

Industry 4.0 Technologies: Bridging the Gap in Health Information Practices

Umar Faruk Abubakar

Department of Health Information Management, Kashim Ibrahim University Maiduguri, Borno State, Nigeria.
Corresponding Authors Email: Famzarab@Gmail.com

Direct Research Journal of Public Health and Environmental Technology



Vol. 11(3), Pp. 120-125, October 2026

Author(s) retains the copyright of this article

This article is published under the terms of the

Creative Commons Attribution License 4.0.

<https://journals.directresearchpublisher.org/index.php/drjphet>; <https://www.ajol.info/index.php/drjphet>

Research Article

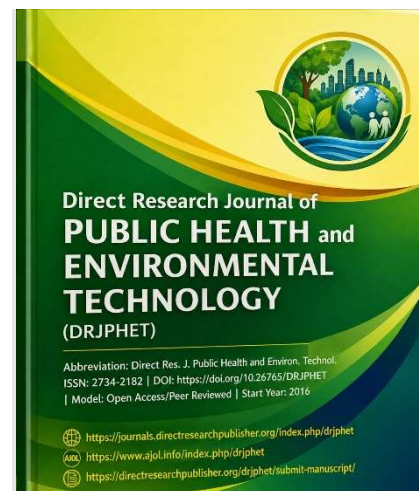
ISSN: 2734-2182

Received 22 August 2026, Accepted 25 September 2026, Published 29 October 2026

ABSTRACT

Health systems depend on information: to diagnose and treat patients, to plan services, to monitor diseases and to make policy. Yet in many developing countries, including Nigeria, health information practices remain weak. Records are largely paper-based and fragmented, data are often incomplete, late and of poor quality, facilities cannot share information easily, rural communities have limited access to reliable health information, and the data collected are under-used for decision-making. At the same time, the Fourth Industrial Revolution, or Industry 4.0, has produced a set of converging technologies, including artificial intelligence, the Internet of Medical Things, cloud computing, big data analytics, blockchain, mobile health and digital twins, that are transforming how information is created, stored, shared and used. This conceptual paper examines how these technologies can bridge the gaps in health information practices. It clarifies the concepts of Industry 4.0 and health information practices, identifies the major gaps in the Nigerian context, and maps each technology to the gaps it can address. Drawing on the Technology–Organisation–Environment framework, it proposes a conceptual model in which Industry 4.0 technologies bridge health information gaps to produce improved health information outcomes, provided that enabling conditions such as infrastructure, skills, standards, data protection and ethical governance are in place. The paper discusses the challenges of adoption, highlights the central role of health information professionals and librarians, and recommends practical strategies for government, health institutions, training institutions and professionals.

Keywords: Industry 4.0; Fourth Industrial Revolution; health information practices; artificial intelligence; Internet of Medical Things; digital health; health information management; Nigeria



Citation: Umar F.A. (2026). Industry 4.0 Technologies: Bridging the Gap in Health Information Practices. *Direct Research Journal of Public Health and Environmental*. Vol. 11(3), Pp. 120-125.
<https://doi.org/10.4314/drjphet.v11i3.15>

INTRODUCTION

Information is the lifeblood of health care. Every clinical encounter generates and depends on information: a patient's history, test results, diagnoses, prescriptions and follow-up plans. Beyond the individual patient, health information supports disease surveillance, planning and budgeting, research, quality improvement and policy.

When health information is accurate, complete, timely and accessible, clinicians make better decisions, patients receive safer care and health systems use their resources more efficiently. When it is missing, wrong or locked away, the result is duplication of tests, medical errors, delayed responses to outbreaks and poor planning. In many deve-

loping countries, health information practices have not kept pace with the demands placed on health systems. In Nigeria, most health facilities still rely on paper records, patients often carry their own folders between facilities, and electronic medical records are uncommon or non-existent in many settings (Akwaowo et al., 2022). Routine health data are frequently incomplete or late, information systems in different facilities and programmes rarely communicate, and data that are collected are seldom analysed and used for decisions at the point where they are produced.

The world is now in what Schwab (2016) called the Fourth Industrial Revolution, a period in which physical, digital and biological systems are converging through technologies such as artificial intelligence (AI), the Internet of Things (IoT), cloud computing, big data, robotics and blockchain. The term Industry 4.0, first used in Germany to describe smart, connected manufacturing (Kagermann et al., 2013), is now widely applied to other sectors, including health. In health care, these technologies are already reading medical images, monitoring patients remotely, predicting disease risk and securing the exchange of records (Topol, 2019). The World Health Organization's Global Strategy on Digital Health 2020–2025 urges countries to adopt such technologies in ways that are people-centred, evidence-based, ethical and integrated into national health systems (WHO, 2021a).

This raises an important question for health information professionals, managers and policymakers: how can Industry 4.0 technologies be used to close the persistent gaps in health information practices, especially in resource-constrained settings such as Nigeria? This conceptual paper addresses that question. Its objectives are to:

1. Clarify the concepts of Industry 4.0 and health information practices;
2. Identify the major gaps in health information practices, with particular reference to Nigeria;
3. Examine how specific Industry 4.0 technologies can bridge these gaps;
4. Propose a conceptual model linking gaps, technologies, enabling conditions and outcomes; and
5. Discuss the challenges of adoption, the role of health information professionals, and the way forward.

CONCEPTUAL CLARIFICATIONS

Industry 4.0 and the Fourth Industrial Revolution

The first industrial revolution used water and steam power to mechanise production; the second used electricity for mass production; the third used electronics and information technology to automate production. The fourth builds on the third but is distinguished by the speed, scope and depth of change brought about by the fusion of technologies that blur the lines between the physical, digital and biological spheres (Schwab, 2016). Industry 4.0

originally described "smart factories" in which machines, products and people are connected through cyber-physical systems and the Internet of Things, exchange data in real time and make decentralised decisions (Kagermann et al., 2013). Applied to health, Industry 4.0 (sometimes called Health 4.0) refers to the use of these connected, intelligent and data-driven technologies to make health care more predictive, personalised, preventive and participatory. Its core technologies include AI and machine learning, the Internet of Medical Things (IoMT), cloud computing, big data analytics, blockchain, mobile and 5G communication, robotics, three-dimensional printing, augmented and virtual reality, and digital twins.

Health Information Practices

Health information practices refer to the ways in which health information is created, captured, organised, stored, retrieved, shared, analysed, used and protected across the health system. They cover clinical documentation and medical records, health management information systems that collect routine service data, disease surveillance, health statistics and research data, as well as the provision of health information to professionals and the public through libraries, information centres and digital channels. Good health information practices produce information that is accurate, complete, timely, accessible, interoperable, secure and used for decisions. Health information practices are therefore the shared concern of several professions: health information management and medical records officers, health librarians and information scientists, health informatics and ICT specialists, statisticians and epidemiologists, clinicians and managers. Industry 4.0 technologies affect all of them.

The Gap in Health Information Practices

In this paper, the "gap" refers to the distance between the health information practices that a modern health system requires and those that currently exist. It has technological dimensions (such as paper records and incompatible systems), organisational dimensions (such as weak data culture and inadequate skills) and environmental dimensions (such as poor infrastructure, limited funding and weak regulation). Bridging the gap means moving from fragmented, manual and under-used information to integrated, digital, secure and actionable information.

Theoretical Underpinning

The paper is guided by the Technology–Organisation–Environment (TOE) framework (Tornatzky & Fleischer, 1990), which explains the adoption of technological innovations by organisations in terms of three contexts. The technological context covers the characteristics and availability of the technology; the organisational context covers the size, structure, resources, leadership and

human capacity of the organisation; and the environmental context covers the industry, infrastructure, regulation and government support within which the organisation operates. The TOE framework is useful here because the successful use of Industry 4.0 technologies in health information practice depends not only on the technologies themselves but also on whether health institutions have the skills, leadership and resources to use them, and on whether the wider environment provides infrastructure, standards and supportive policy.

The paper is also informed by Rogers' (2003) Diffusion of Innovations theory, which holds that innovations spread through a social system over time according to their relative advantage, compatibility, complexity, trialability and observability. Industry 4.0 technologies that offer clear advantages, fit existing work practices and can be tried on a small scale are more likely to be adopted by health information professionals and institutions.

Gaps In Health Information Practices in Nigeria

Although Nigeria has made progress through the District Health Information System (DHIS2), electronic records in some tertiary hospitals and several donor-supported programmes, important gaps remain. Seven are particularly significant:

Paper-based and fragmented records: Many facilities still keep paper folders that are easily lost, damaged or duplicated. A patient's information is scattered across facilities and departments, so no clinician has a complete picture. A multi-state study found that electronic medical records were not common in the Nigerian health system and that clinicians relied largely on manual records (Akwaowo et al., 2022).

Poor data quality and timeliness: Routine data are often incomplete, inconsistent or late because they are collected manually, transcribed several times and reported through slow channels.

Weak interoperability and information sharing: Where digital systems exist, they are often isolated: hospital systems, laboratory systems, programme databases and national reporting platforms do not exchange data, so information must be re-entered and cannot follow the patient.

Limited access to health information in rural and underserved areas: Health workers in rural facilities have limited access to current clinical guidance and literature, and communities lack reliable, understandable health information in local languages.

Under-use of data for decision-making: Data are collected mainly for upward reporting and are rarely analyzed and used by managers and clinicians to improve services.

Weak privacy, security and trust: Paper records and poorly secured systems expose patient information to loss and misuse; concerns about data security also reduce clinicians' willingness to adopt electronic records (Akwaowo et al., 2022).

Skills and workforce gaps: Many health information and health workers lack the digital and analytical skills needed to manage electronic data and use modern information tools.

Recognising these problems, the Federal Ministry of Health and Social Welfare in 2024 inaugurated a committee for the Nigeria Digital in Health Initiative, which focuses on standards and solutions, governance and regulation (including patient data privacy), infrastructure and services, and workforce and stakeholder management (Federal Ministry of Health and Social Welfare, 2024). This creates a favourable policy moment for applying Industry 4.0 technologies to health information practices.

Industry 4.0 Technologies and How they Bridge the Gaps

Artificial Intelligence and Machine Learning

AI refers to computer systems that perform tasks normally requiring human intelligence, such as recognising patterns, understanding language and making predictions; machine learning allows these systems to learn from data. In health, AI is already used to interpret medical images, predict patient deterioration, support diagnosis and automate administrative tasks (Topol, 2019; Davenport & Kalakota, 2019). For health information practices, AI can improve data quality by detecting errors and duplicates, extract structured information from clinical notes through natural language processing, automate clinical coding, and turn large volumes of routine data into predictions and alerts. Generative AI tools can summarise records and literature and help produce health information for patients in plain language. These capabilities address the gaps in data quality, data use and access to information, provided that outputs are validated and used under human oversight (WHO, 2021b).

Internet of Medical Things (IoMT)

The IoMT connects medical devices, wearables and sensors to networks so that they can collect and transmit health data automatically (Islam et al., 2015). Devices that measure blood pressure, glucose, heart rate, temperature or medication use can send readings directly into health records or monitoring platforms. This reduces manual data entry and transcription errors, provides real-time and continuous data rather than occasional readings, and extends monitoring to patients at home and in remote communities. It thus addresses the gaps of data quality, timeliness and access.

Table 1: Mapping Industry 4.0 Technologies to Gaps in Health Information Practices

Gap in health information practice	Bridging Industry 4.0 technologies	Expected improvement
Paper-based, fragmented records	Cloud-based EMRs; mobile data capture	Digital, complete and portable patient records
Poor data quality and timeliness	IoT devices; AI-based validation; automation	Accurate, real-time data with fewer transcription errors
Weak interoperability and sharing	Cloud platforms; data standards; blockchain	Secure exchange of information across facilities
Limited access in rural areas	mHealth; telemedicine; AI chatbots in local languages	Wider access to care and reliable information
Under-use of data for decisions	Big data analytics; AI prediction; dashboards	Evidence-based planning and early warning
Weak privacy and security	Blockchain; encryption; access control and audit trails	Trustworthy, protected health information
Skills and workforce gaps	AR/VR training; e-learning; AI assistants	Competent digital health information workforce

Cloud Computing

Cloud computing provides computing power, storage and software as services over the internet, so that institutions do not need to buy and maintain all their own servers. In health care it offers scalable storage for records and images, shared platforms that many facilities can use, and access to information from any location (Kuo, 2011). For resource-constrained health institutions, cloud-based electronic medical records and health information systems lower the cost of digitisation, support data back-up and recovery, and make it easier to share information between facilities, addressing the gaps of fragmented records and weak sharing.

Big Data Analytics

Health systems generate very large, fast-moving and varied data from records, laboratories, devices, insurance claims, surveillance and social media. Big data analytics uses advanced tools to integrate and analyse such data to reveal patterns, predict trends and support decisions (Raghupathi & Raghupathi, 2014). Applied to Nigerian health information practice, analytics dashboards can turn routine DHIS2 and hospital data into actionable information for managers, support early detection of outbreaks, and identify populations and facilities that need attention. This directly addresses the under-use of data for decision-making.

Blockchain

Blockchain is a distributed ledger in which records are stored in linked, tamper-resistant blocks shared across many computers. In health care it has been proposed for managing patient consent, securing the exchange of medical records, tracking medicines through the supply chain and ensuring the integrity of research data (Kuo et al., 2017). Blockchain-based approaches can give patients greater control over who accesses their records and provide an auditable trail of every access (Azaria et al., 2016). These features address the gaps of privacy, security, trust and secure information sharing, although the

technology is still maturing in health settings.

Mobile Health, Telemedicine and Advanced Connectivity

Mobile phones, mobile applications, SMS and voice services, together with expanding 4G and 5G networks, allow health information to reach people wherever they are. Telemedicine connects patients and health workers in remote areas with specialists; mobile tools allow community health workers to capture data at the point of care; and mobile channels deliver reminders and health education in local languages. These technologies address the gaps of access and timeliness, and are particularly relevant in Nigeria, where mobile phone ownership is far higher than access to computers.

Digital Twins, Augmented and Virtual Reality, and Robotics

A digital twin is a virtual representation of a physical object, process or system that is continuously updated with real data, allowing simulation and prediction (Fuller et al., 2020). In health, digital twins of hospitals can support planning of beds, staff and supplies, while digital twins of patients are an emerging tool for personalised care. Augmented and virtual reality support immersive training of health and health information workers, and robotic process automation can take over repetitive information tasks such as data transfer and report generation. These technologies address the skills gap and the efficiency of information work. The relationship between the identified gaps in health information practices, the relevant Industry 4.0 technologies, and their expected improvements is summarized in Table 1.

Proposed Conceptual Model

Drawing on the foregoing discussion and the TOE framework, the paper proposes the conceptual model shown in Figure 1. The model holds that Industry 4.0 technologies serve as a bridge between the current gaps in health information practices and improved health

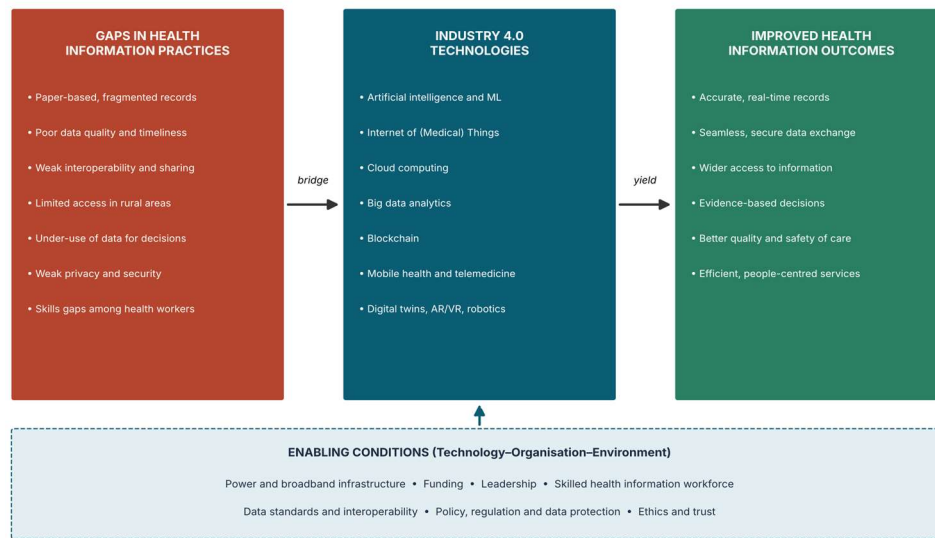


Figure 1: Conceptual model of Industry 4.0 technologies bridging the gap in health information practices (Author's construct, 2026).

information outcomes. The gaps on the left (paper-based and fragmented records, poor data quality, weak interoperability, limited access, under-use of data, weak security and skills gaps) are addressed by the technologies in the centre (AI, IoMT, cloud computing, big data analytics, blockchain, mobile health and telemedicine, and digital twins, AR/VR and robotics). When these technologies are appropriately applied, they yield the outcomes on the right: accurate, real-time records; seamless and secure data exchange; wider access to information; evidence-based decisions; better quality and safety of care; and efficient, people-centred services.

Crucially, the bridge only holds when the enabling conditions at the base of the model are present. In line with the TOE framework, these include technological conditions (power and broadband infrastructure, data standards and interoperability), organisational conditions (funding, leadership and a skilled health information workforce) and environmental conditions (policy, regulation and data protection, ethics and public trust). Without these, Industry 4.0 technologies risk becoming isolated pilot projects that do not change everyday health information practice.

Challenges of Adopting Industry 4.0 Technologies in Health Information Practice

Infrastructure deficits: unreliable electricity, limited broadband in rural areas and the high cost of data and devices limit the use of connected technologies.

Funding constraints: health budgets are small, and digital projects often depend on donors, which threatens their sustainability after external funding ends.

Interoperability and standards: many systems are built without common data standards, so they cannot share information; new technologies may add to fragmentation if standards are not enforced.

Skills shortages: health information professionals and health workers often lack training in data analytics, informatics, cybersecurity and the responsible use of AI.

Privacy, security and ethics: large digital health datasets are attractive targets for cyber-attacks, and AI can reproduce bias or give misleading outputs. The Nigeria Data Protection Act 2023 provides a legal framework, but its application to health data must be strengthened, and WHO guidance on the ethics and governance of AI for health should be followed (WHO, 2021b).

Resistance to change: clinicians and staff used to paper systems may resist new technologies that increase workload in the short term or are seen as complex, as diffusion theory predicts (Rogers, 2003).

Digital divide: urban and well-resourced facilities may benefit while rural communities, women and low-literacy populations are left behind, widening inequalities.

The Role of Health Information Professionals And Librarians

Industry 4.0 technologies do not replace health information professionals; they change and enlarge their roles. Health information management professionals become data stewards who ensure that digital records are complete, accurate, standardised and secure, and who manage clinical coding and data quality in AI-supported

environments. Health librarians and information scientists become guides to trustworthy information in an environment flooded with digital and AI-generated content: they teach digital and AI literacy, verify sources, curate evidence for clinicians and policymakers, and produce health information for the public in accessible formats and local languages. Health information professionals are also well placed to champion ethical practice, including privacy, informed consent, transparency and fairness in the use of data and AI, and to bridge communication between clinicians, ICT specialists and managers. To play these roles, they must acquire new competencies in data analytics, informatics standards, cybersecurity awareness, AI literacy and change management, and their training curricula must be updated accordingly.

Conclusion

Health information practices in Nigeria and many other developing countries are marked by paper-based and fragmented records, poor data quality, weak interoperability, limited access, under-use of data, weak security and skills shortages. Industry 4.0 technologies, namely AI, the Internet of Medical Things, cloud computing, big data analytics, blockchain, mobile health and telemedicine, and digital twins, AR/VR and robotics, offer powerful means of bridging these gaps and producing accurate, secure, accessible and actionable health information. However, technology alone is not enough. As the proposed conceptual model shows, the bridge holds only when supported by enabling conditions: infrastructure, funding, leadership, a skilled workforce, data standards, sound regulation and ethical governance. With these in place, and with health information professionals at the centre of the transformation, Industry 4.0 can help move health information practice from a weakness to a strength of the health system.

RECOMMENDATIONS

1. Government should accelerate implementation of the Nigeria Digital in Health Initiative, with particular attention to national data standards, interoperability of health information systems, and investment in power and broadband for health facilities.
2. Health institutions should adopt Industry 4.0 technologies in phases, beginning with cloud-based electronic records, mobile data capture and analytics dashboards, and scaling up proven solutions rather than multiplying isolated pilots.
3. Health institutions should establish data governance structures, including data protection officers and clear policies on access, consent and the responsible use of AI, in line with the Nigeria Data Protection Act 2023 and WHO guidance.
4. Training institutions should revise curricula in health information management, library and information science

and health informatics to include data analytics, AI literacy, informatics standards and cybersecurity.

5. Professional bodies and employers should provide continuous professional development for health information professionals and health workers on Industry 4.0 technologies.

6. Researchers should conduct empirical studies on the readiness, adoption and impact of Industry 4.0 technologies in Nigerian health information practice, to test and refine the proposed conceptual model.

7. Stakeholders should ensure inclusive adoption by designing solutions that work on basic phones, in local languages and in low-connectivity settings, so that rural and disadvantaged populations are not left behind.

REFERENCES

- Akwaowo, C. D., Sabi, H. M., Ekpenyong, N., Isiguzo, C. M., Andem, N. F., Maduka, O., Dan, E., Umoh, E., Ekpun, V., & Uzoka, F.-M. (2022). Adoption of electronic medical records in developing countries—A multi-state study of the Nigerian healthcare system. *Frontiers in Digital Health*, 4, 1017231. <https://doi.org/10.3389/fdgth.2022.1017231>
- Azaria, A., Ekblaw, A., Vieira, T., & Lippman, A. (2016). MedRec: Using blockchain for medical data access and permission management. In *2016 2nd International Conference on Open and Big Data (OBD)* (pp. 25–30). IEEE. <https://doi.org/10.1109/OBD.2016.11>
- Davenport, T., & Kalakota, R. (2019). The potential for artificial intelligence in healthcare. *Future Healthcare Journal*, 6(2), 94–98. <https://doi.org/10.7861/futurehosp.6-2-94>
- Federal Ministry of Health and Social Welfare. (2024). Nigeria Digital in Health Initiative. <https://www.digitalhealth.gov.ng/about>
- Fuller, A., Fan, Z., Day, C., & Barlow, C. (2020). Digital twin: Enabling technologies, challenges and open research. *IEEE Access*, 8, 108952–108971. <https://doi.org/10.1109/ACCESS.2020.2998358>
- Islam, S. M. R., Kwak, D., Kabir, M. H., Hossain, M., & Kwak, K.-S. (2015). The Internet of Things for health care: A comprehensive survey. *IEEE Access*, 3, 678–708. <https://doi.org/10.1109/ACCESS.2015.2437951>
- Kagermann, H., Wahlster, W., & Helbig, J. (2013). Recommendations for implementing the strategic initiative INDUSTRIE 4.0: Final report of the Industrie 4.0 Working Group. acatech – National Academy of Science and Engineering.
- Kuo, A. M.-H. (2011). Opportunities and challenges of cloud computing to improve health care services. *Journal of Medical Internet Research*, 13(3), e67. <https://doi.org/10.2196/jmir.1867>
- Kuo, T.-T., Kim, H.-E., & Ohno-Machado, L. (2017). Blockchain distributed ledger technologies for biomedical and health care applications. *Journal of the American Medical Informatics Association*, 24(6), 1211–1220. <https://doi.org/10.1093/jamia/ocx068>
- Raghupathi, W., & Raghupathi, V. (2014). Big data analytics in healthcare: Promise and potential. *Health Information Science and Systems*, 2, 3. <https://doi.org/10.1186/2047-2501-2-3>
- Rogers, E. M. (2003). *Diffusion of innovations* (5th ed.). Free Press.
- Schwab, K. (2016). *The fourth industrial revolution*. World Economic Forum.
- Topol, E. J. (2019). High-performance medicine: The convergence of human and artificial intelligence. *Nature Medicine*, 25(1), 44–56. <https://doi.org/10.1038/s41591-018-0300-7>
- Tornatzky, L. G., & Fleischer, M. (1990). *The processes of technological innovation*. Lexington Books.
- World Health Organization. (2021a). *Global strategy on digital health 2020–2025*. WHO.
- World Health Organization. (2021b). *Ethics and governance of artificial intelligence for health: WHO guidance*. WHO.