

How is Innovation Changing Healthcare Supply Chains? – Review of Innovation Models and Their Impact

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Abstract: Innovation and Artificial Intelligence (AI) technologies frequently appear together in discussions, as AI is considered a tool for driving innovation. While many sectors pursue innovation primarily for competitive advantages, the healthcare sector embraces it from an ethical perspective. The commitment to innovation in healthcare is not just about competition; it's fundamentally about improving quality of life, effectively curing patients, and introducing new medications to the market. The prevalence of AI-driven applications is increasing within the Healthcare sector. In this systematic literature review, we explore various innovation models employed and examine how these relate to AI solutions in the healthcare sector. Additionally, we offer a comprehensive overview of the theoretical foundations behind these models and their practical significance and utility within healthcare supply chain context.

Keywords: Innovation model, Healthcare Supply Chain, Health care, Artificial Intelligence, Literature review

1 Introduction

Supply chain responsiveness and innovation are indisputably essential to build a resilient Healthcare Supply Chain (HSC) to fight unexpected challenges when the demand uncertainties are extremely high [1]. The increasing number of patients, population growth, increasing prevalence of chronic diseases and rising healthcare costs are not only significant challenges for healthcare systems but also motivating key factors to boost innovation [2].

The healthcare industry continuously prioritizes the development of innovative medicines and treatments to enhance human life quality and longevity. However, the development of these innovations alone is not sufficient; ensuring their accessibility to the end-user is critical, with Healthcare Supply Chain (HSC) playing a crucial role [3]. This underscores the importance of managing Healthcare Supply Chains, as medical and pharmaceutical equipment can be vital for human lives.

So our research question is: What role does AI play in driving innovation within healthcare supply chains, and how does it contribute to improving overall healthcare delivery and patient outcomes?

To answer our question, we used a systematic literature review to examine the current and future role of AI in Healthcare Supply Chains.

2 Review of the relevant literature

The authors decided to use a systematic approach to provide a clear and comprehensive overview of the available literature in this field. The selection of papers was finalized using the Scopus database, chosen for its extensive coverage and advanced search features. The selected papers, dated from 2020 to 2024, were all written in English and covered the following subject areas: Business, Management and Accounting, Engineering, Computer Science, Medicine, Decision Sciences, Environmental Sciences, Social Sciences.

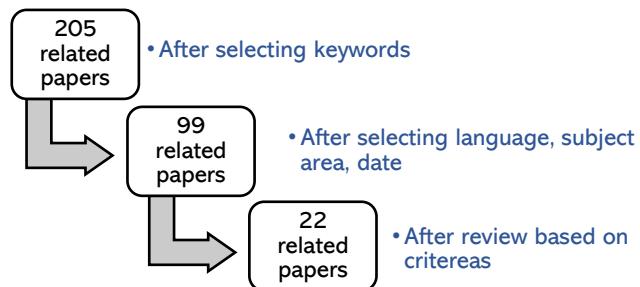


Fig. 1.
Systematic literature review steps

Keywords and why: The keywords of this study included: (TITLE-ABS-KEY ("innovation") OR TITLE-ABS-KEY ("innovative") AND TITLE-ABS-KEY ("Healthcare supply chain") OR TITLE-ABS-KEY ("Health care supply chain").

The authors reviewed the articles and selected those that met the following criteria:

- Articles introducing new technological tools in healthcare supply chains, whether evaluated or not.

- Any articles examining AI technologies in healthcare and healthcare supply chains.
- Any paper pertinent to any research methods such as empirical, case study, modelling, or analytical.

Based on the exclusion criteria, we excluded all articles that did not affect the health sector, and those that did not focus on innovative solutions in the healthcare sector (the latter could include new technology or AI introduction). Finally, we recognized 22 relevant papers in Scopus database. The relatively fewer research articles on AI in Healthcare in Europe compared to other regions like Asia or North America can be explained by various reasons including regulatory challenges, funding issues, data privacy concerns. More investigations are needed within Europe to obtain a more relevant picture of the potential innovation opportunities and enchain our understanding of the dynamic landscape of this region.

3 Innovation and exploring some innovation models

The standard ISO 56000:2020 defines innovation as "a new or changed entity realizing or redistributing value". But nowadays we talk about business model innovation [4], or business relationships/networks can also be a source of innovation [5]. And innovative business networks pose specific challenges for the actors [6]. The innovation must bring economic and financial results, since innovation means a new, higher quality way of satisfying consumer needs. Innovation is usually classified into three groups: incremental (means constant progress, continuous improvement, e.g. the company is wants to get the most out of its existing products and services without, without making significant changes or investing large amounts of money), radical (is the result of a non-continuous development and brings radical change to the market and/or the industry), and disruptive (is replacing old products, "disrupting" the market, this innovation may even lead to a new market). AI clearly falls into this last category [7].

3.1 Healthcare Supply Chain (HSC)

The supply chain process plays an essential role in facilitating healthcare services. It is a crucial factor to ensure the delivery of services and goods to the ultimate recipient - the patient. The HSC stands apart from others; unlike many other sectors, where innovation is driven mainly by competitive reasons, the healthcare industry embraces innovation more from an ethical perspective. To ensure a more resilient HSC, healthcare supply chains should receive more operational support through diverse software applications, facilitating both data processing and data making processes. AI technologies can potentially help to make HSCs more resilient to disruptions like the worldwide pandemic in 2019. [8][9][10]

Under the current model of value-based care, health systems are required to improve patient outcomes while reducing costs [11]. Specifically, in the healthcare industry, managing the supply chain is indispensable. Given that the products within the HSC have critical relevance as they are directly linked to the well-being of patients, the timely and accurate delivery of healthcare products is crucial for patient care and outcomes [12]. The general purpose of Supply Chains is to ensure the right product in the right quantity is available at the right place at the right times. The healthcare supply chain is more complex due to its diverse and specialized products, such as pharmaceuticals and medical devices, which might require special handling and storage. [13] The HSC operates within an extremely regulated framework to ensure the safety of patients, as well as efficacy and quality of the healthcare products. It encompasses the movement of various product types and involves multiple stakeholders. Its primary objective is to ensure the timely delivery of products to meet the demands of healthcare providers. The most important business stakeholders in the HSC are categorized into three principal groups based on their roles: producers, purchasers, and providers [14].

Unquestionably, the final element of the supply chain is the patient, but we have enumerated the other elements that appear along the product or service's journey. So, there are many members in the HSC. The first is the manufacturer; the availability of medicines and healthcare products depends on them. The second members are the distributors, including wholesale distributors, logistic partners, and third-party logistics. Their key role is to obtain the products from the manufacturing facilities and focus on delivering the goods to the providers. The providers receive the medicines and products from the distributors and their role is to deliver these various healthcare products to the end-users - the patients. [15] The management of the healthcare supply chain presents challenges, particularly as healthcare systems are more complex and unpredictable. Uncertainty and risks are inherent in every stage of the healthcare decision-making process. Inefficiencies in managing the HSCs can lead to adverse effects on the overall healthcare system. [16] [17]

4 Importance of innovation models (based on selected papers)

In the following discussion, we aim to highlight the importance of defining the innovation model. In the absence of a clearly defined innovation model and strategy, alongside a defined characterization of the necessary innovation portfolio, employees may encounter challenges in executing tasks effectively [18]. In Table 1 we have compiled all pertinent innovation models and innovation related theories utilized in the reviewed articles.

Innovation models and theories	The rationale behind their use	Authors
SIAP model	Examine relations between BDA, SCI, RSC, and SCR. According to the SIAP model, the firms adjust in the business environment by following 3 theoretical basic steps, which are: scanning, interpreting, and responding.	[1] Bag et al.
Adoption of AI in the Healthcare Industry Model	Contextualizes the factors influencing adoption of AI in the healthcare industry.	[2] Roppelt et al.
Service innovation model	Customer is considered as a source of innovation. Innovation concept: innovation as process.	[5] Hara et al.
Disruptive innovation	The specialized literature uses disruptive innovation as a synonym for disruptive technology, and it refers to the disruptive effects of new technologies within a domain. The most common disruptive technologies were examined in the article's database n=97.	[7] Pävälöaia et al.
Technological innovation	The most prominent technological innovations in the healthcare supply chain were identified in this SLR.	[10] Arji et al.
A business model of innovation	The model used in the paper presents a useful approach to describe the relationships behind an innovation model and creates a framework (Input, Process, Output, and Outcome) to describe innovation at the business unit level.	[18] Davila et al.
Technology Innovation model	The technology innovation model emphasizes radical innovation driven by a company's technology group, and this article reflects on the importance of keeping these people focused and motivated.	[18] Davila et al.
Disruptive innovation	Disruptive innovation is a broader term that addresses both technology and business model changes. Disruptive innovations include technology-driven innovation.	[18] Davila et al.
Technological innovation	R&D in HCSC will lead to innovation and improved decision support systems. Implementing big data and predictive analytics (HCSCI&T 2) Implementing big data analytics is needed to optimize HCSC activities through forecasting and decision-making.	[19] Hossain et al.
Sustainable Oriented Innovation (SOI)	This research aim is to propose a sustainability-oriented innovation (SOI)-driven assessment guide and decision-making framework for health care managers to enhance sustainability.	[30] Elabed et al.

Table 1
Innovation models and theories used in the reviewed papers

Upon examination of the table, it became apparent that the predominant findings revolve around "technology innovation" and "technological innovation". This trend is not coincidental, as it can largely be attributed to the widespread and rapidly growing adoption of AI. The wording "technological innovation" and "technology innovation" are often used interchangeably, but they may represent distinct nuances in certain contexts. In the reviewed literature, both "technological innovation" and "technology innovation" were employed within the same contextual framework. To ensure clarity we summarize as follows: introduction or advancement of novel technologies, processes, and resulting notable enhancements in products, services, or systems [10][18][19].

Technological innovation, within the realm of information system theory, examines how users adopt and use technology. According to this model, various factors shape users' decisions regarding the adoption and timing of new technologies. A series of studies on technological innovation has laid the groundwork for disruptive innovation, as elucidated by Christensen and other co-authors. [20][21] AI and technological innovation are closely linked, as they symbiotically advance together. AI technology can enable new possibilities in various technological domains, and vice versa. This synergy between AI and technological innovation contributes significantly to the rapid evolution and adoption of cutting-edge technologies. [22] How AI stimulates technological innovation? Based on reviewed papers we see that AI fosters technological innovation via three primary mechanisms:

1. accelerates knowledge creation and creates technology spillover,
2. enhancing firms' abilities to learn and integrate new advancements,
3. increasing investments in research and development as well as nurturing human talent.

While the significance of AI is widely acknowledged and its usage is growing, scholarly research examining its influence on technological innovation is still rare. A cursory review of existing literature reveals that studies investigating the impact of AI on technological innovation are still in their early stages, primarily concentrating on defining these concepts. [23] The research conducted by Davila (2006) underscores the significance of both business model innovation and technology innovation for successful innovation outcomes. It suggests that companies need to understand and prioritize both types of innovation to achieve industry-changing advancements.

5 AI and HSC based on systemized literature review

5.1 AI's current involvement in Healthcare

AI has been present in healthcare for a long time, continuously and increasingly. AI technologies are able to diagnose diseases, create personalized treatment strategies, and aid clinicians in decision-making. The primary goal is to advance these AI technologies that can elevate patient care. In the following figure, we have listed the main healthcare areas where AI-based technologies are present and most commonly used.

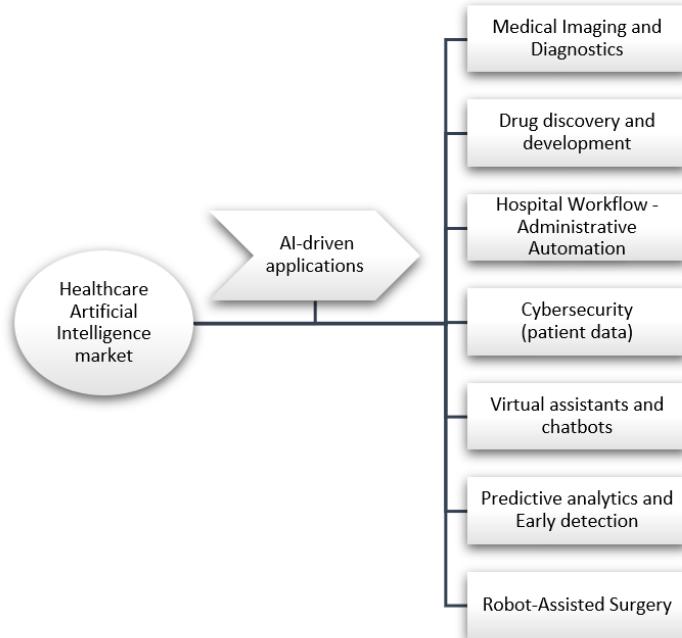


Fig. 2.
Artificial Intelligence in Healthcare Market by Application Area based on literature [24][25]

Based on [24, 25] we have listed the distribution of AI-based application areas in Healthcare market on Figure 2. Many articles attempt to quantify how they are distributed in terms of proportion, for instance, on websites like Statista.com. Estimated forecasts can be found, for example, on the Statista.com website.

Conclusions

Concerning the future directions of AI in HSC, the Healthcare Supply Chain stands as a crucial operation, necessitating high levels of integrity, agility, resilience, and cost-efficiency. Traditional supply chains fall short in addressing contemporary challenges such as counterfeiting, geopolitical tensions, disruptions caused by global health crises, and the scarcity of skilled personnel essential for delivering products and services to end-users [26][27]. Emerging technologies like AI, Deep Learning, Human-Machine Interface, Machine Learning, block chain, robotics, cloud computing, Big Data Analytics, Digital Twins, Industry 4.0, IoT, and control towers are pivotal in developing end-to-end intelligent, integrated and data-driven supply chains [28].

Implementing innovations associated with logistics and supply chain management activities could assist the health-care industry in deriving effective agile lean practices. This could reduce annual costs, improve the quality of care, and limit treatment cycle time [29][30][31]. Based on the 22 papers from the systematic literature review, we have identified the most important trends expected to reshape the future of Healthcare Supply Chains:

1. Lessons learned from the COVID-19 pandemic highlight the need for resilience, including contingency planning and disruption management. Enhanced resilience is crucial for optimizing performance, reducing disruptions, and staying competitive [32][33][34].

2. Increased integration of AI technologies will enhance efficiency, traceability, and transparency in chain management. For instance, Block chain technology improves security and transparency, ensuring accountability in healthcare and supply chains [35][36].
3. Automation, driven by AI, reduces errors, releases manual tasks, and promotes smoother collaboration among chain members. Industry 4.0, built on IoT, cloud computing, and big data analytics, streamlines value chain optimization and supply chain efficiency [37].
4. Predictive analysis using historical and big data aids in forecasting medical supply demand, reducing shortages, and improving patient care. However, risks associated with AI applications require careful consideration [38][39].
5. Ensuring high-quality care involves timely delivery and enhanced patient care. AI applications in the US continue to rise, surpassing 500 approvals in patient care by 2023 [39].

Integrating innovative solutions, especially AI-powered ones, can transform and empower Supply Chains. The Healthcare sector must capitalize on innovative opportunities to enhance its development and efficiency, as people's lives and quality of life depends on it. One of the biggest challenges will be the integration of these new, innovative technologies and the accelerated adoption of telemedicine.

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