Toward Medical Services Quality Improvement through Industry 4.0 in Healthcare

Aurora PREDA[1]
Marcela PĂCURARU[2]
Ştefan TIRITEU[3]
Ciprian Sorin CHIRVASE[4]
Ştefănuţ BUHUS[5]
Andreea ZAMFIR[6]
Elena-Oana CROITORU[7]

DOI: 10.24818/mer/2024.02-14

ABSTRACT

This study aims to reveal how Industry 4.0 and its technologies can be used in medicine in order to improve the quality of the medical act in the healthcare sector. Industry 4.0 represents a significant technological revolution characterised by interconnectivity, automation, machine learning, and real-time data transfer, effectively merging physical operations and production with advanced digital technology. This revolution underpins the integration of cyber-physical systems, cloud computing, the Internet of Things (IoT), artificial intelligence (AI), and other cutting-edge technologies within the industrial production environment. Due to its vast scope and profound impact, Industry 4.0 is evolving at an exponential rate. These digital transformations are also profoundly affecting the healthcare sector, transitioning traditional systems into intelligent systems with the goal of enhancing the quality of medical services. The significance of Industry 4.0 in healthcare can be observed in the improved interaction between providers and patients, the enhanced performance of medical teams, and the increased promptness and efficiency in delivering medical services while achieving desired outcomes at reduced costs. Additionally, it ensures the continuity and safety of medical care. Industry 4.0 is crucial for the healthcare system as it supports the essential quality attributes that underpin the delivery of medical services. It enhances accessibility, effectiveness, and efficiency, promotes professional competence, facilitates interpersonal relationships, ensures continuity and safety of care, and contributes to the development of innovative medical solutions. The adoption of these technologies is vital for establishing a modern, patient-centred healthcare system.

KEYWORDS: *Industry 4.0, digitalisation, healthcare, artificial intelligence.*

JEL CLASSIFICATION: *L86, I10, O33.*

[1] Bucharest University of Economic Studies, Bucharest, Romania, preda_auro@yahoo.com Corresponding author
[2] Bucharest University of Economic Studies, Bucharest, Romania, marcela@pacuraru.com
[3] Bucharest University of Economic Studies, Bucharest, Romania, tiriteu@yahoo.com
[4] Bucharest University of Economic Studies, Bucharest, Romania, sorin.cchirvase@icloud.com
[5] Bucharest University of Economic Studies, Bucharest, Romania, buhus.stefanut@gmail.com
[6] Bucharest University of Economic Studies, Bucharest, Romani, andreea.zamfir@man.ase.ro
[7] Bucharest University of Economic Studies, Bucharest, Romani, elena.croitoru@man.ase.ro

1. INTRODUCTION

The history of industry and its associated technologies (Figure 1) is outlined as follows:

Industry 1.0 – Mechanisation: The invention and implementation of the steam engine marked the first industrial revolution, ushering in an era of industrialisation. This revolution occurred at the end of the 18th century and the beginning of the 19th century. In 1765, James Watt invented the first steam engine, significantly impacting the mechanisation of production processes. This period saw a gradual shift from an agriculture-based economy to one dominated by industry. The large-scale exploitation of coal and the steam engine's invention created a new energy source, leading to the development of railways and increased economic exchanges. Important advancements were also made in metallurgy, introducing new metalworking methods, which facilitated the creation of factories and the rise of the first industrial cities, where workers primarily focused on supervision and machine control.

Industry 2.0 – Electrification: The advent of electricity drove the second industrial revolution that occurred at the end of the 19th century. This revolution introduced a new energy source: electricity. This period saw the birth of the first internal combustion engines, the development of the steel processing industry, and new chemical synthesis methods, leading to the creation of synthetic fibres, paints, and fertilisers. Communication means were revolutionised with the invention of the telegraph and telephone. The early 20th century witnessed the emergence of cars and airplanes, factory electrification, mass production, assembly lines, and partial automation of production processes.

Industry 3.0 – Digitisation: The third industrial revolution was triggered by the increased efficiency of computers and data processing systems, which allowed machines to be controlled by software. This era began with the development of nuclear energy as a new power source. It progressed with the invention of the transistor, the microprocessor in 1970, and the expansion of the telecommunications and computer industries. New fields of research have emerged, particularly in space and biotechnology. This period marked the beginning of automated production processes, the introduction of industrial robots, computers, and numerical control systems, and significant advancements in electronics and industrial automation.

Industry 4.0 – System Integration and Networking: Industry 4.0 represents a technological revolution characterised by interconnectivity, automation, machine learning, and real-time data transfer, thereby integrating physical operations and production with advanced digital technology. Materials used or produced in this context are easily identifiable and capable of independent communication. This revolution is driven by the integration of cyber-physical systems, cloud computing, the Internet of Things (IoT), artificial intelligence (AI), and other advanced technologies within the industrial production environment. Due to its vast scope and profound impact, Industry 4.0 is evolving at an exponential rate, tracing its origins back to the early 21st century with the advent of the Internet. Unlike previous revolutions, it is not predicated on the discovery of a new form of energy, but on the latest technological phenomenon: digitisation. Artificial intelligence is now ubiquitous, manifesting in autonomous vehicles, drones, and virtual assistants. Technology has facilitated the creation of new products and services aimed at enhancing both personal and professional lives. This era emphasises human-machine collaboration and worker empowerment, where humans collaborate with advanced robots and AI to address complex problems. It focuses on human creativity, intuition, and innovation, while machines handle repetitive and routine tasks.

When considering developments such as AI, robotics, IoT, autonomous vehicles, 3D printing, augmented and virtual reality, wearables, and nanotechnology, it becomes evident that we are on the cusp of Industry 5.0 (European Commission, 2020). Industry 5.0 centres on the relationship between humans and machines, aiming to create a smarter world where both can collaborate harmoniously, maximising their respective capabilities. This phase is driven by the imperative to maintain humanity at the core of industrial activities, underscoring the value of human creativity and collaboration within the context of advanced manufacturing.

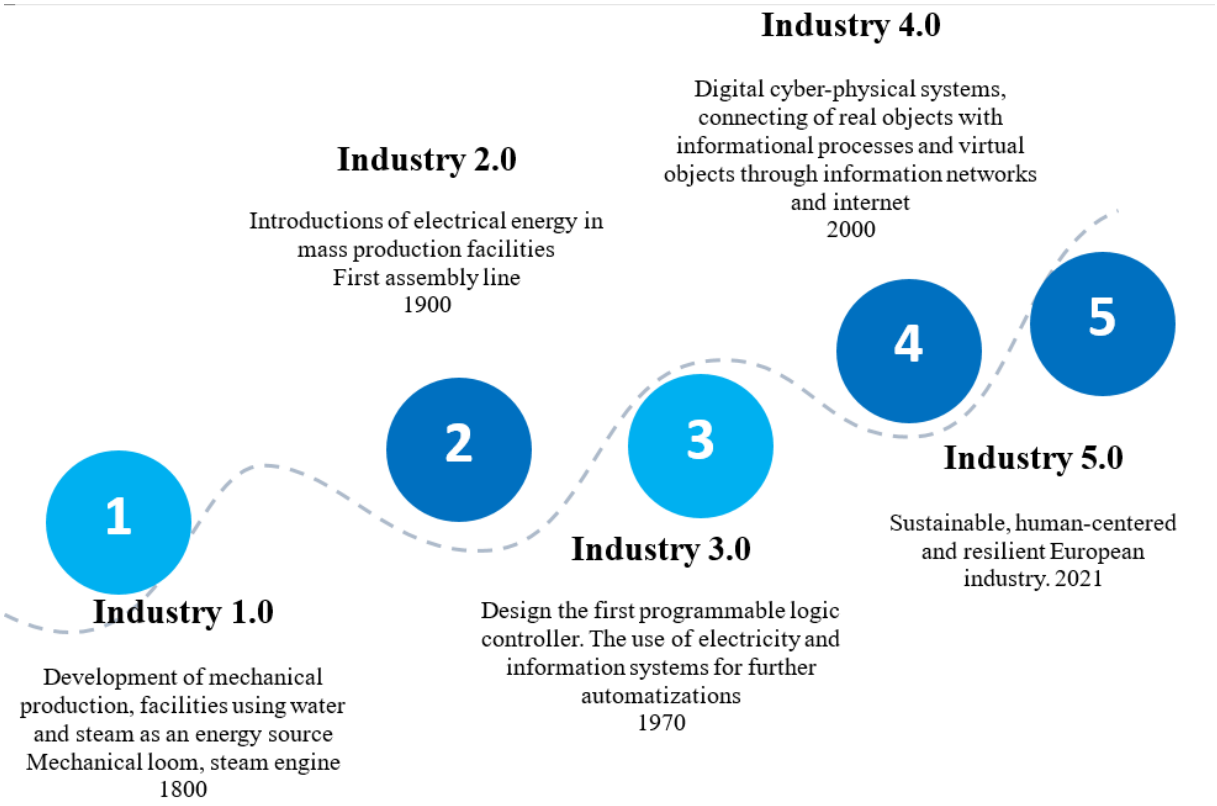

Figure 1. The evolution of the industry
Source: European Commission (2020)

2. INDUSTRY 4.0 IN HEALTHCARE

The fourth industrial revolution, known as Industry 4.0, significantly improves the quality of medical care through digitisation, telecommunications, and artificial intelligence. This revolution comprises a cluster of innovative technologies, some still in development, which establish the foundation for transformative changes in information processing and management.

In the healthcare sector, Industry 4.0 encompasses a wide range of emerging technologies, including digitisation, artificial intelligence, user response data (ergonomics), human psychology, the Internet of Things (IoT), machine learning, big data mining, and augmented reality (Figure 2). This technological integration is driving a paradigm shift that improves patient comfort through early detection and proactive intervention in the treatment of various diseases.

While the industry is advancing towards the next phase, Industry 5.0, the specific issues motivating this review require further attention. This review analyses the latest trends in this

research area, summarising the complexity of new capabilities to guide and prepare the healthcare sector for an Industry 5.0-enabled system. Industry 5.0 emphasises direct collaboration between humans and intelligent machines, where robots are designed to assist humans in working more efficiently by leveraging IoT and big data.

Work processes under Industry 4.0, which support individuals both physically and mentally, add a personal and human touch, thereby enhancing overall healthcare delivery.

Industry 5.0 envisions a sustainable, intelligent, and fully connected society leveraging cutting-edge technologies to enhance both the quality of life and the global environment. Organisations within this paradigm depend on digital services, platforms, and infrastructures, integrating technologies such as artificial intelligence, augmented and virtual reality, blockchain, and the Internet of Things.

Figure 2. Emerging technologies of Industry 4.0 in the healthcare sector
Source: authors' conception

It may sound futuristic, but in reality, it is almost entirely feasible. Based on the current state of knowledge and product development, transforming entire societies is possible, often to a degree comparable to the industrial revolution of the 18th and 19th centuries. From intelligent surgical robots capable of manipulating instruments with greater precision than humans to scientific algorithms aiding doctors in making accurate diagnoses, modern technology is already saving countless lives. Gradually, other areas of work and life will follow this transformation.

Industry 5.0, also known as the fifth industrial revolution, is a new paradigm developed and promoted by the European Commission. The primary objective of this vision is for all industrial activities to overcome economic and technological barriers, achieving the dual goals of productivity and efficiency. Furthermore, Industry 5.0 seeks to promote additional essential elements for future industries, including human well-being, resilience, and

sustainability. The term Industry 5.0 was developed by the European Commission as a complementary concept to Industry 4.0. This new approach will drive industrial development towards a manufacturing model that focuses not only on innovation and economic growth, but also on commitment to environmentally responsible practices.

The European Commission developed the term Industry 5.0 as a complementary concept to Industry 4.0. This new approach aims to advance industrial development towards a manufacturing model that prioritises not only innovation and economic growth but also a commitment to environmentally responsible practices.

3. ARTIFICIAL INTELLIGENCE IN MEDICINE

Artificial intelligence (AI) has become ubiquitous and has transformed the value creation processes within companies. AI is conceptualised as "computational agents that act intelligently to perceive, learn, memorise, reason, and solve problems toward goal-directed behaviour" (Mariani et al., 2023). Artificial intelligence is an extensive scientific field with foundations in mathematics, computer science, statistics, and even philosophy. Its purpose is to analyse the factors and variables of the external environment, react to them promptly, and target them specifically. The goal is to understand and develop systems that can operate autonomously. Winston (1993) defines artificial intelligence as a set of "constraint-enabled algorithms, exposed through representations that support models of loops that interconnect thought, perception, and response, respectively".

The management of healthcare organisations and healthcare processes is rapidly evolving with the implementation of AI systems. This transformation underscores the significant impact AI will have on various activities, particularly in health processes related to early detection and diagnosis. Previous research indicates that AI can enhance the quality of healthcare services. AI-based technologies improve the quality of life by making tasks easier, safer, and more productive. AI continues to demonstrate superiority over humans in terms of accuracy, efficiency, and the timely execution of medical and administrative processes. The benefits for patients are directly linked to AI's capabilities in diagnosis, treatment, counseling, and health monitoring for the self-management of chronic diseases. Future research directions are identified in the areas of value-added health services for medical decision-making, data security and patient privacy, health monitoring capabilities, and innovative IT service delivery models using AI.

The adoption of AI can significantly improve business models, reduce costs, and increase productivity while simultaneously creating new markets. Due to its vast application scope and impact, Industry 4.0 is evolving at an exponential rate within the medical field. AI, despite its numerous advantages and challenges, is an integrated component of Industry 4.0. The primary applications of AI in medicine include managing medical data, optimising appointments and resources, medical diagnosis, personalised treatment, monitoring, and telemedicine.

Artificial intelligence (AI) is a vast discipline focused on understanding and designing systems that exhibit intelligent properties, with learning – gaining knowledge from data – being the most crucial. Peter Norvig and Stuart Russell define artificial intelligence as "the study of agents that receive perceptions from the environment and, by analysing them, manage to perform actions" (Russell & Norvig, 2020).

The recent explosive progress in this field is largely attributable to machine learning, a specific feature of AI, where computers are programmed to make associations based on extensive "learning" datasets. This advancement is significantly due to the development of deep learning technologies, which process raw data such as digital image pixels. Deep learning systems are now widely used, setting new standards in various fields where digital data is essential, offering substantial economic incentives by automating tasks and predicting reactions. These systems create robots that do not require salaries, do not ask for holidays, and can work continuously.

In the healthcare sector, AI-enabled customer services (e.g., app-based health monitoring, chatbot-based customer service, adoption of call analytics, handling high volumes of patient queries, and use of patient feedback analytics) are expected to generate superior performance capabilities (Esmaeilzadeh, 2020). The adoption of AI technologies will lead to substantial automation in many clinical and administrative services aspects, shifting traditional healthcare institutions towards more patient-centric services (Kumar et al., 2023).

Previous studies have highlighted AI's capabilities in healthcare for image analysis, speech recognition, precision medicine, and clinical notes (Wang et al., 2021). Consequently, healthcare organisations recognise the importance of AI-based service strategies and patient relationships. For instance, maintaining a good relationship with patients as customers allows healthcare providers to follow their changing needs, thereby enabling productivity and sustainability (Chatterjee & Rana, 2021).

However, it is crucial to manage data privacy issues carefully and ensure that AI is used ethically and responsibly in the medical field, maintaining a balance between AI use and human involvement in medical decision-making. John McCarthy defines AI as "the science and engineering of creating intelligent machines and, in particular, intelligent computer programs. It is related to the idea of using computers to understand the mechanisms of human intelligence, but AI should not be limited to methods that are biologically observable and quantifiable" (McCarthy, 2023).

The Turing Test, in which a human attempts to differentiate between responses given by a human and a computer, laid the foundation for the concept of artificial intelligence decades before others tried to define it. Although the results have been uncertain and variously interpreted, there is evidence suggesting that it may never be possible for machines to gain consciousness.

Norvig and Russell (1995) in "Artificial Intelligence: A Modern Approach" analyse four objectives or possible definitions to distinguish between computer systems that think from the perspective of rationality and behaviour itself. They approach "problems" from several perspectives: human approaches ("systems that think like people" and "systems that take into account how people act") and ideals ("systems that think rationally" and "systems that act rationally"). According to the tests he created, Turing's definition falls into the category of "systems that behave like humans", which has sparked debate in many fields and raised questions of ethics and integrity. Turing's work "Computing Machinery and Intelligence" (1950) and the Turing test predicted the concept of artificial intelligence, which is a branch of computer science that seeks to simulate human intelligence in machines capable of independent thought (Turing, 1950).

Service innovation in healthcare is an essential strategy to foster growth and resilience within organisations. Researchers argue that healthcare innovation is critical due to the sector's complexity, urgency, and technological advancements (Khanra et al., 2020). AI capabilities in patient communication are promising for innovation as they can enhance our understanding of customer needs and preferences. Healthcare organisations equipped with AI can track patient behavior and gain insights into changing demand patterns (Mostafa & Kasamani, 2021). Increased demand for smart devices and health monitoring has opened opportunities for innovation in new product lines (Palanica & Fossat, 2020). AI-powered healthcare CRM platforms, tools, and services enable organisations to develop new healthcare services or modify existing service designs (Daugherty et al., 2018). Therefore, AI's capabilities in patient communication will enhance service innovation in the medical field. Scientists and practitioners argue that innovation is urgently needed to achieve a healthier life (Skålén et al., 2014).

Healthcare organisations operating in emerging markets must possess the flexibility and capability to meet diverse customer needs. Patients, as customers, not only demand but also appreciate more personalised services. Furthermore, the COVID-19 pandemic has highlighted the necessity of rapidly adapting to various uncertainties, including disease complexity, diagnostic requirements, changing clinical conditions, and medical stockpiles. Thus, healthcare organisations need to develop dynamic capabilities in the form of AI and its role in service innovation (Khanra et al., 2020).

4. CONCLUSIONS

This study provides a comprehensive overview of Industry 4.0 in the healthcare sector, focusing on its impact on the flexibility of customer services and innovation within health services. Given its extensive application and significant influence, Industry 4.0 is evolving at an exponential rate in the medical field. Artificial Intelligence (AI), with its numerous advantages and challenges, is a core component of Industry 4.0.

Modern AI-based platforms enhance clinical understanding and knowledge. The primary applications of AI in medicine include managing medical data, optimising appointments and resources, medical diagnosis, personalised treatment, monitoring, and telemedicine.

The future of healthcare illustrates that AI has become an integral part of the industry, revolutionising the planning of health services through its predictive capabilities. AI enables healthcare providers to anticipate patient demand, facilitating the allocation of resources to ensure that medical units are adequately staffed and equipped (Grand View Research, 2023). This leads to more efficient and effective care, ultimately improving the quality of medical services.

REFERENCES

Chatterjee, S., & Rana, N. S. (2021, August 13). Assessing Organizational Users' Intentions and Behavior to AI Integrated CRM Systems: a Meta-UTAUT Approach. *Information Systems Frontiers*, *23*(3), 589-608. https://doi.org/10.1007/s10796-021-10181-1

Daugherty, P. R., Wilson, J. H., & Chowdhury, R. (2018). Using Artificial Intelligence to Promote Diversity. *MIT press in book: How Al Is Transforming the Organization* (pp.15-22). https://doi.org/10.7551/mitpress/12588.003.0006

Esmaeilzadeh, P. (2020). Use of AI-based tools for healthcare purposes: a survey study from consumers perspectives. *BMC Medical Informatics and Decision Making*, *20*(1), 7-22. https://doi.org/10.1186/s12911-020-01132-1

European Commission (2020). Directorate-General for Research and Innovation, *Industry 5.0 – Human-centric, sustainable and resilient*, Publications Office, https://data.europa.eu/doi/10.2777/073781

Grand View Research. (2023). AI In Healthcare Market Size, Share & Trends Analysis Report By Component (Hardware, Services), By Application, By End-use, By Technology, By Region, And Segment Forecasts, 2024 – 2030, Report ID: GVR-3-68038-951-7, Retrieved from: https://www.grandviewresearch.com/industry-analysis/artificial-intelligence-ai-healthcare-market

Khanra, S., Dhir, A., Islam, A. K. M. N., & Mäntymäki, M. (2020). Big data analytics in healthcare: a systematic literature review. *Enterprise Information Systems*, *14*(7), 878-912. https://doi.org/10.1080/17517575.2020.1812005

Kumar, P., Sharma, S. K., & Dutot, V. (2023). Artificial intelligence (AI)-enabled CRM capability in healthcare: The impact on service innovation. *International Journal of Information Management*, *67*, 102361. https://doi.org/10.1016/j.ijinfomgt.2022.102598

Mariani, M. M., Machado, I., Magrelli, V., & Dwivedi, Y. K. (2023). Artificial intelligence in innovations research: A systematic review, conceptual framework and future research directions. *Technovation*, *103*, 102217. https://doi.org/10.1016/j.technovation.2022.102623

McCarthy, P. J. (2023). What is AI? / Basic Questions, Retrieved September 29, 2023, from http://jmc.stanford.edu/artificial-intelligence/what-is-ai/index.html

Mostafa, R. B., & Kasamani, T. (2021). Antecedents and consequences of chatbot initial trust. *European Journal of Marketing*, *55*(9), 2553-2576. https://doi.org/10.1108/EJM-02-2020-0084

Palanica, A., & Fossat, Y. (2020). COVID-19 has inspired global healthcare innovation. *Springer Canadian Journal of Public Health*, 111(5), 645-648. https://doi.org/10.17269/s41997-020-00406-2

Russell, S., & Norvig, P. (2020). *Artificial Intelligence: A Modern Approach* (3rd ed.). Pearson. https://doi.org/10.5555/2196326

Skålén, P., Gummerus, J., von Koskull, C., & Magnusson, P. (2015). Value propositions and service innovation: a service-dominant logic study. *Journal of the Academy of Marketing Science*, *43*(2), 137-158. https://doi.org/10.1007/s11747-013-0365-2

Turing, A. M. (1950). Computing Machinery and Intelligence. *Mind*, 59(236), 433-460. https://doi.org/10.1093/mind/LIX.236.433

Wang, C., Teo, T. S. H., & Janssen, M. (2021). Public and private value creation using artificial intelligence: An empirical study of AI voice robot users in the Chinese public sector. *International Journal of Information Management*, 61(4):102401. https://doi.org/10.1016/j.ijinfomgt.2021.102401

Winston, P. H. (1993). *Artificial Intelligence*. Boston: Addison-Wesley Publishing Company.