entrepreneurship 4.0. This approach aims to optimize resource use and reduce waste by adopting business models based on reuse, recycling, and material recovery. Industry 4.0, with its innovative technologies (such as additive manufacturing (3D printing) and IoT-based tracking systems), facilitates the application of these principles by providing solutions for more efficient management of resources and end-of-life products or those intended for disposal,

thereby playing a vital role in the transition to a circular economy. For example, additive manufacturing enables on-demand production of parts, thus reducing stock surpluses and manufacturing waste (Ponis et al., 2021). IoT tracking systems allow for more precise management of product lifecycles, facilitating the collection and recycling of end-of-life materials (Kirchherr et al., 2023).

Furthermore, companies adopting circular models can achieve substantial savings by reducing production costs and improving supply chain efficiency (Jabbour et al., 2018). The circular economy also offers competitive advantages by enabling companies to differentiate themselves through their commitment to sustainability and innovation (Lewandowski, 2016).

Moreover, integrating circular economy principles into Entrepreneurship 4.0 can enhance businesses' resilience against fluctuations in raw material markets. Companies become less vulnerable to cost variations and supply risks by reducing dependence on virgin resources and optimizing waste management (Bellezoni et al., 2022).

Finally, the circular economy, supported by Industry 4.0 technologies, constitutes a strategic lever for promoting sustainability and improving economic performance. By adopting circular practices, companies can contribute to environmental preservation and achieve significant cost and competitiveness gains.

2. Construction of a conceptual model

The construction of a conceptual model aims to develop a simplified and realistic representation of an existing phenomenon capable of detecting its dynamic operating mechanisms. The first step involves identifying the elements or variables that constitute the system or phenomenon in question and subsequently determining the causal relationships between these variables (Snyder, 2019). In our case, the goal is to explain the variables that promote the success of Entrepreneurship 4.0.

Our in-depth literature review has identified the key factors illuminating the complex dynamics of entrepreneurship in the era of Industry 4.0. These findings highlight the significant relationships among various aspects that entrepreneurs need to consider to enhance their chances of success, as well as emerging trends that warrant particular attention. Drawing on these theoretical insights, we have developed a conceptual model that aims to synthesize these relationships and structure them coherently (Snyder, 2019). This conceptual model will rigorously expose the interactions between the identified variables, enabling us to formulate

hypotheses that can be tested through exploratory or confirmatory research to obtain validated and approved answers.

Firstly, an entrepreneur's success in the era of Industry 4.0 primarily depends on reorganizing organizational structure and the level of commitment and skills of the involved employees. Hence, the following hypotheses are proposed:

- H1: Redefining organizational structure promotes entrepreneurial success in the age of Industry 4.0.

- H2: Employees' skills promote entrepreneurial success in the age of Industry 4.0.

Secondly, there are factors related to clients' increased demands that constrain or motivate them to be satisfied and, consequently, loyal. This involves variables related to innovation, production, and personalized customer experience. This leads to the formulation of the following hypotheses:

- H3: Innovation and customized production promote entrepreneurial success in the age of Industry 4.0.

- H4: Customer experience personalization promotes entrepreneurial success in the age of Industry 4.0.

Finally, the technological aspect and the dimension of sustainability are also considered. Hence, our fifth and sixth research hypotheses state:

- H5: Adopting advanced technology promotes entrepreneurial success in the age of Industry 4.0.

- H6: Sustainability promotes entrepreneurial success in the age of Industry 4.0.

After formulating our research hypotheses, we propose the model below, Figure 1, synthesizing the relationships among the variables.

Figure 1 : The research conceptual model
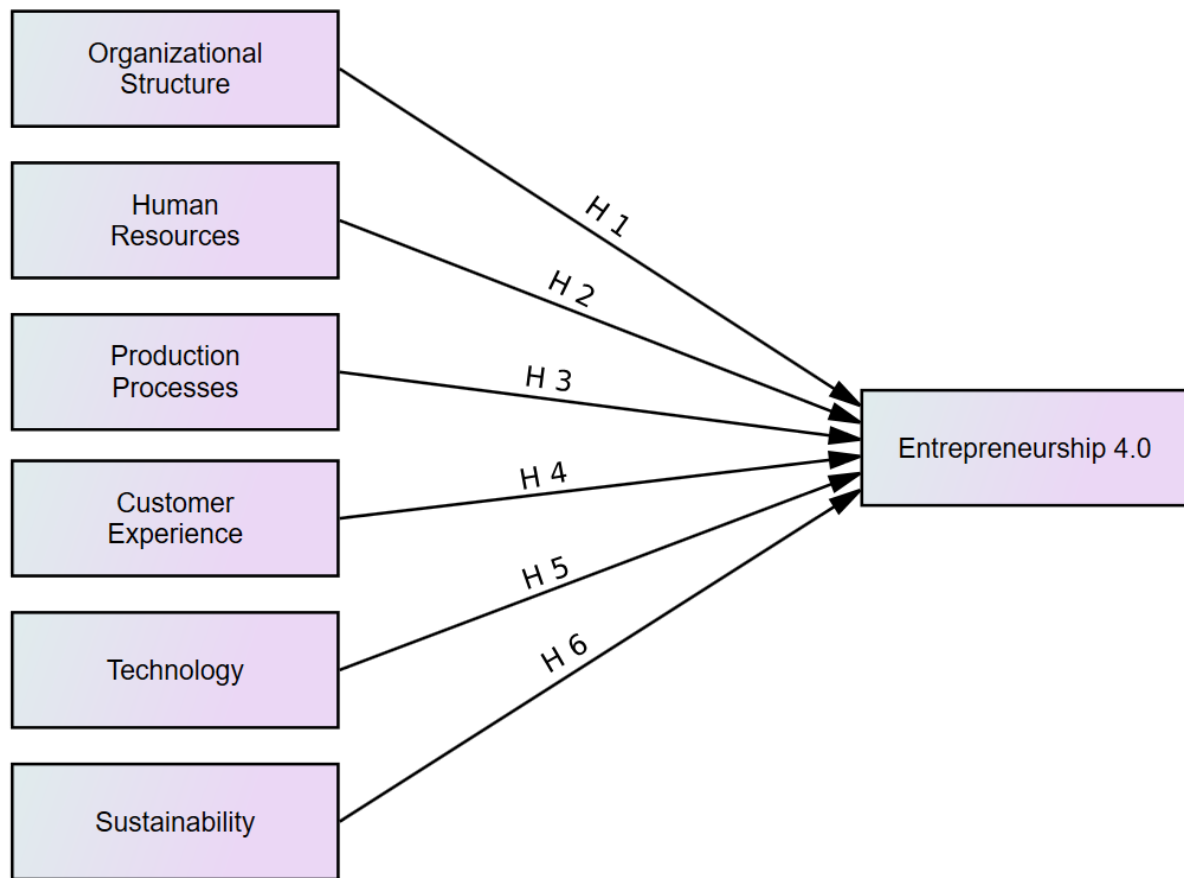
Source: Authors (based on the literature review)

Conclusion

At the dawn of Industry 4.0, advanced digital technologies such as Artificial Intelligence and Internet of Things profoundly transform industrial processes, organizational structures, and entrepreneurship. This fourth industrial revolution does not merely enhance existing processes but fundamentally reconfigures production, distribution, and innovation methods.

Industry 4.0 ushers in a new era of adaptable and customized production, made possible by intelligent systems capable of real-time adaptation to market fluctuations and consumer preferences. This transition is marked by implementing cyber-physical systems and autonomous machines that optimize resource management, reduce waste, and enable increased product customization. The emergence of "smart factories" represents a significant advancement in production process efficiency while integrating sustainable practices to balance economic performance with environmental responsibility.

Entrepreneurship 4.0 is marked by reorganizing organizational structures towards more horizontal and decentralized models. These new models promote team autonomy and inter-team collaboration, reducing bureaucratic processes and enhancing organizational efficiency. A reevaluation of internal processes shows that companies must undergo structural evolution to ensure smooth coordination and rapid adaptation to market demands.

With the advent of intelligent technologies, human resources skills are evolving towards more excellent proficiency in digital technologies, teamwork, and complex problem-solving. Continuous learning becomes essential to maintaining employee engagement and ensuring organizational competitiveness. Effectively integrating technologies into work processes is crucial for optimizing human resource management and maximizing organizational performance.

Data collection and analysis technologies, enabled by AI and IoT, allow companies to respond more accurately to customer expectations and personalize services to an unprecedented level. These advancements foster a significant increase in customer satisfaction and loyalty. Simultaneously, the improvements brought about by AI in perception, creativity, and strategic decision-making open new perspectives for innovation in business models while raising ethical and security concerns that require appropriate regulation.

Technologies of Industry 4.0 also promote a more sustainable approach to entrepreneurship by enhancing resource management and reducing environmental impacts. Leveraging IoT sensors

for monitoring energy consumption and waste management, and promoting circular economy practices, strengthens companies' ecological performance and resilience to market fluctuations.

In summary, Industry 4.0 and Entrepreneurship 4.0 offer unprecedented opportunities to reinvent business models, optimize production processes, and improve customer experiences while adopting a responsible and sustainable approach. Companies that successfully integrate these technologies strategically will be better equipped to face a complex and competitive market environment and contribute to inclusive and environmentally respectful economic development.

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