Making Artificial Intelligence Sustainable for Healthcare

Anna Bastone, Giulia Nevi, Francesco Schiavone, Fabian Bernhard, Luca Dezi

In Journal of Innovation Economics & Management 2024/2 No 44, pages 87 to 117
Publisher De Boeck Supérieur

DOI 10.3917/e.jie.pr1.0157
Uploaded: 05/17/2024

Making Artificial Intelligence Sustainable for Healthcare[1]

Anna BASTONE
Department of Management Studies and Quantitative Methods
University of Naples Parthenope
Via Generale Parisi 12, 80132, Napoli, Italy
anna.bastone001@studenti.unipartenope.it

Giulia NEVI
Department of Management
Polytechnic University of Marche
Piazzale Martelli 8, 60121 Ancona, Italy
g.nevi@univpm.it

Francesco SCHIAVONE
Department of Management Studies and Quantitative Methods
University of Naples Parthenope
Via Generale Parisi 12, 80132, Napoli, Italy
Paris School of Business
59 Rue National, 75013 Paris, France
francesco.schiavone@uniparthenope.it

Fabian BERNHARD
Faculty of Management & Humanities
EDHEC Business School in Paris
16-18 Rue du 4 Septembre, 75002 Paris, France
fabian.bernhard@edhec.edu

Luca DEZI
Department of Communication and Social Research
Sapienza University
Via Salaria 113, 00185 Roma, Italy
luca.dezi@uniroma1.it

1. *Acknowledgement*: the authors want to thank the Guest Editors and the reviewers of this journal for their valuable and constructive comments and suggestions which helped to improve the manuscript. The authors also want to thank the cultural association "Knowmedtech" (Italy) for the support in the development of this article.

DOI: 10.3917/jie.pr1.0157

ABSTRACT

This research aims to define a roadmap for the sustainable implementation of Artificial Intelligence (AI) in healthcare. Based on Triple Bottom Line (TBL) and the theory of dynamic capabilities (DC), the study highlights which steps and capabilities are needed to ensure an Artificial Intelligence (AI) implementation guaranteeing the three levels of sustainability (*people, profit and planet*). This study tries to respond to the following research question: *How can healthcare organizations ensure sustainable implementation of Artificial Intelligence?* An exploratory qualitative analysis was conducted using the focus group method. The results highlight six main steps for the sustainable implementation of AI, each with specific capabilities to be developed. This study provides implications for both theory and practice. Future research will be needed to investigate the emerging aspects.

KEYWORDS: AI, Sustainable Development, Healthcare Ecosystem, Dynamic Capabilities, Roadmap

JEL CODES: M21, I15, O30

Innovation is a multi-stage process that enables firms to compete in the marketplace by transforming their products and services (Baregheh *et al.*, 2009). Innovation and sustainability issues are directly linked and pose a real challenge for companies. As evidenced by Uzunidis (2009), sustainability is responsible for every business and allows growth and expansion. Companies should consider their operations' impact on communities and the environment in addition to profit (Björn *et al.*, 2021). Based on this, the Sustainable Development Goals (SDGs) era introduces a new approach to sustainable corporate development (WCED, 1987). Creating responsible organizations that invest in technological growth through partnership actions with other companies requires a strong and proactive approach, thereby initiating a worldwide and universal sequence of sustainable development for all businesses (Vinuesa *et al.*, 2020). Sustainable development could be crucial for organizations' competitive position (Sachs *et al.*, 2019; Martínez, Del Bosque, 2013).

The triple bottom line is the primary theoretical framework used to discuss sustainability. According to this approach, companies must pay particular attention to the potential social and environmental effects of their decisions (Elkington, 1997). Organizations should plan activities that ensure that economic rewards positively impact the environment and society (Tseng *et al.*, 2020). In this vein, companies can raise production value, attract more investors and clients, and foster a social and environmental corporate culture (Elmqvist *et al.*, 2019).

Today, digital innovation significantly impacts every industrial sector, particularly healthcare (Kraus *et al.*, 2021; Appio *et al.*, 2020; Leone *et al.*, 2021). COVID-19 highlighted several areas for improvement and enhancement, with healthcare being one of the most critical sectors. There is a need to adopt a more sustainable approach that ensures health and wellbeing without discrimination. As Brem *et al.* (2021) point out, the digital nature makes new technologies highly interoperable and adaptable to application contexts, regardless of the function for which they were originally designed. Additionally, the proliferation of digital devices reduces learning times by lowering barriers to entry for new entrants.

The quality of care in the healthcare ecosystem could be increased by adopting high-tech solutions that optimize the allocation of scarce resources (Butt *et al.*, 2019). Thus, advanced technologies such as Industry 4.0 and AI play a key role (Khan *et al.*, 2020). Artificial intelligence (AI) has become widely accepted to gain a competitive advantage (Haenlein, Kaplan, 2019; Di Vaio *et al.*, 2020; Carlson, Sakao, 2020; Kumar *et al.*, 2022). It positively impacts all SDGs through technological advancements that lead to better results in various sectors, enhancing development and substantially impacting civil society and the environment (Santosh and Gaur, 2022; Papa *et al.*, 2018; Santoro *et al.*, 2018). Several studies define AI as "the ability of a computer-controlled robot or digital machine to perform tasks traditionally performed by intelligent beings" (Copeland, 2024; Haenlein, Kaplan, 2019).

However, AI technologies have been studied to increase consumer value, enhance cost-effectiveness, and boost revenue (Åström *et al.*, 2022). They also push organizations to adapt and innovate their business strategies (Ferras-Hernandez *et al.*, 2022). The outbreak emphasizes that healthcare represents a fertile ground for the spread of AI (Kraus *et al.*, 2021; Fletcher *et al.*, 2020). Healthcare facilities can adopt a patient-based strategy and create individualized care pathways by implementing innovative technologies, ensuring high-quality treatment (Leone *et al.*, 2021; Kraus *et al.*, 2021; Schiavone *et al.*, 2021). Healthcare has undergone significant technological change, creating dynamic skills essential for profitable expansion and targeted strategic transformation (Pundziene *et al.*, 2022; Teece, 2019). Organizations must react quickly and with the dynamic agility necessary to survive (Loureiro *et al.*, 2021). To use these technologies, there is a need to develop new dynamic capabilities (Chakravorty *et al.*, 2020; Heart *et al.*, 2017).

The concept of sustainability is prevalent in the health sector today. According to the vision of the 2030 Agenda, health is inextricably linked to the social, economic, and cultural context (Sachs *et al.*, 2019). Zollo *et al.* (2016) underline that innovation must consider the health setting and the socioeconomic structure to be sustainable. AI could represent a valuable tool to guarantee the sustainable development of healthcare (Santosh, Gaur, 2022; Ilan, 2021; Tsagkaris *et al.*, 2021). From this perspective, the research question emerges: *How can healthcare organizations ensure the sustainable implementation of Artificial Intelligence?* Although numerous studies have addressed the topic of sustainability and AI (Nishant *et al.*, 2020; Courtland, 2018), there is still a gap in the literature on the process of sustainable implementation of AI in healthcare. This research paper aims to construct an initial roadmap identifying the main steps for AI implementation in healthcare that ensure economic, social, and environmental sustainability. Furthermore, the analysis aims to identify the dynamic capabilities underlying each step. Due to the explanatory nature and the evolving field, a qualitative analysis was adopted by conducting different focus groups.

From late October to mid-November 2022, online interviews were conducted with two focus groups (Table 1), lasting 88 minutes each. The transcriptions were carefully analyzed using content analysis, resulting in the identification and discussion of nodes and key dimensions aligned with the study's theoretical framework. The analysis revealed six critical steps for the sustainable implementation of AI in healthcare, along with associated dynamic capabilities. This research has important implications for management, theory, and policy, serving as a valuable tool for organizational and institutional strategy development. It also offers insights for management studies. The article is structured as follows: Section 2 reviews relevant contributions in sustainability development, AI, dynamic capabilities, and healthcare management. Section 3 outlines the methodology, data collection, and analysis stages. Section 4 presents the analyzed and discussed results, followed by implications for academia, practitioners, and policymakers in Section 5. The analysis concludes by addressing limitations and suggesting ideas for future research.

Theoretical Background

Sustainable Development Goals

The WCED (World Commission on Environment and Development) focused on sustainable issues, defining sustainable development as "*development that meets the needs of the present without compromising the ability of future generations to meet their own needs*" (WCED, 1987). The association stressed the need for intensive international cooperation on development and resource use issues. This definition highlights the importance of developing production strategies that consider the economy, society, and the environment (Olawumi, Chan, 2018; Elkington, 1994). Adopting a company's sustainable strategy allows organizations to gain a critical competitive advantage (Björn *et al.*, 2021). The environmental sustainability of products demonstrates the company's reliability and moral values (Herbas Torrico *et al.*, 2018; Martínez, Del Bosque, 2013). Furthermore, academic literature has shown that a strong sense of social responsibility leads consumers to develop trust and loyalty and engage in positive word-of-mouth (Martínez, Del Bosque, 2013).

Sustainable development includes social and economic considerations in addition to environmental preservation. Vinuesa *et al.* (2020) have provided evidence of the link between the SDGs (Sustainable Development Goals) and the triple-bottom-line approach, which is a theoretical framework to consider when discussing sustainability. According to the triple bottom line (TBL) business concept, firms should aim to measure their social and environmental impact in addition to their financial success, rather than solely concentrating on profit production or the traditional "bottom line." The "three Ps" can be summarized as profit, people, and the planet (Elkington, 1997). The intersection of social, environmental, and economic activities can help organizations engage in activities that positively affect the natural environment and society while also having long-term economic benefits (Tseng *et al.*, 2020). Elmqvist *et al.* (2019) report that these three factors enable organizations to increase their production value, attract more investors and customers, and foster a socially and environmentally sustainable work environment among employees.

The Sustainable Development Goals (SDGs) can be considered supported by this theoretical framework. The 2030 Agenda emphasizes time-bound goals for Prosperity, People, Planet, Peace, and Partnership, known as the "five Ps" (Sachs *et al.*, 2019). International development goals can expedite the transition to more complex objectives but necessitate structural and profound changes across all societal sectors (McArthur, Rasmussen, 2018). Sustainable TBL-based strategies should meet several requirements to guarantee a competitive advantage (Ferro *et al.*, 2019). The scientific literature evidence that these strategies should be implemented throughout the entire organization, not just at the corporate level (Schulz, Flanigan, 2016). When defining corporate sustainability plans, the needs of all stakeholders should be considered (Svensson *et al.*, 2018). Finally, to enhance stakeholder connections, businesses should actively share their sustainability efforts and successes (Blenkhorn, MacKenzie, 2017). Thus, to ensure long-term sustainable development, companies must be oriented towards technological change, providing a framework for accelerating technological innovation, development, and dissemination (Sachs *et al.*, 2019).

AI and sustainability share concepts that are often discussed without a precise understanding of their meanings. The same applies to the SDGs, where the exact measurements and criteria for assessing them are fragmented. In 2018, Oxford University initiated a project aimed at tracking AI solutions to support the SDGs (Project Finder, 2018[2]). Those initial projects focused solely on specific SDGs, resulting in unequal coverage compared to SDG 9 (Industry Innovation and Infrastructure), which is the most addressed in contrast to SDGs 5 (gender equality), 6 (clean water and sanitation), and 15 (life on land). On the other hand, achieving all 17 goals is not an easy task. Vinuesa *et al.* (2021) and Gupta *et al.* (2021) confirm how AI solutions could enable the adoption of SDGs. Nasir *et al.* (2022) provide evidence that many AI solutions remain confined to achieving specific goals while underestimating others, especially environmental goals. The authors highlight the fragmented priorities and emphasize the need for unified actions to understand how to achieve the SDGs with AI.

AI for New Competitive Strategies

The core principle of AI is to create computers with autonomous learning and adaptive skills, motivated by human learning models (Haenlein, Kaplan, 2019; Di Vaio *et al.*, 2020; Leone *et al.*, 2021). The term "Artificial Intelligence" was coined to describe the human intelligence exhibited by machines (Bini, 2018). AI has been mainly applied (Haenlein, Kaplan, 2019). There are different subsets of AI. The first form of AI is machine learning (ML) solutions, which allow algorithms to be used to build models that "train" the machine (Helm *et al.*, 2020). The second subset of AI is "neural networks", which aim to reproduce the functioning of neural connections in the human brain (Topol, 2019). The impact of AI on all sectors is disruptive, and numerous studies highlight how AI systems can be helpful in a more aware and optimized management of resources (Di Vaio *et al.*, 2020; Nishant *et al.*, 2020; Carlson, Sakao, 2020; Kumar *et al.*, 2022). However, there are numerous and growing questions and challenges regarding the real sustainability of AI (Yigitcanlar, Cugurullo, 2020).

These systems require significant energy consumption, components that require rare resources, and often involve complex and lengthy processing. Dhar (2020) recognized that AI has a dual role as both a helper and an obstacle. On the one hand, it helps reduce the effects of the climate crisis. Indeed, as the analysis by Leal Filho *et al.* (2022) shows, digital technologies help support research on climate change adaptation and SDGs implementation,

2. https://www.aiforsdgs.org/all-projects

increasing operational efficiency (Calabrese *et al.*, 2023). On the other hand, it consumes and significantly impacts carbon dioxide. AI validly supports health decision-making (Shortliffe *et al.*, 2018; Pietronudo *et al.*, 2022), reducing costs and optimizing resource allocation (Govindan, 2022). Additionally, AI technologies can improve organizational performance by speeding up processing, reducing bottlenecks, and increasing overall operational efficiency (Olan *et al.*, 2022; Schiavone, Festa, 2021).

Moreover, as Garbuio and Lin (2018) have identified, AI's potential in the healthcare field extends to all stakeholders in the sector. It creates value at the patient, clinical, operational, and financial administrative levels. The healthcare sector has been estimated to have an environmental impact of around 1%-5% of the global impact, with some countries exceeding that threshold. Resolving this impact remains critical, and the TPB (Total Physical Burden) remains sustained (Lenzen *et al.*, 2020). At the public level, the link between sustainability and AI is strong, particularly in terms of public health and the well-being of nations (Santosh, Gaur, 2022).

One of the most critical dimensions is the management of human resources; these systems could lead to better management (Papa *et al.*, 2018) and knowledge management (Santoro *et al.*, 2017). Consequently, Santosh and Gaur (2022) hypothesize that adopting AI tools in healthcare could be a solution not only to this reduction but also a means of reducing social inequalities. Along the same lines, Ilan (2021) highlights how these systems make it possible to aid even the poorest or most disadvantaged areas. The authors identify a series of challenges that not only concern AI but also the sustainability of the healthcare system and the critical issues that introducing AI systems entails.

The adoption of AI in healthcare is frequently linked to ethical reflections, such as errors of such systems at the diagnosis level (Obermeyer, Topol, 2021), system malfunctions, or issues with connected robotics (Jiang *et al.*, 2021). By utilizing wearable sensors, the Internet of Things, and portable Internet to collect information dynamically and connect individuals, entities, and organizations involved in healthcare, Industry 4.0 technologies are transforming conventional healthcare organizations into smart healthcare (Ahmed *et al.*, 2022; Yang *et al.*, 2022). Implementing AI in healthcare could be a helpful game-changer in improving the quality of life (Katsaliaki *et al.*, 2022; Escobar *et al.*, 2021; Grenier *et al.*, 2019). The role of both developing and sustainably using AI systems, especially about environmental impact, remains critical (Richie, 2022). Few studies have explored the intersection of sustainability and AI in the healthcare sector, even in Italy. The current scenario in Italy is characterized by fragmentation and specialization within specific areas of study (Avanzo *et al.*, 2021). Nevertheless, the significant potential of such solutions in addressing the weaknesses of the Italian healthcare system has been recognized. Cingolani *et al.* (2023) investigated the limitations and opportunities of home care for elderly people, while Bellini *et al.* (2022) highlighted weaknesses in education and programming in Italian clinical laboratories.

Dynamic Capabilities for New Challenges

Firms require a unique set of dynamic competencies to adopt successful sustainable development strategies (Adams *et al.*, 2016; Inigo, Albareda, 2019). Dynamic capability is defined as "*the firm's ability to integrate, build, and reconfigure internal and external competencies to address rapidly changing environments*" (Teece *et al.*, 1997, p.2). The original definition of dynamic capabilities included three clusters of processes: sensing the environment, which led to the identification and understanding of business opportunities; seizing opportunities through the integration and repurposing of resources to address these opportunities and to reap the benefits from doing so; and transforming through continuous renewal to carry out and sustain innovation at scale (Bogers *et al.*, 2019). There are two sustainability drivers: external and endogenous (Cezarino *et al.*, 2019).

Cultural variables such as motivation, knowledge distribution, managerial commitment, and long-term horizon are major drivers of ecological responsiveness (Eikelenboom, De Jong, 2019). Innovation plays a critical role (Zollo *et al.*, 2016). A company's innovativeness is crucial in developing eco-capacity and environmental attitudes (Hanaysha *et al.*, 2022). Thus, the overall organizational strategy must incorporate sustainability concepts first. Utilizing cutting-edge technologies, having a history of working with suppliers and consumers, and having an innovative mindset are all qualities that support an organization's capacity to apply environmental management principles continually and collaborate with the environment (Sermontyte-Baniule *et al.*, 2022).

Inigo and Albareda (2019) identified the following crucial elements in the sustainable challenge: 1) the ability to involve stakeholders in the innovation process; 2) the capacity to recognize and react to regulatory and technological changes; 3) a systemic approach to the business in which the relationship with other actors in the ecosystem is well managed; 4) the development of trusting relationships. Due to the profound technological changes in the healthcare sector, developing dynamic capabilities is key to profitable growth and targeted strategic change (Pundziene *et al.*, 2022; Teece, 2019). Healthcare organizations must be mindful of rapid organizational changes: when the demands of users and professionals change, organizations must respond rapidly with the dynamic agility required for survival (Loureiro *et al.*, 2021).

Healthcare providers have identified the efficient use of digital technologies as the primary strategy for gaining a competitive advantage (Heart *et al.*, 2017). Even though new technologies have improved the efficiency and practicality of managing healthcare, their use necessitates higher awareness and comprehension and can interfere with daily routines (Chung *et al.*, 2022). In this regard, new clinical, organizational, and strategic capabilities should be developed (Chakravorty *et al.*, 2020).

Rialti *et al.* (2019) highlight the key role of dynamic capabilities in disseminating and adopting digital solutions such as big data and AI. Implementing such technologies can be seen as "*a constant generation and diffusion of knowledge, through which they enable managers and analysts to identify good opportunities and discard unprofitable ones*". Therefore, they could influence the ability of a process to adapt to changing situations. Sustainability is inextricably linked to health and well-being, and the new One Health approach emphasizes the interdependence of sustainability, well-being, and health (Benis *et al.*, 2021). Goal 3 of the 2030 Agenda for Sustainable Development is aligned with this approach (WHO, 2021). Therefore, it is essential to establish dynamic capabilities within the health ecosystem to strategically integrate long-term sustainability goals (Di Vaio *et al.*, 2020).

Long-term strategies must be developed as a crucial value proposition component (Chakravorty *et al.*, 2020). This process is facilitated by digital advancements (Khan *et al.*, 2020). Organizations must integrate healthcare, sustainability, and digital strategy to meet evolving care needs.

Method

Data Collection and Data Analysis

Due to the exploratory nature of the study and the limited existing literature on sustainability and AI in healthcare, a qualitative methodology was chosen. Two online focus groups were conducted with experts, academics, and companies involved in AI solutions in healthcare. Focus groups create a natural environment for discussion and yield valuable results on complex subjects. The sample size varied but ensured sufficient participation for in-depth discussions. Participants were purposively selected based on their healthcare experience and involvement in AI projects. Academics and companies were chosen based on their expertise and the scientific nature of their AI solutions. In September 2022, initial contact was made with the sample, resulting in a response rate of 25%. The focus groups were conducted online from late October to mid-November 2022, with an average duration of 88 minutes.

Table 1 **– List of interviewees**

Focus Group	
1° Focus group Five Components	
2° Focus Group Five Components	
Participants	**Occupation and AI Experience**
Int.1	AI Product Manager
Int.2	Lecturer
Int.3	Researcher
Int.4	Healthcare professional
Int.5	Sustainability Consultant in Healthcare
Int.6	AI Consultant and Lecturer
Int.7	Lecturer and Healthcare professional
Int.8	CEO
Int.9	Manager
Int.10	CEO of an AI Italian Association

In conducting the focus group, it was preferred to maintain a heterogeneous group composition without hindering the discussion (Morgan, 1988 ; Freitas *et al.*, 1998). The focus group was conducted online, on a digital platform, and in Italian. It was a dual-moderator focus group, with two researchers acting as moderators and facilitators of the discussion (Saunders *et al.*, 2009). Participants were allowed to freely express their thoughts and seek answers (Malhotra, 2019) through a roundtable format. To ensure harmonization and consistency, the discussions focused on a specific guide that included preselected topics based on the current state of the literature. At the end, participants from each focus group were invited to create a roadmap (Ghobakhloo *et al.*, 2022) for the implementation of sustainable AI solutions in healthcare. The focus group sessions were recorded and manually transcribed to capture important pauses and passages while maintaining participant privacy through coding. The coding process involved manual procedures to enhance linguistic and contextual understanding. The main themes and sub-themes of the coding are provided in the Appendix. Focus groups provide rich data beyond session notes, and content analysis was used to analyze the transcribed sessions. This analysis identified nodes and dimensions consistent with the study's theoretical framework. To ensure triangulation (Yin, 2003), secondary data sources such as reports, white papers, archival records, and online documentation were utilized as evidence. This reinforced the analysis and contributed to the development of a comprehensive roadmap, as defined by Moretto *et al.* (2018), which guides progress towards a goal and provides an extended view into the future.

Findings

Content analysis revealed five key nodes: the definition of AI and sustainability, TPL-related nodes (sustainability and planet, sustainability, people, and profit), critical issues in AI and Sustainability, and emerging capabilities for sustainable AI systems in healthcare. Table 2 displays representative quotes from the focus group, while the subsequent paragraph provides a breakdown of the main themes that emerged.

In Search of Definition

From the content analysis, three main nodes emerged as all participants had difficulty defining AI and Sustainability. During the analysis, it was possible to find three very specific nodes that referred to AI Sustainability and were coherent with the TBL approach: *AI sustainability and Planet – AI sustainability and People – AI sustainability and Profit*. The last one is a critical issue tied to the implementation. The main quotes are in Table 2.

AI Sustainability and Planet

The first node, *Sustainability and Planet*, identifies the link between sustainability and AI. Participants in the focus group recognized that environmental sustainability should not be taken for granted. However, it is necessary to distinguish between macro and micro levels. When considering the macro aspect, AI poses certain challenges due to its energy consumption and the components of the supporting tools. Yet, on a micro level, particularly in medical assistance and management, AI in healthcare is perceived as sustainable. For instance, Int. 5 mentioned, "*A hospital, for example, is an intrinsically energy-intensive structure. Then there is intelligence-building management. But we are not talking about AI applied to healthcare but about infrastructure and supply management. AI is an intrinsically sustainable technology. If we want to make it sustainable, it must be adopted and well communicated*". To ensure environmental sustainability, creating an ecosystem that enhances coordination and communication is necessary. As expressed by Int. 6, "*Honestly, in most applications, and I don't think that in the social and health sector, there is a big problem of environmental impact, but it is important to create cooperation among different structures*". To implement AI sustainably, fostering a sustainable mindset through the dissemination of a green-oriented culture is crucial.

AI Sustainability and People

At a societal level, AI presents its greatest potential and is perceived as an essential solution to alleviate various problems within the health sector. It facilitates time reduction across several domains. Firstly, it addresses the entire spectrum of medical activities, spanning from prevention to diagnosis and treatment. AI allows for the redistribution of time and workloads, thereby enhancing and improving activities and the services offered to enhance effectiveness and efficiency. Indeed, according to Int. 9, "*AI will play an accelerating role in implementing services to support healthcare professionals, improving the ability to take charge and plan purposes. AI in healthcare will also act as a facilitator, enabling continuity, access, and personalization of care to achieve greater effectiveness and efficiency*".

AI Sustainability and Profit

AI demonstrates economic sustainability by reducing inefficiencies, accelerating operational times, and enhancing human resource management. Shortening diagnosis times, promptly identifying diseases, and improving preventive measures reduce costs for the entire healthcare system while enhancing quality. As mentioned by Int. 5, "*Reducing environmental impact enhances people's quality of life and translates into reduced health costs*". Furthermore, AI implementation optimizes resource allocation, minimizing healthcare expenditure. These technologies foster an ecosystem for sharing tools and information. In addition to these well-known aspects in the literature, the focus groups aimed to illustrate how AI can alleviate certain barriers to entry, emphasizing the necessity for comparison among various stakeholders. However, reducing models may lead to these solutions being managed in a semi-oligopoly manner.

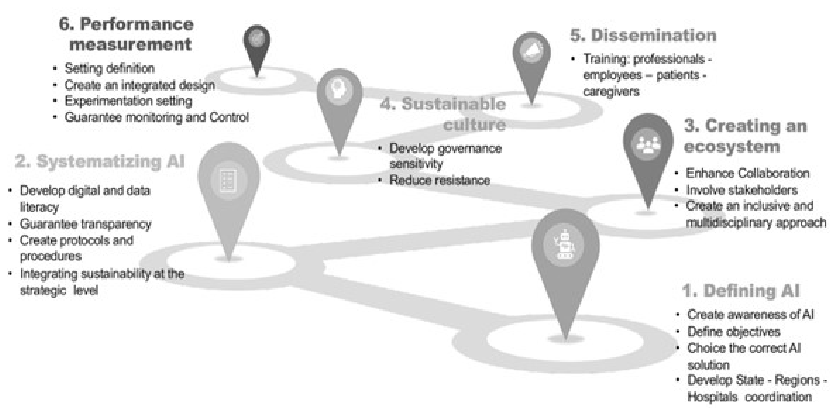
AI and Sustainability: A Critical Issue

To establish credibility for AI and sustainability, overcoming current critical issues is imperative. Respondents perceive both advantages and disadvantages in terms of personnel reduction, the emergence of a new non-healthcare-oriented doctor-patient relationship, potential decrease in doctors' capacity that could be exploited, to the detriment of patient health and the system, and the necessity to develop new skills. These skills aren't solely technical but require specific development for all stakeholders within the healthcare ecosystem. It's crucial to adopt measurement and control systems by defining new tools and measures for assessment and improvement. However, this is notably complex, particularly in the healthcare sector. Primarily, as mentioned earlier, the development of an organizational culture is essential. Int. 4 emphasized, "*The real challenge lies within the human aspect of doctors and managers, who must comprehend and effectively use AI to their advantage. We need to cultivate a culture and adeptness with technology; presently, we're still in a rudimentary phase*".

Discussion and implications

Our findings demonstrate the relationship between AI and healthcare sustainability. The ability to create a plan for sustainable AI adoption (Figure 1) enables healthcare facilities to guarantee the three levels of sustainability of TBL – *economic, social and environmental* – (Figure 2) (Elkington, 1997). The model allows us to identify the key dynamic capabilities (Pundziene *et al.*, 2022; Teece, 2019; Chakravorty *et al.*, 2020).

Figure 1 – RoadMap for a sustainable AI implementation



Source: Authors' research

Table 2 **– Table of representative quotes**

Quotes	Respondent	Theme	Roadmap
"First, let's delve into what we mean by artificial intelligence, avoiding technical jargon. At the political level, for instance, consulting an online encyclopedia defines within the scope of a discipline. However, within this year's European Parliament documents, artificial intelligence is defined as the capability of machines or algorithms to replicate certain human characteristics. These two definitions offer vastly different perspectives on artificial intelligence, don't they? Additionally, the choice of funding also varies based on these definitions. Financing something associated with a discipline contrast with funding projects focused on emulating human attributes".	Int.3	*In search of Definition*	Defining AI
"We also need to better define the term 'sustainable.' In certain contexts, such as when engaging with the Ministry of Health or conversing with the general directors of local health authorities, the primary consideration is predominantly economic, followed by organizational aspects".	Int.6		Defining Sustainability
"We need regulation and a clear definition. There is still a lot of confusion regarding certifications, responsibility, and the level of authority and power".	Int.2		Defining AI

Quotes	Respondent	Theme	Roadmap
"AI systems are, by default, connected to computers, and the hardware requirements, particularly regarding energy consumption associated with training machine learning algorithms, are becoming increasingly demanding. Consequently, in Europe, there is a growing focus on "green AI", aimed at developing AI techniques and algorithms that consume fewer resources. Presently, when confronted with system issues, there is a tendency to adopt more high-performing systems, leading to the creation of incredibly powerful systems, such as 7000 CPU systems, typically used for gaming or multimedia presentations".	Int.8	*AI Sustainability and Planet*	Performance measurement
"AI is inherently sustainable because all indicators, including real-use cases, demonstrate its sustainable nature".	Int.4		Sustainable culture
"A hospital, for example, is an intrinsically energy-intensive structure. Then there is intelligence-building management. But we are not talking about AI applied to healthcare but about infrastructure and supply management. AI is an intrinsically sustainable technology. If we want to make it sustainable, it must be adopted and well communicated."	Int.5		Dissemination
"Honestly, in most applications, and I don't think that in the social and health sector, there is a big problem of environmental impact, but it is important to create cooperation among different structures."	Int.6		Creating an Ecosystem

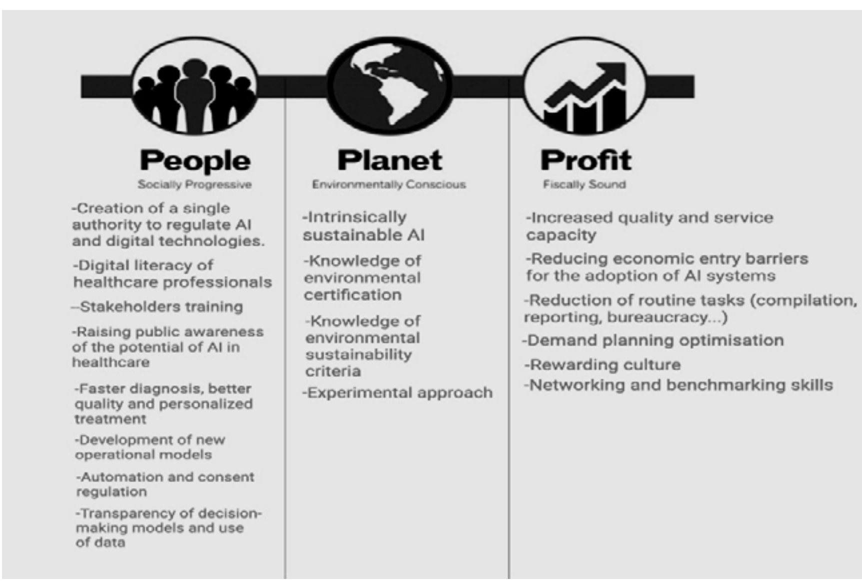
Quotes	**Respondent**	**Theme**	**Roadmap**
"It saves us time, optimizes resources, and expedites decision-making processes, which shortens distances for various reasons, contributing significantly to sustainability. In my opinion, how can we introduce AI to support medicine?".	Int.7	*AI Sustainability and People*	Sustainable culture
"AI will play an accelerating role in implementing services to support healthcare professionals, improving the ability to take charge and plan purposes. AI in healthcare will also act as a facilitator, enabling continuity, access, and personalization of care to achieve greater effectiveness and efficiency".	Int.9		Performance measurement
"Reducing environmental impact enhances people's quality of life and translates into reduced health costs."	Int.5	*AI Sustainability and Profit*	Performance measurement
"In my opinion, it not only diminishes repetitive tasks but also generally enhances the quality and service capacity of a department, consequently benefiting the hospital".	Int. 9		Sustainable culture
"To avoid unnecessary resource wastage, it's crucial to skip these initial stages. Local hospitals have conducted individual experiments, the phase of pilot projects has elapsed, and it's now imperative to extract best practices to establish a comprehensive system".	Int.8		Systematizing AI
"Without an "ethical" brake, there could be a significant automation of many processes that are currently within the realm of human competence. While this could maximize profit, it might significantly reduce performance quality and increase risks."	Int.2	*AI and Sustainability – Critical Issue*	Sustainable culture – Dissemination

Quotes	Respondent	Theme	Roadmap
"In our hospital, attempts to implement AI in the radiological emergency department have shown limited usage and acceptance. To address this challenge, there's a need for enhanced digital skills, data literacy, a supportive culture, and ensuring interoperability between systems".	Int.7		Systematizing AI
"We require acknowledgment of monitoring and reporting systems to comprehend the situation and establish long-term goals. Additionally, a new Key Performance Indicator (KPI) for Sustainability and AI is needed".	Int. 5		Performance measurement

Several authors have highlighted AI as a transformative technological and societal innovation, particularly in the healthcare industry (Åström *et al.*, 2022; Leone *et al.*, 2021; Pietronudo *et al.*, 2022). AI has the potential to enhance operational efficiency and patient satisfaction (Martins *et al.*, 2020; Leone *et al.*, 2021; Shortliffe *et al.*, 2018; Brem *et al.*, 2021). However, regulatory obstacles need addressing to facilitate its effective adoption and ensure awareness of its benefits. The healthcare industry faces significant regulatory fragmentation (Steinhauser *et al.*, 2020), and a clear definition of AI is crucial for its successful implementation and to empower stakeholders in the healthcare ecosystem (Spena, Mele, 2019). This would allow for precise goal setting and the selection of appropriate AI solutions. Cooperation between states, regions, and institutions can facilitate national standardization of AI regulations (Kandel *et al.*, 2020) and reduce the proliferation of diverse AI models caused by conceptual and regulatory fragmentation.

AI enables access to vast amounts of data (Lindebaum *et al.*, 2020), necessitating the development of digital and data literacy skills (Kraus *et al.*, 2021). Therefore, the consolidation of these skills is crucial to adapt to significant technical and socioeconomic shifts (Heart *et al.*, 2017). Strengthening networking skills and digital literacy among healthcare professionals is essential for sustainable AI implementation from both social and economic perspectives (see Figure 2).

Figure 2 **– AI, TBL key insights**



Source: Authors' research

Notably, there are three areas in which action can be taken: the more specific one involves training public and private personnel, both on the demand and supply sides; the more generalist one focuses on promoting literacy for all in the full utilization of digital services; and the more advanced one revolves around specialized and transdisciplinary preparation (Frey, Osborne, 2017). Additionally, protocols should be established to apply AI solutions, ensuring data transparency and interoperability (Balasubramanian *et al.*, 2021). The vast amount of environmental and personal data collected by computer systems daily is now being leveraged to enhance AI approaches and technologies (Bresciani *et al.*, 2021a, 2021b; Frey, Osborne, 2017). The usefulness of the data and its interoperability determine the feasibility of using new technologies. Data quality should be guaranteed at the source through the widespread acceptance of principles and suitable content standards (Wang *et al.*, 2018) for environmentally conscious AI implementation (Figure 2). Indeed, strategic sustainability management becomes crucial (Schulz, Flanigan, 2016).

The first two steps of the roadmap support the ability of stakeholders to define validated AI models that adhere to specific rules and procedures and ensure the pursuit of clear and sustainable objectives, enabling overall sustainability. First, AI implementation times are significantly reduced: healthcare facilities no longer need to navigate through bureaucracy and can minimize diagnosis time (Obermeyer, Topol, 2021). The result is a halving of costs, environmental impact, and increased satisfaction for all stakeholders. Additionally, a clear definition of AI allows facilities to access funding easily. Standardizing models, rules, and procedures highlights the need to build an AI healthcare ecosystem (Secundo *et al.*, 2021; Leone *et al.*, 2021). A service ecosystem comprises actors and resources linked by value propositions in a network of connections (Frow *et al.*, 2016). Actors are drawn to share their resources because of value propositions that promise possibly better results (Svensson *et al.*, 2018; Calabrese *et al.*, 2023; Govindan, 2022). Sharing resources makes the ecosystem dynamic. The health sector is a precious testing ground. A more comprehensive range of participants (actors) and a more extensive set of collaborative actions have started to be considered in recent years (Secundo *et al.*, 2021; Leone *et al.*, 2021; Svensson *et al.*, 2018).

In terms of TBL sustainability, our results show that the development of an ecosystem enables resource allocation optimization, cost savings, and increased stakeholder involvement. High degrees of stakeholder participation are achievable from this standpoint. Facilities should balance the expenses and resources consumed and define strategies of inclusion and collaboration that focus on the well-being of stakeholders (Schiavone *et al.*, 2021). Social and economic sustainability (Elkington, 1997) are strongly correlated, and the effects of AI adoption on sustainability in healthcare contexts are in the medium to long term. A sustainable culture must spread within the healthcare ecosystem (Di Vaio *et al.*, 2020; Eikelenboom, De Jong, 2019). Implementing strong communication and social inclusion strategies should be crucial. The analysis underpins opening dialogue in organizations and promoting a multidisciplinary and rewarding culture characterized by solid communication could be necessary (Figure 2). Healthcare structures should develop the ability to listen to the needs of stakeholders, ensuring a high level of sensitivity in governance. It is possible to create a culture focused on sustainability that is reflected in a reduction of resistance to change. Sharing knowledge and validated models within the health ecosystem allows for virtuous examples. The next phase is disseminating the results (Blenkhorn, MacKenzie, 2017; Sachs *et al.*, 2019). This raises awareness of the advantages of AI and makes it possible for everyone involved to engage in a training process.

It emerges that AI can be applied to prevention. It can have an impact on long-term sustainability from both an economic perspective (for the national welfare system) and a social perspective (reducing the burden of care on families) (Shortliffe *et al.*, 2018; Santosh, Gaur, 2022). The ability of facilities to develop appropriate monitoring and performance control systems is crucial for the sustainable application of AI in healthcare. Making the quality of care "visible" and measurable is a key component of healthcare (Agarwal *et al.*, 2019; Schiavone *et al.*, 2022). Monitoring clinical performance has gained global importance, particularly with the emergence of AI (Rana *et al.*, 2022; Akter *et al.*, 2020). It allows for striking a balance between economic performance, growth, and control (Yu *et al.*, 2018), enabling managers to meet predetermined business goals (Martins *et al.*, 2020).

Our analysis emphasizes the need to define the scope. Additionally, facilities should develop an integrated measuring system that captures three levels of TBL (Triple Bottom Line) sustainability. Continuous assessment enables healthcare organizations to reformulate existing procedures and establish more stable and long-term forms of collaboration (Schiavone *et al.*, 2022; Martins *et al.*, 2020; Yu *et al.*, 2018). It improves the quality of care and overall performance (Wamba *et al.*, 2020; Mikalef, Gupta, 2021). This research work offers several theoretical, managerial, and policy implications. From a theoretical standpoint, it provides new insights to academics regarding the relationship between AI and sustainability, offering a roadmap for the "responsible" implementation of AI in the health sector. The plotted roadmap serves as a starting point, where each stage completely pervades the other and influences its development. We chose to represent the roadmap in this way because the concept of a roadmap consists of a path to reach a specific goal (Moretto *et al.*, 2018), such as the one in this research.

It highlights the possibility of analyzing digital technologies from a different perspective and emphasizes the utility of AI, not merely in mechanical terms. It could be a valuable tool from an intuitive and empathetic standpoint. Additionally, it allows for the merging of different fields of research. It contributes to four main streams: dynamic capabilities, AI, sustainable development, and healthcare management. From a managerial perspective, the results show that healthcare managers should take up the challenge of developing sustainable AI implementation strategies from a stakeholder perspective. The aim should be to ensure the technical feasibility of the pathways in the long term and to guarantee overall sustainability.

Furthermore, the analysis emphasizes the need to invest in training and communication to create a sustainable, shared culture within the healthcare ecosystem. Finally, this research work offers food for thought for policymakers. The widespread use of AI and its clear benefits in clinical, technical, and sustainable terms should push institutions to break down regulatory fragmentation and define uniform protocols and procedures. Consequently, a single supervisory authority should be established to ensure the rules are correctly applied. Hence, there is a need to envisage a performance monitoring system based on a dashboard of key performance indicators (KPIs) consisting of indicators of different natures (*e.g.*, clinical and economic).

Conclusions and Limitations

This research presents a roadmap for the sustainable implementation of AI in healthcare, showcasing AI's significant potential in terms of sustainability from a Triple Bottom Line (TPL) perspective within healthcare. It offers insights into AI implementation theories and assists healthcare managers in identifying key factors for future strategies. However, the paper has limitations as focus groups were conducted solely with an Italian sample. Future research should incorporate samples from different nations, considering contextual sensitivity and cultural differences in healthcare systems. Additionally, future research could explore the dimensions identified in each step of the roadmap, such as conducting content analysis of research reports or normative documents to define AI in healthcare.

Future research could focus on understanding how AI structures the new Sustainable AI Healthcare Ecosystem. Subsequent studies should map the primary components and comprehend critical points by exploring value-creation opportunities. In the fourth phase, research should prioritize understanding different perceptions and reducing resistance. Experimental studies are recommended to observe results in the fifth phase and capture reactions to communication, training, roles, and health settings. Incorporating design thinking approaches in the final stage could be intriguing. Emphasizing the significance and criticality of each phase is crucial. Establishing and promoting a sustainable culture beyond AI and disseminating results are essential. Future research should analyse the longitudinal progression of AI and track sustainable opportunities it creates. Additionally, researchers must not underestimate the negative aspects of AI and the reciprocal influence of sustainability practices.

Future research aims to identify and analyse the three lines of the Triple Bottom Line (TBL). Economically, it can explore building ecosystems for sustainable value creation and developing effective collaborations. It can also investigate elements enabling the integrated management of sustainable AI practices. Companies and healthcare facilities must understand resource management for adequate care. Exploring the integration of AI and sustainability with Sustainable Development Goals (SDGs), as well as understanding country-specific differences and the role of health sectors, is interesting. Research can evaluate sustainable AI implementation in various healthcare structures and fields. At the individual level, studies can focus on strategies for training stakeholders in sustainability and reducing resistance to change. It is worth examining the acceptance and accuracy of different AI types and how they foster professional-institutional cooperation.

Field investigations can be conducted to identify the adoption of AI in daily life among patients, doctors, and healthcare workers. Additionally, creating a dashboard of key performance indicators (KPIs) for each aspect of the Triple Bottom Line (TBL) could be valuable for investment assessment, monitoring sustainable AI use in healthcare, and ensuring continuous improvement. Future research should concentrate on studying the effectiveness of tools and methods to prevent distortions and abuses resulting from improper use or speculation on data. This includes examining medical diagnosis and ensuring the suitability of AI for medical settings, as well as monitoring indicators over time. Furthermore, it would be beneficial for future studies to explore the skills and knowledge required for sustainability management and AI, highlighting how they can enhance the value of stakeholders in the ecosystem.

REFERENCES

ADAMS, R., JEANRENAUD, S., BESSANT, J., DENYER, D., OVERY, P. (2016), Sustainability-Oriented Innovation: A Systematic Review, *International Journal of Management Reviews*, 18(2), 180-205.

AGARWAL, S., SRIPAD, P., JOHNSON, C., KIRK, K., BELLOWS, B., ANA, J., BLASER, V., KUMAR, M. B., BUCHHOLZ, K., CASSEUS, A., CHEN, N., DINI, H. S. F., DEUSSOM, R. H., JACOBSTEIN, D., KINTU, R., KURESHY, N., MEOLI, L., OTISO, L., PAKENHAM-WALSH, N., ZAMBRUNI, J. P., RAGHAVAN, M., SCHWARZ, R., TOWNSEND, J., VARPILAH, B., WEISS, W., WARREN, C. E. (2019), A Conceptual Framework for Measuring Community Health Workforce Performance within Primary Health Care Systems, *Human Resources for Health*, 17(1), 1-20.

AHMED, I., JEON, G., PICCIALLI, F. (2022), From Artificial Intelligence to Explainable Artificial Intelligence in Industry 4.0: A Survey on What, How, and Where, *IEEE Transactions on Industrial Informatics*, 18(8), 5031-5042.

AKTER, S., MICHAEL, K., UDDIN, M. R., MCCARTHY, G., RAHMAN, M. (2020), Transforming Business Using Digital Innovations: The Application of AI, Blockchain, Cloud and Data Analytics, *Annals of Operations Research*, 1-33.

APPIO, F. P., FRATTINI, F., MESSENI PETRUZZELLI, A., NEIROTTI, P. (2020), Digital Transformation and Innovation Management: Opening up the Black Box, *Journal of Product Innovation Management*, 1-6.

ÅSTRÖM, J., REIM, W., PARIDA, V. (2022), Value Creation and Value Capture for AI Business Model Innovation: A Three-Phase Process Framework, *Review of Managerial Science*, 16(7), 2111-2133.

ÅSTRÖM, J., REIM, W., PARIDA, V. (2022), Value Creation and Value Capture for AI Business Model Innovation: A Three-phase Process Framework, *Review of Managerial Science*, 16(7), 2111-2133.

AVANZO, M., PORZIO, M., LORENZON, L., MILAN, L., SGHEDONI, R., RUSSO, G., MASSAFRA, R., FANIZZI, A., BARUCCI, A., ARDU, V., BRANCHINI, M., GIANNELLI, M., GALLIO, E., CILLA, S., TANGARO, S., LOMBARDI, A., PIRRONE, G., DE MARTIN, E., GIULIANO, A., BELMONTE, G., METTIVIER, G. (2021), Artificial Intelligence Applications in Medical Imaging: A Review of the Medical Physics Research in Italy, *Physica Medica*, 83, 221-241.

BALASUBRAMANIAN, S., SHUKLA, V., SETHI, J. S., ISLAM, N., SALOUM, R. (2021), A Readiness Assessment Framework for Blockchain Adoption: A Healthcare Case Study, *Technological Forecasting and Social Change*, 165, 120536.

BAREGHEH, A., ROWLEY, J., SAMBROOK, S. (2009), Towards A Multidisciplinary Definition of Innovation, *Management Decision*, 47(8), 1323-1339.

BELLINI, C., PADOAN, A., CAROBENE, A., GUERRANTI, R. (2022), A Survey on Artificial Intelligence and Big Data Utilisation in Italian Clinical Laboratories, *Clinical Chemistry and Laboratory Medicine* (CCLM), 60(12), 2017-2026.

BENIS, A., TAMBURIS, O., CHRONAKI, C., MOEN, A. (2021), One Digital Health: A Unified Framework for Future Health Ecosystems, *Journal of Medical Internet Research*, 23(2), e22189.

BINI, S. A. (2018), Artificial Intelligence, Machine Learning, Deep Learning, and Cognitive Computing: What Do These Terms Mean and How Will They Impact Health Care?, *The Journal of Arthroplasty*, 33(8), 2358-2361.

BJØRN, A., LLOYD, S., MATTHEWS, D. (2021), From the Paris Agreement to Corporate Climate Commitments: Evaluation of Seven Methods for Setting 'Science-Based' Emission Targets, *Environmental Research Letters*, 16(5), 054019.

BLENKHORN, D. L., MACKENZIE, H. H. (2017), Categorising Corporate Social Responsibility (CSR) Initiatives in B2B Markets: The Why, When and How, *Journal of Business Industrial Marketing*, 32(8), 1172-1181.

BOGERS, M., CHESBROUGH, H., HEATON, S., TEECE, D. J. (2019), Strategic Management of Open Innovation: A Dynamic Capabilities Perspective, *California Management Review*, 62(1), 77-94.

BREM, A., GIONES, F., WERLE, M. (2021), The AI Digital Revolution in Innovation: A Conceptual Framework of Artificial Intelligence Technologies for the Management of Innovation, *IEEE Transactions on Engineering Management*.

BRESCIANI, S., FERRARIS, A., ROMANO, M., SANTORO, G. (2021), Human Resource Management and Digitalisation, in Bresciani, S., Ferraris, A., Romano, M., Santoro, G. (eds), *Digital Transformation Management for Agile Organisations: A Compass to Sail the Digital World*, Emerald Publishing Limited, 117-138.

BRESCIANI, S., HUARNG, K. H., MALHOTRA, A., FERRARIS, A. (2021), Digital Transformation as A Springboard for Product, Process and Business Model Innovation, *Journal of Business Research*, 128, 204-210.

BUTT, I., IQBAL, T., ZOHAIB, S. (2019), Healthcare Marketing: A Review of the Literature Based on Citation Analysis, *Health Marketing Quarterly*, 36(4), 271-290.

CALABRESE, A., COSTA, R., TIBURZI, L., BREM, A. (2023), Merging Two Revolutions: A Human-artificial Intelligence Method to Study How Sustainability and Industry 4.0 Are Intertwined, *Technological Forecasting and Social Change*, 188, 122265.

CARLSON, A., SAKAO, T. (2020), Environmental Assessment of Consequences from Predictive Maintenance with Artificial Intelligence Techniques: Importance of the System Boundary, *Procedia CIRP*, 90, 171-175.

CEZARINO, L. O., ALVES, M. F. R., CALDANA, A. C. F., LIBONI, L. B. (2019), Dynamic Capabilities for Sustainability: Revealing the Systemic Key Factors, *Systemic Practice and Action Research*, 32(1), 93-112.

CHAKRAVORTY, T., JHA, K., BARTHWAL, S., CHAKRABORTY, S. (2020), Digital Technologies as Antecedents to Process Integration and Dynamic Capabilities in Healthcare: An Empirical Investigation, *Journal of International Technology and Information Management*, 28(4), 84-111.

CHUNG, G. K. K., STRONG, C., CHAN, Y. H., CHUNG, R. Y. N., CHEN, J. S., LIN, Y. H., KO, N. Y. (2022), Psychological Distress and Protective Behaviors During the COVID-19 Pandemic Among Different Populations: Hong Kong General Population, Taiwan Healthcare Workers, and Taiwan Outpatients, *Frontiers in Medicine*, 9, 800962.

CINGOLANI, M., SCENDONI, R., FEDELI, P., CEMBRANI, F., (2023), Artificial Intelligence and Digital Medicine for Integrated Home Care Services in Italy: Opportunities and Limits, *Front Public Health*, 10, 1095001.

COPELAND, B. J. (2024, *Artificial Intelligence*. Retrieved from: www.britannica.com/technology/artificialintelligence

COURTLAND, R. (2018), Bias Detectives: The Researchers Striving to Make Algorithms Fair, *Nature*, 558, 357-360.

DHAR, P. (2020), The Carbon Impact of Artificial Intelligence, *Nature Machine Intelligence*, 2(8), 423-425.

DI VAIO, A., PALLADINO, R., HASSAN, R., ESCOBAR, O. (2020), Artificial Intelligence and Business Models in the Sustainable Development Goals Perspective: A Systematic Literature Review, *Journal of Business Research*, 121, 283-314.

EIKELENBOOM, M., DE JONG, G. (2019), The Impact of Dynamic Capabilities on the Sustainability Performance of SMEs, *Journal of Cleaner Production*, 235, 1360-1370.

ELKINGTON, J. (1994), Towards the Sustainable Corporation: Win-Win-Win Business Strategies for Sustainable Development, *California Management Review*, 36(2), 90-100.

ELKINGTON, J. (1997), Cannibals with Forks: The Triple Bottom Line of 21st Century Business, *Alternatives Journal*, 25(4), 42.

ELMQVIST, T., ANDERSSON, E., FRANTZESKAKI, N., MCPHEARSON, T., OLSSON, P., GAFFNEY, O., TAKEUCHI, C., FOLKE, C. (2019), Sustainability and Resilience for Transformation in the Urban Century, *Nature Sustainability*, 2(4), 267-273.

ESCOBAR, O., LEONE, D., MALAFRONTE, P., MELE, S. (2021), The Effect of Telemedicine on Patients' Wellbeing: A Systematic Review, *Journal of Innovation Economics & Management*, 35, 9-31.

FERRAS-HERNANDEZ, X., NYLUND, P. A., BREM, A. (2022), Strategy Follows the Structure of Artificial Intelligence, *IEEE Engineering Management Review*, 50(3), 17-19.

FERRO, C., PADIN, C., HØGEVOLD, N., SVENSSON, G., VARELA, J. C. S. (2019), Validating and Expanding A Framework of a Triple Bottom Line Dominant Logic for Business Sustainability through Time and Across Contexts, *Journal of Business Industrial Marketing*, 34(1), 95-116.

FLETCHER, G., GRIFFITHS, M. (2020), Digital Transformation during a Lockdown, *International Journal of Information Management*, 55, 102185.

FREITAS, H., OLIVEIRA, M., JENKINS, M., POPJOY, O. (1998), The Focus Group, A Qualitative Research Method, *Journal of Education*, 1(1), 1-22.

FREY, C. B., OSBORNE, M. A. (2017), The Future of Employment: How Susceptible are Jobs to Computerisation?, *Technological Forecasting and Social Change*, 114, 254-280.

FROW, P., MCCOLL-KENNEDY, J. R., PAYNE, A. (2016), Co-creation Practices: Their Role in Shaping A Health Care Ecosystem, *Industrial Marketing Management*, 56, 24-39.

GARBUIO, M., LIN, N. (2018), Artificial Intelligence as a Growth Engine for Health Care Startups: Emerging Business Models, *California Management Review*, 61, 59-83.

GHOBAKHLOO, M., IRANMANESH, M., VILKAS, M., GRYBAUSKAS, A., AMRAN, A. (2022), Drivers and Barriers of Industry 4.0 Technology Adoption among Manufacturing SMEs: A Systematic Review and Transformation Roadmap, *Journal of Manufacturing Technology Management*, 33(6), 1029-1058.

GOVINDAN, K. (2022), How Artificial Intelligence Drives Sustainable Frugal Innovation: A Multitheoretical Perspective, *IEEE Transactions on Engineering Management*, 71, 638-655.

GRENIER, C., PAUGET, B., HUDEBINE, H. (2019), Innovations in Healthcare and Wellbeing: A Focus on Actors and Collaborations at the Boundaries, *Journal of Innovation Economics & Management*, 30(3), 1-15.

GUPTA, S., LANGHANS, S. D., DOMISCH, S., FUSO-NERINI, F., FELLÄNDER, A., BATTAGLINI, M., TEGMARK, M., VINUESA, R. (2021), Assessing Whether Artificial Intelligence is an Enabler or an Inhibitor of Sustainability at Indicator Level, *Transport Engineering*, 4, 100064.

HAENLEIN, M., KAPLAN, A. (2019), A Brief History of Artificial Intelligence: On the Past, Present, and Future of Artificial Intelligence, *California Management Review*, 61(4), 5-14.

HANAYSHA, J. R., AL-SHAIKH, M. E., JOGHEE, S., ALZOUBI, H. M. (2022), Impact of Innovation Capabilities on Business Sustainability in Small and Medium Enterprises, *FIIB Business Review*, 11(1), 67-78.

HEART, T., BEN-ASSULI, O., SHABTAI, I. (2017), A Review of PHR, EMR and EHR Integration: A More Personalised Healthcare and Public Health Policy, *Health Policy and Technology*, 6(1), 20-25.

HELM, J. M., SWIERGOSZ, A. M., HAEBERLE, H. S., KARNUTA, J. M., SCHAFFER, J. L. (2020). Machine Learning and Artificial Intelligence: Definitions, Applications, and Future Directions, *Current Reviews in Musculoskeletal Medicine*, 13, 69-76.

HERBAS TORRICO, B., FRANK, B., TAVERA, C. A., (2018), Corporate Social Responsibility in Bolivia: Meanings and Consequences, *International Journal of Corporate Social Responsibility*, 3(7), 1-13.

ILAN, Y. (2021), Improving Global Healthcare and Reducing Costs Using Second-Generation Artificial Intelligence-based Digital Pills: A Market Disruptor, *International Journal of Environmental Research and Public Health*, 18(2), 811.

INIGO, E. A., ALBAREDA, L. (2019), Sustainability Oriented Innovation Dynamics: Levels of Dynamic Capabilities and their Path-dependent and Self-reinforcing Logics, *Technological Forecasting and Social Change*, 139, 334-351.

JIANG, L., WU, Z., XU, X., ZHAN, Y., JIN, X., WANG, L., QIU, Y. (2021), Opportunities and Challenges of Artificial Intelligence in the Medical Field: Current Application, Emerging Problems, and Problem-solving Strategies, *Journal of International Medical Research*, 49(3), 03000605211000157.

KANDEL, N., CHUNGONG, S., OMAAR, A., XING, J. (2020), Health Security Capacities in the Context of COVID-19 Outbreak: An Analysis of International Health Regulations Annual Report Data from 182 Countries, *The Lancet*, 395(10229), 1047-1053.

KATSALIAKI, K., KUMAR, S. (2022), The Past, Present and Future of the Healthcare Delivery System through Digitalization, *IEEE Engineering Management Review*, 50(4), 21-33.

KHAN, O., BADHIWALA, J. H., GRASSO, G., FEHLINGS, M. G. (2020), Use of Machine Learning and Artificial Intelligence to Drive Personalised Medicine Approaches for Spine Care, *World Neurosurgery*, 140, 512-518.

KRAUS, S., SCHIAVONE, F., PLUZHNIKOVA, A., INVERNIZZI, A. C. (2021), Digital Transformation in Healthcare: Analysing the Current State-of-research, *Journal of Business Research*, 123, 557-567.

KUMAR, Y., GUPTA, S., SINGLA, R., HU, Y. C. (2022), A Systematic Review of Artificial Intelligence Techniques in Cancer Prediction and Diagnosis, *Archives of Computational Methods in Engineering*, 29(4), 2043-2070.

LEAL FILHO, W., WALL, T., MUCOVA, S. A. R., NAGY, G. J., BALOGUN, A. L., LUETZ, J. M., ARTIE, W. NG., KOVALEVA, M., AZAM, F. M., S., ALVES, F., GUEVARA, Z., MATANDIROTYA, N. R., SKOULOUDIS, A., TZACHOR, A., MALAKAR, K., GANDHI, O. (2022), Deploying Artificial Intelligence for Climate Change Adaptation, *Technological Forecasting and Social Change*, 180, 121662.

LENZEN, M., MALIK, A., LI, M., FRY, J., WEISZ, H., PICHLER, P., CHAVES, L. S. M., CAPON, A. G., PENCHEON, D. (2020), The Environmental Footprint of Health Care: A Global Assessment, *The Lancet Planetary Health*, 4(7), e271-e279.

LEONE, D., SCHIAVONE, F., APPIO, F. P., CHIAO, B. (2021), How Does Artificial Intelligence Enable and Enhance Value Co-creation in Industrial Markets? An Exploratory Case Study in the Healthcare Ecosystem, *Journal of Business Research*, 129, 849-859.

LINDEBAUM, D., VESA, M., DEN HOND, F. (2020), Insights from "The Machine Stops" to Better Understand Rational Assumptions in Algorithmic Decision Making and its Implications for Organisations, *Academy of Management Review*, 45(1), 247-263.

LOUREIRO, R., FERREIRA, J. J., SIMÕES, J. (2021), Understanding Healthcare Sector Organisations from A Dynamic Capabilities Perspective, *European Journal of Innovation Management*, 26(2), 588-614.

MALHOTRA, C., HAZIRAH, M., TAN, L. L., MALHOTRA, R., YAP, P., BALASUNDARAM, B., … PISCES STUDY GROUP (2021), Family Caregiver Perspectives on Suffering of Persons with Severe Dementia: A Qualitative Study, *Journal of Pain and Symptom Management*, 62(1), 20-27.

MARTÍNEZ, P., DEL BOSQUE, I. R. (2013), CSR and Customer Loyalty: The Roles of Trust, Customer Identification with the Company and Satisfaction, *International Journal of Hospitality Management*, 35, 89-99.

MARTINS, S. M., FERREIRA, F. A., FERREIRA, J. J., MARQUES, C. S. (2020), An Artificial-intelligence-based Method for Assessing Service Quality: Insights from the Prosthodontics Sector, *Journal of Service Management*, 31(2), 291-312.

MCARTHUR, J. W., RASMUSSEN, K. (2018), Change of Pace: Accelerations and Advances during the Millennium Development Goal Era, *World Development*, 105, 132-143.

MIKALEF, P., GUPTA, M. (2021), Artificial Intelligence Capability: Conceptualisation, Measurement Calibration, and Empirical Study on its Impact on Organisational Creativity and Firm Performance, *Information & Management*, 58(3), 103434.

MORETTO, A., MACCHION, L., LION, A., CANIATO, F., DANESE, P., VINELLI, A. (2018), Designing a Roadmap Towards a Sustainable Supply Chain: A Focus on the Fashion Industry, *Journal of Cleaner Production*, 193, 169-184.

MORGAN, D. L. (1988), *Focus Group as Qualitative Research*, Newbury Park, CA, Sage Publications Inc.

NASIR, O., JAVED, R. T., GUPTA, S., VINUESA, R., QADIR, J. (2022), Artificial Intelligence and Sustainable Development Goals Nexus Via Four Vantage Points, *Technology in Society*, 72, 102171.

NISHANT, R., KENNEDY, M., CORBETT, J. (2020), Artificial Intelligence for Sustainability: Challenges, Opportunities, and a Research Agenda, *International Journal of Information Management*, 53, 102104.

OBERMEYER, Z., TOPOL, E. J. (2021), Artificial Intelligence, Bias, and Patients' Perspectives, *The Lancet*, 397(10289), 2038.

OLAN, F., ARAKPOGUN, E. O., SUKLAN, J., NAKPODIA, F., DAMIJ, N., JAYAWICKRAMA, U. (2022), Artificial Intelligence and Knowledge Sharing: Contributing Factors to Organizational Performance, *Journal of Business Research*, 145, 605-615.

OLAWUMI, T. O., CHAN, D. W. M. (2018), A Scientometric Review of Global Research on Sustainability and Sustainable Development, *Journal of Cleaner Production*, 183, 231-250.

PAPA, A., DEZI, L., GREGORI, G. L., MUELLER, J., MIGLIETTA, N. (2020), Improving Innovation Performance through Knowledge Acquisition: The Moderating Role of Employee Retention and Human Resource Management Practices, *Journal of Knowledge Management*, 24(3), 589-605.

PIETRONUDO, M. C., CROIDIEU, G., SCHIAVONE, F. (2022), A Solution Looking for Problems? A Systematic Literature Review of the Rationalizing Influence of Artificial Intelligence on Decision-making in Innovation Management, *Technological Forecasting and Social Change*, 182, 121828.

PROJECT FINDER, AISDG, https://www.aiforsdgs.org/all-projects.

PUNDZIENE, A., GUTMANN, T., SCHLICHTNER, M., TEECE, D. J. (2022), Value Impedance and Dynamic Capabilities: The Case of Medtech Incumbent-born Digital Healthcare Platforms, *California Management Review*, 64(4), 108-134.

RANA, N. P., CHATTERJEE, S., DWIVEDI, Y. K., AKTER, S. (2022), Understanding the Dark Side of Artificial Intelligence (AI) Integrated Business Analytics: Assessing Firm's Operational Inefficiency and Competitiveness, *European Journal of Information Systems*, 31(3), 364-387.

RIALTI, R., MARZI, G., CIAPPEI, C., BUSSO, D. (2019), Big Data and Dynamic Capabilities: A Bibliometric Analysis and Systematic Literature Review, *Management Decision*, 57(8), 2052-2068.

RICHIE, C. (2022), Environmentally Sustainable Development and Use of Artificial Intelligence in Health Care, *Bioethics*, 36(5), 547-555.

SACHS, J. D., SCHMIDT-TRAUB, G., MAZZUCATO, M., MESSNER, D., NAKICENOVIC, N., ROCKSTRÖM, J. (2019), Six Transformations to Achieve the Sustainable Development Goals, *Nature Sustainability*, 2(9), 805-814.

SANTORO, G., VRONTIS, D., THRASSOU, A., DEZI, L. (2018), The Internet of Things: Building a Knowledge Management System for Open Innovation and Knowledge Management Capacity, *Technological Forecasting and Social Change*, 136, 347-354.

SANTOSH, K. C., GAUR, L. (2022). *Artificial Intelligence and Machine Learning in Public Healthcare: Opportunities and Societal Impact*, Springer Nature.

SAUNDERS, M., LEWIS, P., THORNHILL, A. (2009), *Research Methods for Business Students*, Pearson education.

SCHIAVONE, F., FESTA, G. (2021), Innovative Paradigms for Enhancing Healthcare Service Performance, *Journal of Innovation Economics & Management*, 35(2), 1-7.

SCHIAVONE, F., LEONE, D., CAPORUSCIO, A., KUMAR, A. (2022), Revealing the Role of Intellectual Capital in Digitalised Health Networks: A Meso-level Analysis for Building and Monitoring A KPI Dashboard, *Technological Forecasting and Social Change*, 175, 121325.

SCHIAVONE, F., MANCINI, D., LEONE, D., LAVORATO, D. (2021), Digital Business Models and Ridesharing for Value Co-creation in Healthcare: A Multi-stakeholder Ecosystem Analysis, *Technological Forecasting and Social Change*, 166, 120647.

SCHULZ, S. A., FLANIGAN, R. L. (2016), Developing Competitive Advantage Using the Triple Bottom Line: A Conceptual Framework, *Journal of Business Industrial Marketing*, 31(4), 449-458.

SECUNDO, G., SHAMS, S. R., NUCCI, F. (2021), Digital Technologies and Collective Intelligence for Healthcare Ecosystem: Optimising Internet of Things Adoption for Pandemic Management, *Journal of Business Research*, 131, 563-572.

SERMONTYTE-BANIULE, R., PUNDZIENE, A., GIMÉNEZ, V., NARBÓN-PERPIÑÁ, I. (2022), Role of Cultural Dimensions and Dynamic Capabilities in the Value-based Performance of Digital Healthcare Services, *Technological Forecasting and Social Change*, 176, 121490.

SHORTLIFFE, E. H., SEPÚLVEDA, M. J. (2018), Clinical Decision Support in the Era of Artificial Intelligence, *Jama*, 320(21), 2199-2200.

SPENA, T. R., MELE, C. (2019), Practising Innovation in the Healthcare Ecosystem: The Agency of Third-party Actors, *Journal of Business Industrial Marketing*, 35(3), 390-403.

STEINHAUSER, S., DOBLINGER, C., HÜSIG, S. (2020), The Relative Role of Digital Complementary Assets and Regulation in Discontinuous Telemedicine Innovation in European Hospitals, *Journal of Management Information Systems*, 37(4), 1155-1183.

SVENSSON, G., FERRO, C., HOGEVOLD, N., PADIN, C., SOSA VARELA, J. C. (2018), Developing a Theory of Focal Company Business Sustainability Efforts in Connection with Supply Chain Stakeholders, *Supply Chain Management: An International Journal*, 23(1), 16-32.

TEECE, D. J. (2019), A Capability Theory of the Company: An Economics and (Strategic) Management Perspective, *New Zealand Economic Papers*, 53(1), 1-43.

TEECE, D. J., PISANO, G., SHUEN, A. (1997), Dynamic Capabilities and Strategic Management, *Strategic Management Journal*, 18(7), 509-533.

TOPOL, E. J. (2019), High-performance Medicine: The Convergence of Human and Artificial Intelligence, *Nature Medicine*, 25(1), 44-56.

TSAGKARIS, C., HOIAN, A. V., AHMAD, S., ESSAR, M. Y., CAMPBELL, L. W., GROBUSCH, L., ... KALAITZIDIS, K. (2021), Using Telemedicine for a Lower Carbon Footprint in Healthcare: A Twofold Tale of Healing, *The Journal of Climate Change and Health*, 1, 100006.

TSENG, M. L., CHANG, C. H., LIN, C. W. R., WU, K. J., CHEN, Q., XIA, L., XUE, B. (2020), Future Trends and Guidance for the Triple Bottom Line and Sustainability:

A Data-driven Bibliometric Analysis, *Environmental Science and Pollution Research*, 27(27), 33543-33567.

UZUNIDIS, D. (2009), Innovation, Growth and Sustainable Development: General Presentation, *Journal of Innovation Economics & Management*, 3(1), 5-11.

VINUESA, R., AZIZPOUR, H., LEITE, I., BALAAM, M., DIGNUM, V., DOMISCH, S., FELLÄNDER, A., LANGHANS, S. D., TEGMARK, M., FUSO NERINI, F. (2020), The Role of Artificial Intelligence in Achieving the Sustainable Development Goals, *Nature Communications*, 11(1), 1-10.

WAMBA-TAGUIMDJE, S. L., FOSSO WAMBA, S., KALA KAMDJOUG, J. R., TCHATCHOUANG WANKO, C. E. (2020), Influence of Artificial Intelligence (AI) on Firm Performance: The Business Value of AI-based Transformation Projects, *Business Process Management Journal*, 26(7), 1893-1924.

WANG, Y., KUNG, L., BYRD, T. A. (2018), Big Data Analytics: Understanding its Capabilities and Potential Benefits for Healthcare Organisations, *Technological Forecasting and Social Change*, 126, 3-13.

WCED (1987), *Brundtland Report (Britannica)*, World Commission on Environment and Development. Retrieved from: https://www.britannica.com/topic/Brundtland-Report

WORLD HEALTH ORGANIZATION (2021), *Stronger Collaboration for an Equitable and Resilient Recovery towards the Health-related Sustainable Development Goals: 2021 Progress Report on the Global Action Plan for Healthy Lives and Well-being for All*. Available at: https://www.who.int/publications/i/item/9789240026209

YANG, Y., SIAU, K., XIE, W., SUN, Y. (2022), Smart Health: Intelligent Healthcare Systems in the Metaverse, Artificial Intelligence, and Data Science Era, *Journal of Organizational and End User Computing (JOEUC)*, 34(1), 1-14.

YIGITCANLAR, T., CUGURULLO, F. (2020), The Sustainability of Artificial Intelligence: An Urbanistic Viewpoint from the Lens of Smart and Sustainable Cities, *Sustainability*, 12(20), 8548.

YIN, R. K. (2003), *Case Study Research: Design and Methods*, Applied Social Research Methods, 5.

YU, K. H., BEAM, A. L., KOHANE, I. S. (2018), Artificial Intelligence in Healthcare, *Nature Biomedical Engineering*, 2(10), 719-731.

ZOLLO, M., BETTINAZZI, E. L., NEUMANN, K., SNOEREN, P. (2016), Toward a Comprehensive Model of Organizational Evolution: Dynamic Capabilities for Innovation and Adaptation of the Enterprise Model, *Global Strategy Journal*, 6(3), 225-244.

Appendix

Main themes	**Themes**	**Sub Themes**
AI and Sustainability Definition	Not so easy to define	Machine Learning – Neural Network – Big Data – Sustainability as green transition – Sustainability at 360
	Different definition	Different AI systems – Different Sustainability themes – AI as Discipline or as capability
Planet Sustainability	Macro and Micro level	CPU – Device – Micro components – Rare Lands
	Resource Management	Reduce Waste – Well management of structures – Reduce
	Define new KPI	Benchmark – Define New KPI – Measure – Monitor – Control
People Sustainability	Workflow	More time – Less repetitive task – More simple procedure
	Acceptance	Cultural issue – Capabilities (Digital and data literacy) – Training
	Support to decision making	New relation: Doctor – AI – Patient – Medical and Huma mistakes – New empathic and social capabilities
	Patient Care	Prevention - Diagnosis – Monitoring
Profit Sustainability	Operational – Process	Settings – Capabilities – Cost and time effective
	Systematise	Investment – Project – Settings Avoid the risk to know only one AI solution
	Competition	Oligopoly – Less barriers to entry
	Stakeholders	Involvement – Collaboration