

Artificial Intelligence as an Enabling Tool for Sustainable Entrepreneurship in Startups

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Abstract:

Artificial intelligence is a vital tool for enabling sustainable entrepreneurship in startups, as it contributes to improving efficiency, reducing costs, and enhancing decision-making processes through automation and data analysis. This enables these enterprises to develop innovative solutions that take environmental, social, and economic dimensions into account. Artificial intelligence also helps design smart and sustainable products and services and strengthens enterprises' competitive capacity in markets. Despite its significant benefits, startups face many challenges, such as a shortage of technical competencies and the high cost of certain applications. Nevertheless, integrating artificial intelligence into startup business models is a strategic step toward achieving sustainability and smart growth.

Keywords: Artificial intelligence; startups; sustainable entrepreneurship ; smart growth

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1. INTRODUCTION

Driven by the rapid development of digital technologies—foremost among them artificial intelligence—the world has undergone profound transformations over the past decade. Artificial intelligence is no longer merely a purely technical tool; it has become a strategic lever for stimulating innovation and developing business models that are more efficient and sustainable. Amid these transformations, startups have emerged as a pivotal economic actor in building a digital economy based on open innovation—an economy grounded in the internet, communication networks, and digital products and services. This economy relies heavily on intangible assets, information, innovation, and creativity to expand economic possibilities for all segments of society, anywhere. In doing so, it has helped turn the entire world into a small village centered on leveraging ideas rather than material objects¹. Accordingly, the core elements of the digital economy are digitization, the intensive use of information and communication technologies, and the advancement of knowledge. This is achieved by raising performance levels and building digital relationships through investing in components of social network theory within a digital entrepreneurial behavior that embraces initiatives and calculates digital risks in order to establish new forms of digital business²—seeking a precise balance between profitability requirements, social responsibility, and environmental preservation, which is known as sustainable entrepreneurship.

However, integrating artificial intelligence into startups is not merely a technological choice to enhance operational efficiency or improve competitive capabilities; rather, it is a deep strategic transformation that involves structural challenges linked to these enterprises' ability to embed smart solutions within business models grounded in sustainability principles, in an economic and regulatory environment that is often characterized by

1- Moshira Mohamed Hassan Al-Ashari, The Digital Economy and the Activation of Entrepreneurship Policies within Egyptian Society: A Case Study of Digital Entrepreneurs, The Scientific Journal of the Faculty of Arts, Vol. 12, No. 1, 2023, p. 3.

2- Al-Sannour Khalifat, The Impact of Digital Entrepreneurship on Organizational Performance from the Perspective of Managers of Jordanian Pharmaceutical Manufacturing Companies within the Social Network, The Jordanian Journal of Business Administration, Vol. 16, p. 261.

uncertainty. By virtue of their innovative and flexible nature, startups find themselves facing a difficult equation: on the one hand, there is an urgent need to invest in artificial intelligence technologies to improve performance and offer products and services with environmental and social added value; on the other hand, they must confront constraints related to limited financial resources, weak technological infrastructure, and challenges of compliance with a legal and regulatory framework that has not developed at the same pace as smart technologies. In this context, integrating artificial intelligence into the structure of startups raises multidimensional issues extending from questions of responsibility for harms resulting from decisions made by intelligent systems, to problems of personal data protection and individual privacy in a digital environment where the collection and processing of information is accelerating. Legal questions also arise regarding how to protect intellectual property rights stemming from sales or services in which intelligent systems directly contribute, in the absence of clear legislative adaptation for concepts of intellectual property resulting from machines' autonomous innovation. Moreover, incorporating artificial intelligence into startup business models is not merely a technical shift; it requires comprehensive reengineering of value chains to align with the requirements of sustainable entrepreneurship, taking into account the necessity of overcoming technical and economic challenges on the one hand and complying with legal and regulatory frameworks on the other. In this regard, artificial intelligence becomes a dual enabling tool that offers startups opportunities to enhance innovation and achieve sustainability, provided that a supportive regulatory and legislative environment is available—one that encourages these enterprises and accompanies them along the path of digital transformation.

Based on this reality, we pose the following research problem: How can startups adopt artificial intelligence technologies as an effective mechanism for achieving sustainable entrepreneurship while overcoming technical and economic challenges within a supportive legal and regulatory environment?

To answer this problem, we will adopt a descriptive-analytical approach by examining the theoretical frameworks of artificial intelligence and sustainable entrepreneurship and analyzing the challenges that startups face

in this context. A comparative approach will also be used to identify and analyze applied models and international legislative frameworks that have contributed to achieving sustainable technological innovation within startups.

2. The Theoretical Foundations for Adopting Artificial Intelligence in Sustainable Entrepreneurship for Startups

To understand the relationship between artificial intelligence and sustainable entrepreneurship in startups, it is necessary to examine the theoretical frameworks that define the nature of these concepts and the extent of their overlap in the modern economic context. Adopting artificial intelligence as an enabling tool in an entrepreneurial environment cannot be approached in isolation from understanding the specific characteristics of both artificial intelligence as a strategic technical instrument and sustainable entrepreneurship as an economic and social model. Moreover, the nature of startups requires analyzing them to determine their role in achieving sustainable development through adopting smart and innovative solutions.

2.1 The Conceptual Framework of Artificial Intelligence and Sustainable Entrepreneurship

Approaching the relationship between artificial intelligence and sustainable entrepreneurship requires defining the conceptual frameworks. Artificial intelligence, with its capacities for learning, analysis, and prediction, has become a fundamental element in reshaping innovative processes within organizations. By contrast, sustainable entrepreneurship represents a strategic orientation aimed at achieving a balance among economic, social, and environmental objectives.

2.1.1 Adopting Artificial Intelligence in the Entrepreneurial Environment

Artificial intelligence (AI, Artificial Intelligence) is among the most prominent technologies that have brought about a radical transformation in business models within the digital economy.

A. The Concept and Characteristics of Artificial Intelligence Technology

Encyclopaedia Britannica defines artificial intelligence as the ability of a digital computer or robot; the term is frequently applied to the project of

developing systems that possess intellectual processes characteristic of humans, such as the ability to reason, discover meaning, or learn from past experience³.

Many researchers and specialists have offered varying definitions of artificial intelligence. According to Kurzweil, one of the most well-known researchers in this field, it is the making of machines capable of performing operations that require intelligence when performed by humans. Another scholar defined it as a branch of computing concerned with studying and building computer systems that display certain forms of intelligence. These systems have the ability to derive highly useful inferences about the problem at hand, and they can also understand natural languages, perceive sensory input, and perform other capabilities that would require intelligence if carried out by humans.

Based on the above, artificial intelligence can be described as the ability of machines—such as computers—to acquire intelligence and think logically in a way that resembles human thinking. This is achieved through programs supplied to the computer to help it benefit from data and reason logically in order to reach the desired result⁴.

A.1 Artificial Intelligence: Its Capacities and Types

Artificial intelligence technology is commonly divided into three main types in terms of distinguishing capabilities and the degree to which it simulates human intelligence: weak (or narrow) artificial intelligence, strong artificial intelligence that matches human capacities in certain functions, and superintelligent artificial intelligence, a future form in which machines are expected to surpass human capability.

- **Narrow or weak artificial intelligence:** This is the type that has been successfully achieved at present. It is prepared and designed to perform specific, individual tasks. It does not fully simulate human intelligence; rather, it imitates human behavior within a limited scope, such as facial recognition. It is described as narrow because it operates

3- Encyclopaedia Britannica, Artificial Intelligence, available at: www.britanica.com/technology/artificial-intelligence, (consulted on 12/december/2025).

4- Nermin Magdy, Artificial Intelligence and Machine Learning, Booklet Series Issued by the Arab Monetary Fund, No. 03, United Arab Emirates, 2020, p. 5.

under a restricted set of conditions. It has been used in multiple fields, such as medicine for diagnosing diseases and security through monitoring demonstrators via facial recognition⁵.

- **The second type** refers to the concept of a machine with general intelligence that simulates human intelligence, with the capacity to learn and apply intelligence to solve any problem—more precisely, it thinks, understands, and acts in a way that cannot be distinguished from a human being⁶.
- **Superintelligent artificial intelligence** is the form of intelligence in which machines surpass the capacity of the human brain. This type is expected to develop to simulate emotions, experiences, and abilities as well. Such intelligence would be capable of exceptional performance and, in theory, would be far better at everything it does in fields such as mathematics, science, art, and medicine. It would also have greater memory and a faster ability to process and analyze data; consequently, the decision-making and problem-solving capacities of superintelligent beings would be far higher than those of humans.

From what precedes, artificial intelligence constitutes a genuine pillar supporting other digital transformations, such as cloud computing and big data—particularly through the use of machine learning to analyze and process large datasets and extract important, decision-relevant information. Artificial intelligence is also linked to cybersecurity by analyzing hacking attacks and threats and confronting malicious software that electronic systems may face, thereby forming a defensive line to protect security and privacy and to detect any breach.

A.2 Characteristics of Artificial Intelligence

Artificial intelligence applications are distinguished by a set of characteristics that set them apart from other technological applications, including the following:

- **Unpredictable behavior:** AI applications can act or operate in

5- Sara Ibrahim Hassan, The Role and Impact of Artificial Intelligence in the Field of Intellectual Property: Between One View and Another, The Scientific Journal of Intellectual Property and Innovation Management, Issue 5, March 2022, p. 35.

6- Ibid., p. 36.

unexpected ways because some rely on machine learning. In such cases, the application is programmed in a manner that enables self-development and response to input data without the need for reprogramming to match that data. As a result, the application may undertake tasks different from those it was initially programmed to perform—tasks that were not intended or even anticipated by the developers⁷.

- **Opacity of outcomes:** The outputs produced by AI applications may be difficult to explain. It is said that one can describe what the application did, but not fully explain why or how it happened. Some specialists liken AI to a black box⁸, due to the enormous volume of information with which the application is fed—potentially reaching millions or even billions of data points.
- **Potentially independent operation:** In some cases, AI applications may operate independently of the algorithm or programming used at the time of their creation, without the ability to control or manage them. For example, if an application is designed to seize customer data from a bank's databases, then although the theft initially occurs due to the person who programmed and designed the application, the application may continue stealing that data without being controllable.
- **Domain limitation and specialization:** AI applications are specialized within a limited domain according to how they were programmed. Even if these applications resemble human intelligence and can surpass it in certain tasks, they may, in reality, be unable to hold a conversation with a small child in a field other than the one for which they were programmed. The reality is that AI applications are programmed to perform a specific, narrowly defined task with high proficiency, but they are entirely unable to perform other tasks—even simple ones. To date, there is still no technological application capable

7- Doaa Hamed Mohamed Abdel Rahman, The Impact of Artificial Intelligence Technologies on the Provisions of Intellectual Property Laws, *Journal of Sharia and Law*, Issue 36, Part Two, 2021, p. 1764.

8- David Castelvecchi, Can We Open the Black Box of AI?, available at: <https://www.nature.com/news/can-we-open-the-black-box-of-ai-1.2731>, (consulted on 25/12/2025).

of performing all tasks without prior programming⁹.

B. The Functional Role of Artificial Intelligence in the Startup Entrepreneurship Environment

Artificial intelligence provides many benefits in startup entrepreneurship. It works to:

B.1 Improving the Operational Efficiency of Startups Through Artificial Intelligence

Operational efficiency constitutes a central challenge for startups due to their limited financial and human resources, as well as their dynamic structure that requires a rapid and effective response to market changes. In this context, artificial intelligence represents a strategic tool for enhancing operational efficiency by automating routine tasks that consume time and human resources. By using machine learning techniques, startups can automate customer service, order processing, and the management of administrative tasks without the need for constant human intervention¹⁰.

This supports responsiveness to market changes through process automation, improved supply chain management, and facilitating tactical decision-making.

- **Intelligent automation of routine tasks:** One of the most prominent contributions of artificial intelligence to improving operational efficiency is its ability to automate routine tasks. This enables work teams to focus on high value-added activities such as innovative development and strategic planning.
- **Improving supply chain management:** Supply chain management is among the areas that benefit greatly from artificial intelligence capabilities, especially in startups that rely on external logistics networks. Through real-time data analysis, artificial intelligence can accurately forecast demand, optimize inventory levels, and reduce lead times, thereby improving the enterprise's flexibility in responding to market disruptions.

9- Ryan Abbott, Everything Is Obvious, UCL Law Review, Vol. 66, 2019, pp. 23–28, cited in Doaa Hamed Mohamed Abdel Rahman, the previous reference.

10- Chui, M., Manyika, J., and Mir emadi, M., Where Machines Could Replace Humans and Where They Can't (Yet), McKinsey Quarterly, 2016, p. 63.

- **Predicting operational risks:** Thanks to deep learning techniques, artificial intelligence can analyze long sequences of operational data and predict potential points of failure before they occur, whether at the level of equipment or processes¹¹. This preventive analysis helps startups avoid unplanned disruptions and improves operational continuity. Artificial intelligence also supports management teams in making more accurate and effective daily decisions by providing in-depth analyses of operational performance and productivity indicators. It enables these enterprises to achieve high flexibility in managing resources and directing them toward the most profitable and sustainable activities. In addition, employing artificial intelligence helps reduce costs associated with human resources and infrastructure, enabling growth without having to increase fixed costs in direct proportion to the scale of activity¹².

B.2 Strengthening Innovation in Product and Service Development Through Artificial Intelligence in Startups

Innovation in developing products and services is the cornerstone of startup competitiveness, especially in an entrepreneurial environment characterized by rapid changes in market demand and consumer preferences. Accordingly, artificial intelligence has become a strategic tool that enables startups to accelerate the pace of innovation, improve product fit with customer needs, and deliver smart solutions with a sustainable impact, through the following:

- **A deeper understanding of the user experience:** With artificial intelligence, startups can collect and analyze vast amounts of user data, allowing them to understand customer behaviors and preferences. These analyses enable the development of products and services that align more closely with customers' actual expectations¹³.
- **Iterative product development:** Artificial intelligence allows

11- Bughin, J., Hazan, E., Ramaswamy, S., and Chui, M., *Artificial Intelligence: The Next Digital Frontier*, McKinsey Global Institute, 2018.

12- Brynjolfsson, E., and McAfee, A., *Machine, Platform, Crowd: Harnessing Our Digital Future*, W. W. Norton & Company, 2017, p. 60.

13- Lemon, K. N., and Verhoef, P. C., Understanding Customer Experience Throughout the Customer Journey, *Journal of Marketing*, 2016, p. 71.

startups to adopt iterative development methodologies in which feedback and data are continuously collected from customers and automatically analyzed, enabling periodic improvements to the product or service quickly and efficiently¹⁴. This feature allows startups to launch high-quality products within a short timeframe compared to traditional methods.

- **Forecasting market trends and developing tailored solutions:** Automated analytics and predictive indicators enable startups to anticipate future market changes, helping them develop innovative solutions that match emerging needs before they actually appear in the market¹⁵. This allows enterprises to achieve a strong competitive advantage by staying ahead of competitors. Artificial intelligence also helps startups deliver precisely customized products and services according to each individual customer's needs. By using behavioral data analysis algorithms, individualized offers and solutions can be designed, increasing customer satisfaction and loyalty¹⁶.
- **Enabling sustainable innovation:** Artificial intelligence contributes to steering innovation toward solutions with positive environmental and social impact by developing products with better energy efficiency, smart resource-management systems, and socially oriented services that contribute to achieving sustainable development goals¹⁷.

B.3 Big Data Analysis and Flexibility in Responding to Changes

Thanks to artificial intelligence technologies, startups can effectively process massive quantities of data flowing from multiple sources. This analysis enables entrepreneurs to extract deep insights into market trends,

14- Rigby, D. K., Sutherland, J., and Takeuchi, H., Embracing Agile, *Harvard Business Review*, 2016, p. 44.

15- Gandomi, A., and Haider, M., Beyond the Hype: Big Data Concepts, Methods, and Analytics, *International Journal of Information Management*, 2015, p. 145.

16- Arora, N., Dreze, X., Ghose, A., Hess, J. D., Iyengar, R., Jing, B., Putting One-to-One Marketing to Work: Personalization, Customization, and Choice, *Marketing Letters*, 2008, p. 118.

17- George, G., Merrill, R. K., and Schillebeeckx, S. J. D., Digital Sustainability and Entrepreneurship: How Digital Innovations Are Helping Tackle Climate Change and Sustainable Development, *Entrepreneurship Theory and Practice*, 2021, p. 1169.

consumer behavior, and even competitors¹⁸.

Artificial intelligence technologies also give startups a high capacity to adapt to rapid market changes by enabling real-time decision-making. This allows them to seize opportunities and avoid risks more quickly than enterprises that rely on traditional decision-making mechanisms¹⁹.

In addition, artificial intelligence enables the automation of daily operational decision-making processes—such as determining production quantities, pricing products, and scheduling resources—based on precise algorithms that take multiple variables into account.

2.1.2 The Conceptual Framework of Sustainable Entrepreneurship

Interest in sustainable entrepreneurship has increased in recent years because it combines the achievement of economic profitability with responsiveness to environmental and social challenges—especially in light of digital transformations that constitute a fertile environment for innovative business models. In this context, artificial intelligence has emerged as a strategic tool that enables startups to translate sustainability principles into practical actions within their daily operations.

A. The Theoretical Concept of Sustainable Entrepreneurship

When searching for a concept of entrepreneurship or entrepreneurs in economic analysis, no single unified definition is found. R. Cantillon (1934) defined it as a type of personality that is willing to establish a new project or enterprise and accept full responsibility for uncertain outcomes²⁰. The entrepreneur has also been defined as the person who adopts initiative and creative thinking and is able to organize social and economic mechanisms to transform resources into practical reality—such as introducing a new product, making changes that increase the quality of a good or product, or implementing new organizational forms in industry. Accordingly, entrepreneurship became one of the four basic factors of production

18- Gandomi, A., and Haider, M., Beyond the Hype: Big Data Concepts, Methods, and Analytics, *International Journal of Information Management*, 2015, p. 140.

19- Brynjolfsson, E., and McAfee, A., *Machine, Platform, Crowd: Harnessing Our Digital Future*, W. W. Norton & Company, 2017, p. 88.

20- Samar Al-Amir Ghazi Abdel Hamid and Farouk Fathi Al-Sayyid Al-Jazzar, The Role of Entrepreneurship in Achieving the Sustainable Development Goals with Reference to the Egyptian Context, *The Scientific Journal of Commerce and Finance*, Vol. 40, Special Issue for the College Conference, 2021, p. 3.

alongside land, labor, and capital. Frank Knight and Peter Drucker view entrepreneurship as centered on risk; entrepreneurial behavior reflects an individual's capability through applying a new idea and putting it into practice by investing more time, effort, and capital in a risk whose results are not guaranteed and that relates to the person's profession and financial position.

On this basis, entrepreneurship can be defined as new ideas or methods that enable the creation of a company or the development of an existing company by combining risk with innovation and creativity and elevating it toward the top.

It can also be said that entrepreneurship involves relying on small or medium-sized projects with limited capital, whose ideas are characterized by creativity. The foundation of such projects is the entrepreneur, who is distinguished by personal talent, skills, and the ability to discover an opportunity and transform it into a profit-generating project capable of growth—while bearing risk under conditions of uncertainty.

All of these concepts are linked to the traditional concept of entrepreneurship that focuses on maximizing short-term profits. Sustainable entrepreneurship, by contrast, refers to entrepreneurial activities that seek to create and develop economic opportunities in which entrepreneurs use innovation and opportunity-seeking to achieve development connected to the continuity of the economic, social, and environmental aspects of society and its institutions in meeting their needs. Here, the role of artificial intelligence emerges as a technological means that enables startups to activate the economic, social, and environmental dimensions in practice—by improving efficiency, developing products with low environmental impact, and enhancing social impact through solutions directed at community needs²¹.

The role of entrepreneurship lies in innovating new methods rather than the usual methods that cause depletion and pollution; in order to invest human energies and natural resources in ways whose outcomes are positive for

21- George et al., op. cit., p. 1267.

individuals both now and in the future²².

B. The Applied Dimensions of Sustainable Entrepreneurship

Entrepreneurship is based on providing the means of success for activities and projects; these skills are what qualify entrepreneurs to manage their enterprises successfully. Entrepreneurship has several dimensions, such as readiness and inclination toward risk, in addition to the ability to compete, search for new opportunities²³, and innovate. These are some dimensions with a theoretical orientation. However, sustainable entrepreneurship is not limited to this orientation; it is embodied in practical practices at the level of the business model and operational processes, which can be summarized as follows:

- **Sustainable economic models:** Startups rely on business models that are based on optimal resource utilization, reducing environmental expenditures, and developing financial strategies that balance profitability and sustainability.
- **Smart environmental practices:** Through adopting artificial intelligence technologies such as predictive environmental analytics, startups contribute to reducing environmental impact, improving energy efficiency, and managing natural resources effectively.
- **Added social development:** This is reflected in the enterprise's ability to provide innovative solutions that respond to social needs, such as creating job opportunities for vulnerable groups, developing products targeted to low-income groups, or supporting local development initiatives—along with strengthening transparency and social responsibility and expanding access to services. This is enabled by smart automation that allows startups to scale their social solutions widely at low cost²⁴.
- **Sustainable innovation:** This refers to the process of developing new

22- Sara Madi, Green Startups as a New Trend Toward Sustainable Entrepreneurship: The German Experience, *Journal of Legal and Economic Studies*, Vol. 4, No. 3, 2021, p. 265.

23- Mousa Misfer Abdullah Al-Adhahi, The Role of Entrepreneurship Projects in Achieving Sustainable Development: A Field Study on the Tamiyyaz Region, *Journal of Economic and Management Research*, Vol. 3, No. 2, 2022, p. 36.

24- Muhammad Yunus, Building Social Business: The New Kind of Capitalism that Serves Humanity's Most Pressing Needs, *PublicAffairs*, 2010, p. 34.

products, services, or business models that seek to achieve a positive economic impact while integrating environmental and social considerations. This contrasts with traditional innovation, which focuses primarily on market effectiveness and rapid profitability. Artificial intelligence is considered a fundamental driver of sustainable innovation by enabling startups to redesign their processes and products according to sustainability standards—through designing products with environmental efficiency, and also by advancing sustainable social innovation through analyzing broad social data and developing technological solutions that respond to pressing community needs such as healthcare applications and digital education. It should be noted that measuring the sustainability duration of entrepreneurial activity relies on composite indicators that include environmental performance indicators, sustainable economic performance indicators, social indicators, and green innovation indicators. These indicators are aggregated within international standards, including GRI (Global Reporting Initiative) and the SDGs (Sustainable Development Goals), to assess the extent of startups' contributions and their role in achieving comprehensive sustainability.

2.2 The Specific Characteristics of Startups in Achieving Sustainable Development

Startups are among the main drivers of future economies due to their role in accelerating innovation, creating jobs, and achieving economic diversification. Despite their small size and limited capabilities, they are characterized by organizational flexibility, rapid adaptation to changes, and a high ability to leverage modern technologies to deliver new products or services in a high-risk environment, while seeking fast and scalable growth²⁵.

Based on this definition, startups represent a distinctive organizational pattern within the digital economy system because of structural characteristics that differentiate them from traditional enterprises in terms of operating mechanisms, business models, and innovation strategies. Although

25- Eric Ries, *The Lean Startup: How Today's Entrepreneurs Use Continuous Innovation to Create Radically Successful Businesses*, Crown Publishing, 2011.

these specific features provide competitive advantages in the entrepreneurial environment, they also confront startups with real challenges when they seek to adopt comprehensive sustainability practices, especially given their limited resources.

2.2.1 The Structural Characteristics of Startups

Startups have several essential structural characteristics, most notably small size and simple organizational structures. Most consist of small teams, which gives them flexibility in decision-making and speed in adjusting strategies. These enterprises also adopt rapid experimentation, developing services and products based on continuous market testing.

- **High dynamism in innovation and market adaptation:** This is one of the most prominent foundations of competitiveness for startups. They rely on business models capable of rapid adaptation, seek to exploit market gaps through innovative solutions, and adopt open approaches to innovation through collaboration with innovation networks and technical communities.
- **Limited resources and the challenges resulting from them:** Startups suffer from limited financial and human resources, which leads to weak capacity to invest in long-term projects and difficulty bearing the cost of advanced technologies such as artificial intelligence, alongside the ongoing need to search for innovative financing models that go beyond traditional funding.
- **Non-traditional financing in supporting startup flexibility:** Because they often cannot resort to traditional bank financing, startups rely on venture capital, which is directed toward supporting innovation. They also rely on crowdfunding, which represents contributions from individuals through online platforms, in addition to the role of incubators and accelerators that provide financial and technical support during the early founding stages.

2.2.2 The Role of Startups in Achieving Sustainable Development

Given the growing environmental, social, and economic challenges, sustainable development has become a strategic choice that imposes itself on all economic actors. Because startups possess organizational flexibility, dynamism in innovation, and the capacity to leverage modern technologies—

foremost among them artificial intelligence—they are gaining increasing importance in achieving sustainable development goals.

A. The Contribution of Startups to Achieving the Dimensions of Sustainable Development

The role of startups is not limited to creating wealth and job opportunities; it goes further to include stimulating social innovation, developing smart environmental solutions, and supporting economic and social justice. For example, startups contribute to the economic dimension by creating high-quality job opportunities, especially in technological sectors, and by stimulating innovation in business models, which enhances the efficiency of the national economy and drives the digital economy as a strategic engine of growth. With regard to reinforcing the environmental dimension, startups work on developing environmentally friendly products and services while leveraging green technology to improve the efficiency of resource consumption—such as energy utilization, sustainable development solutions, electromagnetic energy applications, biofuels, smart recycling, and other examples of green technology.

As for embodying the social dimension, it takes shape through providing innovative solutions to social problems such as digital education and smart healthcare, along with promoting a culture of social entrepreneurship and supporting social inclusion through projects targeting vulnerable groups so that startups can achieve a sustainable impact. Technology—especially artificial intelligence—is considered among the most important tools for this, as it helps startups achieve balanced economic growth, improve environmental efficiency, and address social challenges in an innovative and low-cost manner.

Technology is also regarded as a means of enhancing economic efficiency and financial sustainability. Through automation and predictive analytics, it contributes to reducing operating costs and improving resource management in startups, fostering innovation in business models, and reaching new local and international markets without the need for massive physical infrastructure.

In addition, technology can be used as a tool to enhance environmental

sustainability. Environmental performance can be improved by reducing emissions and the consumption of natural resources. By relying on the Internet of Things and artificial intelligence, startups can develop models for smart recycling, product repair, and reuse services²⁶.

2.2.3 Requirements for Activating the Role of Startups in Supporting Sustainable Development

Transforming startups into a driving force for sustainable development requires creating a suitable environment that goes beyond traditional support to include a set of integrated measures that ensure the continuity of these projects and their impact.

- **Legislative requirements:** A flexible legal environment is the cornerstone of stimulating sustainable innovation. This requires drafting specific legislative frameworks that grant legal status to startups that adopt environmental or social objectives. This includes simplifying establishment procedures and protecting innovators' intellectual property.
- **Green financing mechanisms and financial innovation:** Financing represents the greatest challenge to the sustainability of startups. Therefore, there is a justified need for unconventional financing mechanisms based on venture capital that balances material profitability with developmental impact. This is embodied in establishing specialized investment funds that support projects with a sustainability dimension, while facilitating startups' access to concessional loans that do not require excessively burdensome guarantees.
- **Technical support through business incubators:** A sustainability ecosystem cannot be complete without a knowledge-based infrastructure. This requires activating the role of incubators and accelerators that provide technical and administrative training for entrepreneurs. This mechanism lies in building bridges of communication between universities and scientific research laboratories on the one hand and the labor market on the other, to

26- United Nations Conference on Trade and Development (UNCTAD), Technology and Innovation Report 2021: Catching Technological Waves, 2021.

ensure the transformation of technical innovations into applicable business models. This support also includes providing a digital environment and big data that enable startups to innovate smart solutions that contribute to resource efficiency and achieve social inclusion.

3. The Applied Dimensions and Legal Challenges of Adopting Artificial Intelligence in Sustainable Startups

As a result of the digital transformation in the ways entrepreneurship is practiced, artificial intelligence has enabled startups to develop smart business models grounded in sustainable innovation. However, this growing reliance on this technology raises legal and regulatory issues related to data protection, legal liability, and compliance with principles of digital ethics.

3.1 Practices of Sustainable Innovation Through Artificial Intelligence in Startups

Artificial intelligence constitutes a pivotal tool in startups' innovation strategies, as it contributes to developing smart products and services with sustainable economic, social, and environmental impact.

3.1.1 Strategies for Integrating Artificial Intelligence into Sustainable Business Models for Startups

Within startups' pursuit of sustainable entrepreneurship, innovation is no longer confined to developing products or services alone; rather, it has become centered on redesigning business models themselves in a way that integrates artificial intelligence as a core component for achieving economic, environmental, and social impact. Today, artificial intelligence has become a strategic tool that enables these enterprises to formulate flexible and scalable business models capable of addressing environmental and social challenges through innovative approaches.

- **AI-driven business models:** Startups rely on big data analysis to identify opportunities to improve the use of natural resources. Employing artificial intelligence to process these data helps companies make decisions based on accurate information, such as reducing energy consumption in production processes. For example, a study of United States companies listed on the Nasdaq index showed

that adopting artificial intelligence techniques to analyze sustainability data contributes to improving their environmental and social performance.

- **Supporting the circular economy through artificial intelligence:** The circular economy is defined as an economy that aims to rationalize the consumption of materials and resources by recycling and using them efficiently and in environmentally friendly ways in order to reduce carbon emissions. Startups play a pivotal role in activating this model through artificial intelligence by developing technologies capable of sorting and classifying recyclable materials. As an example, the United Kingdom company Greyparrot developed a computer-vision system that uses artificial intelligence to improve waste-management operations, which contributed to increasing recycling efficiency and reducing landfilled waste.
- **Improving agricultural productivity and smart resource management in agriculture:** Artificial intelligence is an effective means of enhancing the efficiency of natural resource use. Startups use AI to analyze soil, weather, and water data, enabling them to improve irrigation operations and reduce water waste. The platform Kilimo in Argentina is an example of this, as it makes it possible to save around 20 percent of water consumption through artificial intelligence solutions integrated with satellite data.

3.1.2 Applied Models of Sustainable Innovation Practices Through Artificial Intelligence in Startups

Applied models of sustainable innovation practices through artificial intelligence constitute an important reference for understanding how startups leverage technology to confront economic, environmental, and social challenges.

A. Applied models in the energy sector:

Startups rely on artificial intelligence to develop smart grids for managing the production and distribution of renewable energy efficiently, which contributes to reducing waste and improving consumption efficiency. The applied models of startups in the sustainable energy sector provide a vivid example of how artificial intelligence can be used as a tool to achieve

economic and environmental efficiency at the same time. Among the most notable models are two in the United States: AutoGrid and Uptake. AutoGrid developed smart platforms for managing power grids that rely on artificial intelligence to analyze big data, enabling electricity distribution companies to balance supply and demand in real time and reduce resource waste. The leading company Uptake developed predictive maintenance systems for power generation plants, using artificial intelligence tools to analyze operational data and reduce technical failures, which helps preserve performance efficiency and reduce emissions. The United Kingdom company Enian also developed a digital platform that connects investors with renewable energy projects, facilitating the financing of sustainable projects and increasing the attractiveness of green investments. In addition, the Canadian company Clir Renewables analyzes the operational performance of wind farms using artificial intelligence to improve efficiency and reduce outages; its technologies have contributed to increasing productivity by approximately 3–5 percent across its projects.

B. Applied models in smart and sustainable transport:

Many startups in the transport sector have launched intelligent shared-mobility applications supported by artificial intelligence, contributing to reducing carbon emissions and strengthening the concept of sustainable mobility. Mobility data analytics have also helped improve urban planning and organize traffic more efficiently. As applied examples, the company BasiGo developed the first electric bus powered by artificial intelligence in Nairobi and Rwanda, launched under a Pay-As-You-Drive model that reduces emissions and lowers transportation costs. Another example is the United Kingdom company Wayve, which developed self-driving vehicles using artificial intelligence to improve the efficiency of urban transport and reduce accidents and emissions within the broader transition toward sustainable smart cities.

C. Applied models in agriculture and smart social services:

In agriculture, smart farming models have shown how startups can use artificial intelligence to analyze soil and climate data accurately, enabling improved productivity and reduced water consumption. There are many

innovations in this area, most notably the creation of smart platforms that analyze satellite and weather data using artificial intelligence to provide precise irrigation recommendations to farmers. This has reduced water consumption by up to 2 percent and noticeably increased overall productivity. Drones, thermal imaging, and artificial intelligence are also used to analyze the health of trees and crops and to predict better pest management and irrigation, which reduces losses and increases agricultural productivity. The company FarmWise also uses computer vision and artificial intelligence to remove weeds in fields without the need for herbicides, supporting cleaner production that is environmentally sustainable. The examples are numerous and varied.

In the field of social services, some startups have continued to use artificial intelligence to develop digital solutions that address social issues such as education and healthcare, through applications capable of analyzing needs and providing customized solutions for vulnerable groups. Applied models of smart social services are also numerous. Examples include an intelligent chat system (AI chatbot) that provides agricultural advice in a local language via WhatsApp for small-scale farmers, and the smart platform Greenhouse Management, which relies on artificial intelligence to tailor plant growth conditions in enclosed greenhouses, reducing water consumption and improving food production efficiency in food-insecure areas.

3.2 Legal and Practical Challenges of Using Artificial Intelligence in Sustainable Startups

Despite the possibilities that artificial intelligence offers for strengthening sustainable innovation practices within startups, the legal and regulatory framework governing its use raises complex issues related to aligning technological progress with the protection of individuals' fundamental rights, and to creating an effective regulatory environment that encourages innovation while simultaneously safeguarding societal values. In the same context, most national and international legislation suffers from a regulatory gap regarding the use of artificial intelligence in entrepreneurial environments, as legal regimes that address the specific features of artificial intelligence—particularly with respect to data, legal liability, and ethical

challenges—have not yet been fully adopted.

3.2.1 Data Protection and Privacy Under the Use of Artificial Intelligence

The protection of personal data represents one of the most prominent legal challenges when adopting artificial intelligence in startups, especially given technologies based on big data and predictive analytics that require the collection of enormous quantities of data.

The General Data Protection Regulation (GDPR, Regulation 679/2016) imposes strict obligations on data controllers, including ensuring transparent processing and enabling individuals to exercise their rights to control the processing of their data. Article 22 of the Regulation provides individuals with the right not to be subject to decisions based solely on automated processing, which imposes complex obligations on startups to ensure the availability of human intervention in decision-making processes—an approach that may not align with the nature of autonomous systems based on deep learning²⁷.

Startups also face difficulties in complying with transparency requirements and explaining the logic of algorithms, as Articles 13 and 14 require them to inform individuals about the methodology and mechanisms of automated decision-making. Since many startups rely on black-box algorithms—a term used for systems or computational models, especially in artificial intelligence, whose decision-making processes or outputs cannot be clearly interpreted or understood—these legal requirements can become a technical and financial obstacle that weighs heavily on startups.

As for liability for startups when adopting artificial intelligence, the problem of identifying the responsible party becomes acute. Is it the algorithm developer who designs the foundational system architecture, the data provider that supplies the system with data needed for learning, the startup itself that uses the system in its products or services, or the system itself—raising questions about whether artificial intelligence could be recognized as an independent legal actor? Current legislative trends, foremost among them the European Union’s Artificial Intelligence Act, do not recognize an intelligent system as a legal actor. Responsibility therefore

27- European Union, General Data Protection Regulation (GDPR), Regulation (EU) 2016/679.

remains directed at the economic user of the system—that is, the startup that integrated the system into its professional activity—unless the startup proves that it took all necessary precautionary and verification measures to ensure the safety of the adopted intelligent systems.

To address this issue, legal calls have increasingly emphasized the need to adopt shared-liability models, whereby the burden of responsibility is distributed among actors based on the extent of their involvement in, and control over, the outputs of the intelligent system. Nevertheless, startups remain the party most exposed to liability risks toward consumers, because they are the final link in the value chain and the direct provider of the service or product. This requires them to adopt proactive measures to manage these risks, such as concluding clear contracts with technology providers that include a precise allocation of responsibilities, adhering to transparency principles and the ability to explain the systems used, and resorting to digital liability insurance to cover potential harms.

Given the organizational, financial, and technical particularities of startups, assigning legal liability to them is a complex matter. Unlike traditional enterprises, startups operate in environments characterized by rapid innovation, limited resources, and reliance on open digital systems, which leads to specific legal challenges in defining the scope and limits of their civil liability under conditions of constrained human and financial resources and weak internal structures. The absence of specialized teams for legal and ethical auditing makes it difficult for these enterprises to meet transparency and accountability requirements imposed by modern legal systems, such as the European AI regulation. Moreover, startups' fundamental dependence on technologies provided by external parties creates a dispersion of harmful conduct across the digital value chain. This environment makes assigning legal liability unclear, as it becomes difficult to prove a direct causal relationship between the startup's actions and the harm resulting from intelligent systems—especially when the startup is merely an end user of technologies it did not develop internally.

Furthermore, because startups rely on experimental business models in which products or services are launched into the market within short periods before technological maturity is fully achieved, this approach—despite its

importance in enhancing competitiveness—raises the likelihood of unforeseen harms resulting from the use of insufficiently tested artificial intelligence solutions, thereby reinforcing the startup's responsibility toward users.

Among the factors that deepen the liability problem for startups is their weak bargaining position when contracting with technology service providers. This imbalance often leads them to accept standard-form contracts that do not ensure a fair distribution of responsibility in the event of harm. In addition, startups face a legal environment that is still taking shape regarding the use of artificial intelligence, as many legislative systems lack clear standards defining the obligations of this category of enterprises in areas such as transparency, data verification, and mechanisms of human oversight.

3.2.2 Challenges Startups Face in Using Artificial Intelligence

In addition to the legal issues related to assigning civil liability to startups when using artificial intelligence technologies, other dimensions emerge concerning these enterprises' responsibility to respect the fundamental principles and values that ensure the fair and responsible use of technology.

- **Transparency and ethical accountability:** One of the most prominent ethical challenges facing startups is how to ensure transparency in the intelligent systems they adopt, given their limited technical and financial capacity to develop algorithms. They also suffer from limited resources needed to audit their data, which makes them vulnerable to using incomplete datasets. As a result, artificial intelligence outputs may reinforce discriminatory patterns against certain groups of users, especially in sensitive sectors such as healthcare, finance, and employment. This constitutes an ethical challenge that requires establishing periodic verification mechanisms to prevent such outcomes.
- **Ensuring respect for fundamental rights and human dignity:** Startups' reliance on artificial intelligence for automated decision-making directly affects individuals' rights to fair and non-arbitrary treatment. These enterprises must also recognize that their

responsibility is not limited to legal compliance; it extends to adherence to principles of digital social responsibility. This requires establishing internal codes for artificial intelligence ethics, publishing clear transparency policies for customers regarding how their data are processed, and cooperating with civil society organizations and academic institutions to develop responsible digital governance mechanisms. Moreover, given the lag of legislative systems in keeping pace with the rapid development of artificial intelligence, startups bear an increased ethical responsibility to adopt internal standards that ensure respect for principles of transparency and non-discrimination.

4. CONCLUSION:

In the context of the digital revolution, artificial intelligence constitutes one of the fundamental tools capable of reshaping business models toward achieving sustainable entrepreneurship, especially within the startup environment that seeks technical solutions to confront environmental, social, and economic challenges. In this sense, artificial intelligence offers these enterprises significant opportunities to improve operational efficiency and strengthen innovation in products and services. However, the use of artificial intelligence is not free of legal and regulatory problems, and it causes startups to face challenges in complying with legal standards in the absence of flexible legislative frameworks that take into account their structural and functional particularities. Based on the foregoing, we reached the following results:

- With a supportive and effective legislative environment, artificial intelligence can serve as a powerful lever for sustainable innovation in startups.
- Achieving sustainable innovation in startups requires moving from a purely performance-oriented use of artificial intelligence to models that treat artificial intelligence as a strategic component in institutional decision-making.
- Gaps in national legislation regarding artificial intelligence push startups toward adopting self-governance standards based on principles of transparency and voluntary accountability.
- There is a need to revisit the concept of responsibility, shifting from focusing solely on the legal actor to creating shared-liability models.

- Personal data protection challenges in the artificial intelligence environment impose pressures on startups to adopt privacy strategies.

In light of the derived results, the following recommendations can be formulated:

- Develop national legislation that takes into account the specific characteristics of startups in adopting artificial intelligence technologies by incorporating legal and technical support mechanisms for these enterprises.
- Develop technical support programs for startups that help them adopt artificial intelligence solutions gradually in ways aligned with their organizational and financial capacities.
- Revitalize the legal frameworks regulating the use of artificial intelligence in a manner consistent with the particularities of startups.
- Assess tax incentives and encouragement measures for startups that integrate artificial intelligence into projects aimed at achieving sustainable development goals.
- Launch open platforms for exchanging data and knowledge that enable startups to access reliable digital resources, allowing them to develop effective and safe artificial intelligence solutions.
- Develop specialized training programs in artificial intelligence ethics directed at entrepreneurs in startups to raise their awareness of ethical and legal risks.

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