International Journal of Applied Science and Engineering
Citation: *IJASE*: **13**(01): 27-46, June 2025
DOI: 10.30954/2322-0465.1.2025.5

IJASE
INTERNATIONAL JOURNAL OF APPLIED SCIENCE AND ENGINEERING

REVIEW PAPER **HEALTH INFORMATION SCIENCE**

Demystifying New Initiative, Issues and Concerns of Digital Healthcare Systems in India for a Sustainable Healthcare Transformation: *A Scientific Study*

P.K. Paul[1*], Mustafa Kayyali[2], Ujan Pradhan[3], Sanjukta Chakraborty[4], Deep Debnath[5], S.K. Jena[6] and R. Saavedra[7]

[1]*Executive Director (MCIS), Asst. Prof., Department of CIS, & Information Scientist (Offg.), Raiganj University, West Bengal, India*
[2]*Manager, QA & Research Directorate, Maaref University of Applied Sciences, Syria*
[3]*BTech (CSE) Pursuing, Department of Computing Technologies, SRM Institute of Science and Technology, Kattankulathar, Chennai, Tamil Nadu, India*
[4]*Head & Asst. Professor, Department of CSE, Seacom Skills University, Bolpur, West Bengal, India*
[5]*DO, Ghanikhan Choudhury Institute of Engineering and Technology (GKCIET), Malda, West Bengal, India*
[6]*Head, Department of LIS, Rajiv Gandhi University, Arunachal Pradesh, India*
[7]*Dean, College of BET, Texas A&M University, Texarkana, USA*

**Corresponding author: pkpaul.infotech@gmail.com*

Received: 19 Mar., 2025 **Revised:** 20 May, 2025 **Accepted:** 02 June, 2025

ABSTRACT

Digital healthcare is a very important topic in our modern era. We can define digital healthcare as a service where patients can get services according to their needs using appropriate technology for efficient and reliability. Some of the notable services in these areas are telemedicine, electronic health records (EHR), mobile health (m-Health), wearable health devices, artificial intelligence-driven diagnostics, robot-assisted surgery, and big data analytics. Digital healthcare is essentially a technology-based approach to making healthcare more efficient, accessible, and accessible to people. This use of technology enables early detection of diseases, the creation of personalized treatment plans, and direct and regular monitoring of patients. There are several advances in healthcare systems and at the same time some important development happened in recent past in India. This paper has discussed several initiatives of Digital Healthcare Systems dedicated for the new age healthcare transformation and sustainability systems including some of the issues and concern in brief.

Keywords: Digital Healthcare, Healthcare Informatics, Health ICT, Digitalization, Emerging Technologies, Sustainable Healthcare

How to cite this article: Paul, P.K., Kayyali, M., Pradhan, U., Chakraborty, S., Debnath, D., Jena, S.K. and Saavedra, R. (2025). Demystifying New Initiative, Issues and Concerns of Digital Healthcare Systems in India for a Sustainable Healthcare Transformation: *A Scientific Study*. *IJASE.*, **13**(01): 27-46.

Source of Support: None; **Conflict of Interest:** None

Digital technology is playing a crucial and transformative role in healthcare in India. From the early days of electronic health records to AI video diagnostics, today it is possible to better treat patients. With the advancement of this technology, the quality of healthcare is improving day by day and at the same time, these services are saving time and money[7],[13]. The Indian government and various private sector organizations have taken several initiatives to build bridges with citizens while constantly improving digital healthcare technology. This article highlights the evolution of digital healthcare in India and the impact of notable projects underway in this sector.

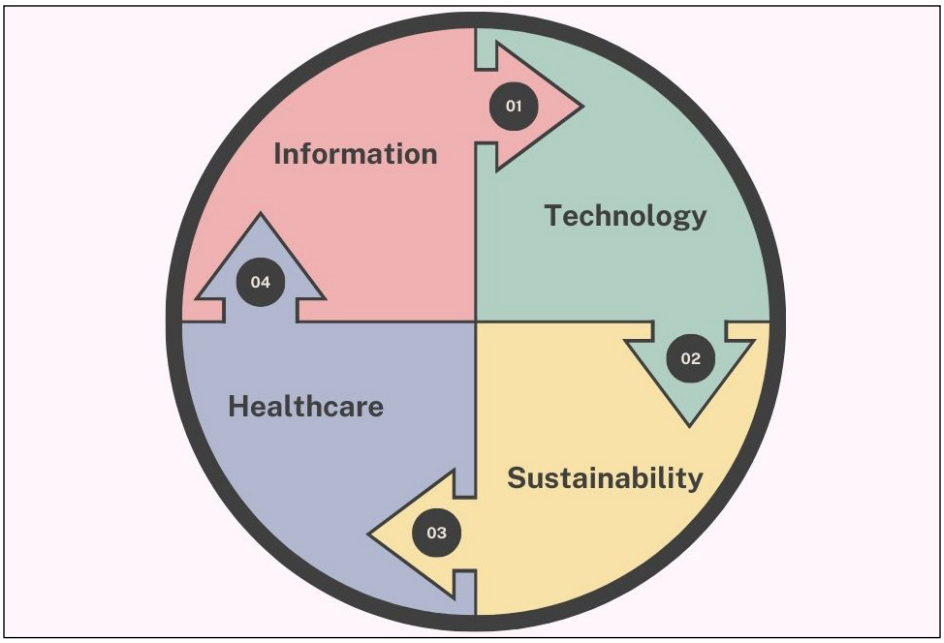

Fig. 1: Basic stakeholders of Digital Healthcare Systems

Digital healthcare is an interdisciplinary facet combining with healthcare systems along with digital technologies specially information and communication technologies *(refer Figure 1 for basic stakeholders in Digital Healthcare systems)*. Digital healthcare is dedicated with cutting edge systems for advancing the healthcare services which is ultimately for the improving of the services dedicated to the patient and administration of the healthcare setups. This is dedicated in improving the accessibility of the healthcare with uses of wide range of facilities, systems and technologies including telemedicine, electronic health records, mobile healthcare systems (mHealth), wearable health technology, robot based surgery, effective data analytical tools, etc. All these technologies are dedicated in disease prevention, finding the best diagnosis, effective treatment plans, personalized healthcare and supports, proper and real-time monitoring, etc. This work is highly concentrated on Digital Healthcare systems with several challenges and issues in Indian perspective[11],[24]. It is an important fact that in India Healthcare system is going rapid changes and progress in diverse areas and there early adoption of electric health records are highly impactful and valuable. AI-driven treatments and diagnostics is the need of the hour and critically important and valuable in advancing healthcare systems progress and advancement. Indian Government along with other private agencies are highly dedicated in effective development and promotion of healthcare transformation. This

paper has focused on several initiatives undertaken by the Government for new age healthcare practices which is impacting precision healthcare and at the same time sustainable healthcare systems. Among the technologies apart from AI some other technologies like Cloud Computing, Big Data Analytics, Internet of Things are dedicated in new-age healthcare efforts and service development[10],[23]. Though there are many benefits associated with the Digital Healthcare Systems but there are some issues and concern related to the Digital Healthcare practices and among them some important are include data privacy, technological challenges, ethical challenges, information and digital literacy issues, regulation issues, framework issues, infrastructure issues, etc. National Digital Health Mission (NDHM) is one of the leading projects for digital healthcare progress for the medical service provision and among other important are Ayushman Bharat Digital Mission, e-Sanjeevani telemedicine services, Aarogya Setu, tele-manas, e-hospital, etc.

OBJECTIVE OF WORK

This work entitled 'Demystifying new initiative, issues and concerns of Digital Healthcare Systems in India for a Digital Healthcare Transformation: *A Scientific Study'* is a theoretical and conceptual in nature and deals with several objective.

- To gather about the foundation of Digital Healthcare including its features and characteristics in respect of education.
- To get knowledge in studying existing works specially on Digital Healthcare and allied technologies.
- To gather latest applications and impact of Digital Healthcare with reference to on-going projects in Indian context.
- To find-out the challenges as well as issues of Digital Healthcare and allied systems in contemporary scenario.

METHODS

The paper entitled 'Demystifying new initiative Issues and Concerns of Digital Healthcare Systems in India for a Digital Healthcare Transformation: *A Scientific Study'* is a conceptual work and therefore it is theoretical in nature and lies on existing literature including books, chapters, journals related to the of Digital Healthcare and allied technologies. For reviewing contemporary and on-going activities and projects, and services of Digital Healthcare several Digital Healthcare initiative's website are studied and observed to learn the emergence and issues of Digital Healthcare.

EXISTING WORKS

Related several works are studied while preparing this work 'Demystifying new initiative Issues and Concerns of Digital Healthcare Systems in India for a Digital Healthcare Transformation: A Scientific Study' and some of them are included herewith.

Agrawal, R. & Prabakaran, S. (2020),[1] worked on a substantial segment of the study examines case studies in which big data has effectively improved clinical decision-making, illustrating its capacity to transform healthcare delivery. The authors underscore the necessity for defined frameworks and data governance standards to guarantee the ethical and efficient use of big data. The report finishes by advocating for a

systematic methodology for healthcare providers to use big data technology while preserving patient confidence and adhering to regulatory compliance.

Chandra, M. *et al.* (2022)[5] they emphasize how these tools helped minimize healthcare inequities and enhanced patient monitoring, but also address the digital gap and infrastructure difficulties that hindered their usefulness. The research includes numerous case studies highlighting successful implementations, stressing the importance of government policies and public-private partnerships in expanding digital solutions. While the article acknowledges the gains made during the epidemic, it also highlights the necessity for long-term investments in digital healthcare infrastructure to guarantee sustainability beyond crisis times.

Dash, S.P. (2020)[8] here the author also discusses problems such as cybersecurity threats, data privacy concerns, and interoperability issues that limit wider implementation. A noteworthy addition of this article is its discussion on India's path for integrating IoT into healthcare, highlighting the necessity for governmental interventions, infrastructural development, and investment in healthcare IT. The report indicates that while IoT has enormous promise, a structured strategy is important to enable seamless integration and security.

Lee, D. & Yoon, S.N. (2021)[22] here researchers have also tackles key problems, such as data protection, ethical considerations, and the possibility for AI bias. A key component of this research is its balanced stance on AI's promise and limits, saying that while AI boosts efficiency, human monitoring remains vital. The report also argues for a legislative structure that assures ethical AI implementation in healthcare. Overall, the study offers AI as a strong instrument that, if managed appropriately, may change healthcare while retaining patient confidence and ethical integrity.

Modgil, S. *et al.* (2022)[30] worked and reported also underscores the significance of government policy and digital infrastructure in supporting this transformation. However, it does not shy away from acknowledging the obstacles, such as cybersecurity concerns, financial restrictions, and regulatory barriers. The study includes instructive case studies of successful digital businesses who harnessed technology to navigate the crisis. It closes by highlighting that while the pandemic hastened digital change, sustained development in digital entrepreneurship required long-term policy support, digital literacy programs, and increased cybersecurity measures.

Pandey, P. & Litoriya, R. (2020)[35] here researchers also report also emphasizes real-world applications, such as electronic health records (EHRs) and smart contracts for insurance claims. Despite its promise, the authors note obstacles such high implementation costs and regulatory uncertainty that hamper adoption. The research indicates that while blockchain can considerably increase healthcare efficiency, a clear legislative framework and infrastructural support are essential for large-scale adoption.

Rana, N.P., Luthra, S. & Rao, H.R. (2020)[41] and they also investigates how digital payment systems, such as UPI and mobile banking, have changed financial transactions, but with issues around fraud and data protection. A important conclusion from this research is the need for improved consumer protection rules and financial literacy initiatives to promote trust in digital banking. The authors conclude that while digital finance holds great prospects for financial inclusion, addressing infrastructural and regulatory impediments is important for wider adoption.

Saraswat, D. *et al.* (2022)[45] they study analyzes several strategies to increase AI explainability, such as model visualization and feature attribution methodologies. However, obstacles persist, including trade-

offs between accuracy and interpretability. The report concludes that while XAI is vital for the ethical deployment of AI in healthcare, continued research and policy development are needed to reconcile innovation with responsibility.

EMERGING PROJECTS AND INITIATIVES FOR ICT-ENABLED HEALTHCARE IN INDIA

Digital Healthcare system is supported by several emerging information and communication technologies and some of them are depicted in Fig. 2. India is making great strides in digitalizing its healthcare sector, with several impactful projects emerging in this domain. Here's a concise overview of some significant initiatives.

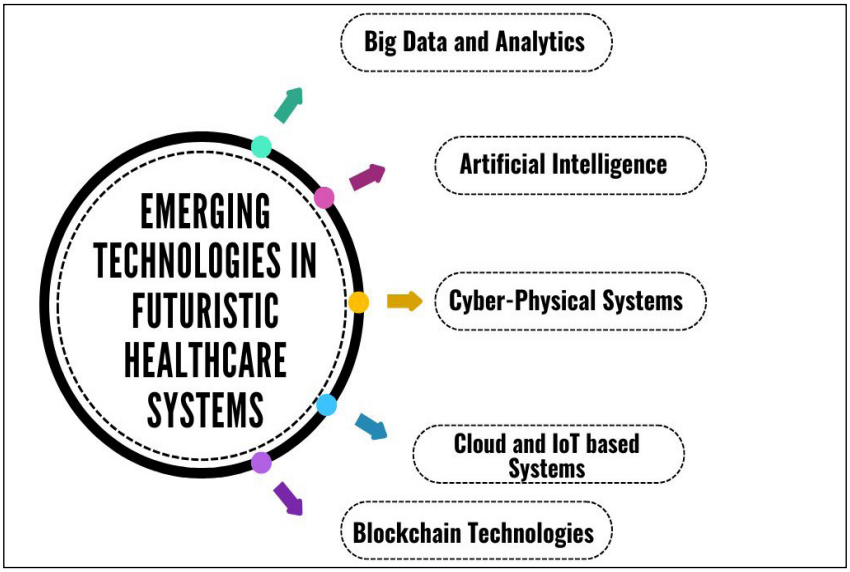

Fig. 2: Emerging technologies in building of Digital Healthcare Systems

Early Developments (Pre-2000s)

Prior to the dawn of the digital age, India's healthcare system heavily depended on conventional paper record management and had minimal technological input. The Telemedicine Pilot Project, spearheaded by ISRO in 2001, was a groundbreaking effort that set the stage for remote healthcare services, allowing patients in rural areas to connect with specialists in urban centers.

The 2000s: Laying the Groundwork for E-Health

As internet access and software innovations blossomed, the early 2000s ushered in Health Management Information Systems (HMIS) within government hospitals[3],[19]. These systems not only digitized patient data but also enhanced hospital management and optimized inventory control.

2010-2020: A Digital Transformation in Healthcare

This decade marked a remarkable expansion of digital healthcare initiatives across India, propelled by mobile applications, cloud technology, and AI-driven healthcare solutions. Noteworthy milestones from this era include:

- **National Health Portal (2014)** – Introduced by the Ministry of Health & Family Welfare (MoHFW), this portal aimed to provide citizens with trustworthy healthcare information.
- **Arogya Setu App (2020)** – Created during the COVID-19 pandemic, this app was instrumental in contact tracing and played a crucial role in managing the pandemic's spread.
- **e-Sanjeevani Telemedicine (2019)** – A government initiative that delivers free online consultations, largely assisting the rural populace.

Post-2020: The Era of AI and Blockchain

As India embraced advancements in artificial intelligence, machine learning, and blockchain technology, its healthcare sector entered a more advanced era. AI-driven diagnostic tools, blockchain for health record management, and IoT-enabled devices have now become vital components of various healthcare initiatives[2],[18].

1. Current Major Digital Healthcare Projects in India

India is developing with several new healthcare initiative and projects and this particular range is increasing and some of them are dedicated as follows (also refer Fig. 3)—

1. **Ayushman Bharat Digital Mission (ABDM):** Initiated in 2021, this ambitious project aims to establish a comprehensive digital health ecosystem throughout India by merging various health services into a cohesive digital platform. Its primary attributes include:
2. **Health ID for every citizen:** A distinct digital identity designed to facilitate access to personal medical records.
3. **Healthcare provider registry:** A digital archive that catalogs physicians and healthcare facilities.
4. **Health facility registry:** An extensive directory encompassing hospitals, clinics, and diagnostic centers.
5. **Personal Health Records (PHR):** This innovative system empowers individuals to manage and share their medical histories conveniently with healthcare professionals.
6. **eSanjeevani (National Telemedicine Service):** Launched in 2019, this initiative revolutionizes remote healthcare delivery through virtual consultations. Key features include:
   - **Two operational modes:** e-Sanjeevani OPD for individual patients and e-Sanjeevani AB-HWC for consultations between healthcare providers at wellness centers.
   - **Extensive reach:** Over 100 million consultations have been conducted, establishing it as one of the largest telemedicine platforms globally.
   - **Support for under-served populations:** Particularly beneficial for individuals in rural areas who have limited access to specialized medical care.

7. **CoWIN Platform:** Introduced in 2020 to oversee and streamline India's COVID-19 vaccination campaign, this platform boasts the following key features:
   - **Digital functionalities:** Includes online registration, appointment scheduling, and the issuance of vaccination certificates[6],[21].
   - **Aadhaar integration:** Facilitates identity verification through the national identification system.
   - **Real-time vaccine management:** Enables tracking of vaccine inventory and distribution across the nation.

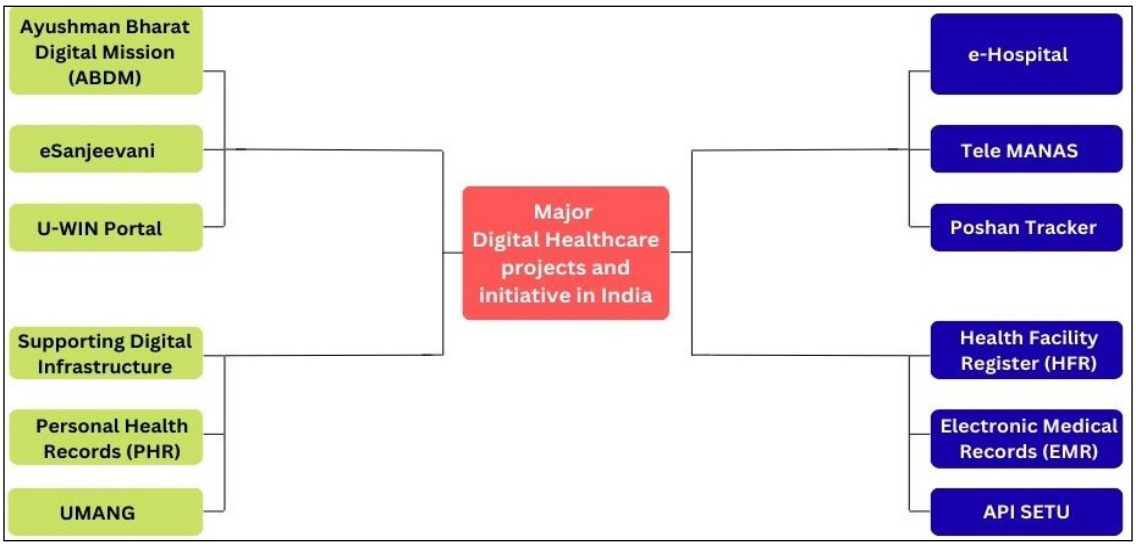

Fig. 3: Major Digital Healthcare projects and initiatives in India

8. **National Digital Health Ecosystem (NDHE):** Launched in 2022, this initiative focuses on creating a robust, standardized, and secure digital health framework. Key components include:
   - **Interoperability:** Fostering seamless data sharing between hospitals, clinics, and laboratories.
   - **Integration of Artificial Intelligence:** Employing AI for enhanced diagnostic capabilities and predictive healthcare analytics.
   - **Blockchain technology for data protection:** Ensuring the security and privacy of patient information[4],[27].

9. **Integrated Health Information Platform (IHIP):** Launched in 2021, this initiative aims to improve real-time disease surveillance and outbreak identification through various innovative features:
   - It harnesses the power of big data analytics to facilitate the early identification of disease outbreaks.
   - Offers real-time updates and reporting for conditions such as tuberculosis, malaria, and COVID-19.
   - Supports policymakers with data-driven insights for more informed decision-making.

10. **National Artificial Intelligence Mission for Healthcare:** This project, initiated in 2023 under the National AI Mission, focuses on integrating AI-led solutions into diagnostics, treatment, and healthcare delivery, featuring:
    - AI-based tools for screening diseases like cancer and tuberculosis.
    - Machine learning applications to forecast disease outbreaks.
    - Innovations in robotic surgeries and AI-assisted drug discovery.
11. **m-Health and Mobile Applications:** A variety of mobile applications and mHealth platforms are enhancing the accessibility of healthcare services:
    - **m-Swasthya:** A mobile application designed for monitoring maternal and child health.
    - **NHP Swasthya Bharat:** Provides reliable health information and recommended practices.
    - **Aayushman Bharat Health Account (ABHA):** Facilitates citizens in digitally storing and accessing their health records.
12. **AI in Oncology and Cancer Detection:** India is actively utilizing AI and machine learning for the early detection of cancer with initiatives such as:
    - **AI-based Lung Cancer Screening:** Implementing deep learning techniques to classify lung nodules [15], [40].
    - **Mitra AI by Tata Memorial Hospital:** An AI tool tailored for the early detection of breast cancer.
    - **Niramai:** A pioneering non-invasive breast cancer screening solution utilizing AI and thermal imaging.
13. **Blockchain-Based Health Records:** Numerous healthcare entities are delving into blockchain technology to safeguard medical records. A notable example is the Apollo Hospitals Blockchain Initiative, which ensures patient data integrity while facilitating seamless access for authorized medical professionals.

In India, the digital healthcare landscape is flourishing, with several cutting-edge technologies, including the introduction of telemedicine, taking the forefront and driving the advancement of Sustainable Healthcare Systems. AI-driven diagnostic tools and medical solutions are propelling the entire healthcare sector forward. Initiatives such as the Ayushman Bharat Digital Mission (ABDM), CoWIN, and eSanjeevani are enhancing the accessibility of healthcare. Although there remain challenges related to technologies like AI, IoT, and big data, India boasts a promising outlook and the potential to enhance its healthcare effectiveness in the near future. The mission of "Digital Health for All" is set to become increasingly achievable through digital health technologies. While the promise of digital health could revolutionize access to medical services, efficiency, and patient outcomes across India, it may also give rise to certain hurdles that need to be addressed. Developing digital infrastructure is vital, encompassing efforts to bridge the digital divide, strengthen capacity, establish legal frameworks and standards, and ensure data privacy protection—these are crucial for a flourishing digital health ecosystem. Governmental initiatives such as the ABDM and the National Digital Health Mission (NDHM) represent significant strides toward this goal[29],[32]. To circumvent current barriers and make digital healthcare accessible to all Indians, a commitment to long-term investment, clear regulations, and progressive digital literacy campaigns will be essential.

ISSUES AND CHALLENGES OF DIGITAL HEALTHCARE, TELEMEDICINE IN INDIA

In India, the ecosystem for digital healthcare has grown quickly over the last few years thanks to new technologies in telemedicine, AI, and data analytics, as well as government programs and private sector support. India has a lot of promise for digital healthcare, but there are a lot of problems with the technology and infrastructure, digital literacy, skill development, legalization and standardization, and data privacy. We need these must-have answers to fix some of the problems that are stopping digital health from working well and being used across the country. Among the major issues some of them are listed as follows (also refer Fig. 4).

1. Technological and Infrastructure Challenges

Infrastructure and technological challenges. Evidence suggests that lack of adequate infrastructure and technology preparedness in India is one of the barriers in realizing enhanced adoption of digital healthcare in the country. The digital solutions are slowly being adopted in the healthcare sector, however, gaps still exist.

Digital Infrastructure and Internet Connectivity

The spread of the internet in urban and rural India is highly uneven. While urbanized areas have access to high-speed internet, the same cannot be said for the bridge in rural and remote regions where the majority of people are still stuck with slow and unreliable internet access[9],[26]. But many health systems in smaller towns lack the most rudimentary digital infrastructure, such as electronic health record (EHR) systems, cloud-based data stores and telemedicine tools. Without a strong digital backbone, the ability to benefit from AI-supported diagnostics, telehealth visits and remote patient monitoring is limited.

Issues of Integration and Interoperability

A significant barrier to integrating digital health care is the interoperability of disparate health systems and platforms. Healthcare providers are using different software solutions at hospitals and clinics that do not talk to each other — resulting in fragmented patient records. The lack of seamless data exchange among different organizations leads to the disruption of care continuity, which directly affects patient outcomes[16],[33].

Access to Power Supply and Equipment

Many rural healthcare centres experience regular power outages and a shortage of up-to-date medical technology. Digital Healthcare – as in every tech-based infrastructure, requires constant power supply and a state-of-the-art supporting ecosystem. The situation is not helped by a lack of investment in upgrading healthcare IT systems.

2. Issues of Digital Literacy and Digital Divide

The digital divide in India is a significant barrier to the adoption of digital healthcare. A big chunk of

the population, particularly in the hinterland, does not have the skills to use digital health solutions properly[17],[28].

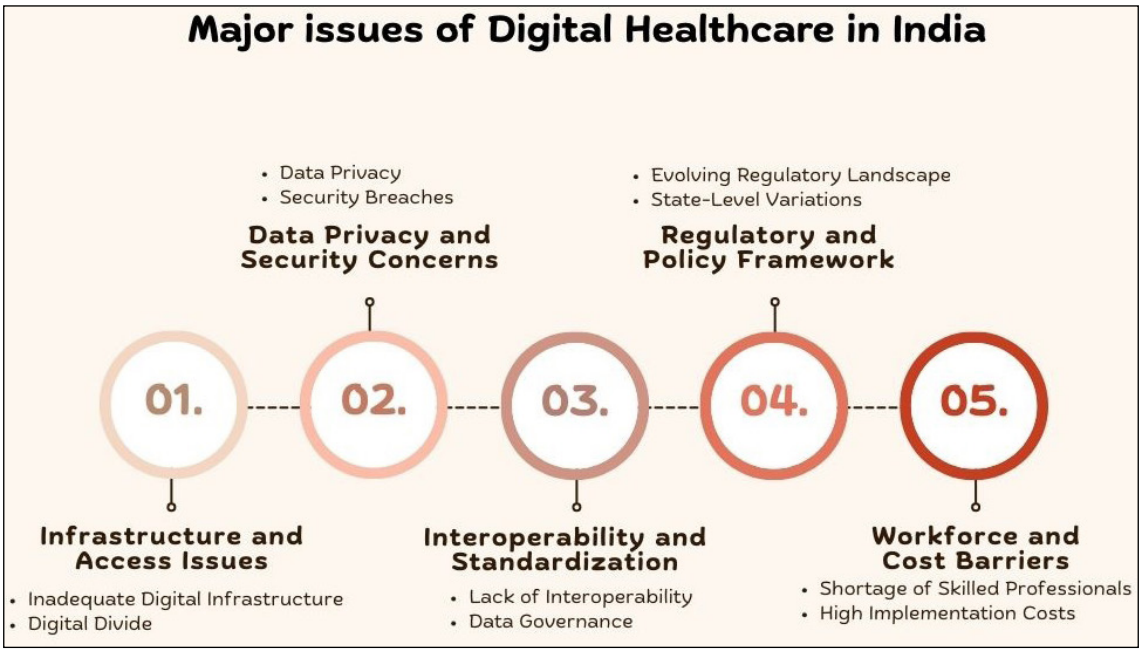

Fig. 4: Major Digital Healthcare issues in India

Low awareness and access

A large segment of rural and semi-urban population is either unaware of the availability of telemedicine, e-pharmacies, and digital health records or do not have access to these services. When these services do exist, a combination of technological illiteracy and distrust of technology creates barriers to their uptake.

Language and Usability Barriers

Most digital health applications and websites are designed in English, which can limit the usability for non-English speaking populations[20],[31]. Since India has multiple regional languages, the lack of multilingual digital health platforms can restrict accessibility.

Digital Gender Divide

Women, especially in rural India, have less access to digital technologies than men. Societal norms limit mobility, and limited access to smartphones as well as very low digital literacy among women prevent them from benefiting from digital healthcare initiatives.

Financial Constraints

Digital literacy programs, internet access, and smartphones all cost money. Such disparities mean that

many lower-income households cannot even afford a smartphone or a data plan, widening the digital healthcare divide.

3. Skill Development Issues

Digital healthcare technologies are progressing at the speed of light, however, it needs a trained workforce and presently, in India, there is a deficiency of professionals who can utilize and implement such solutions.

No expertise of medical practitioners

For example, health care providers (doctors, nurses, allied health professionals) are often not formally trained in the use of digital health solutions (telemedicine platforms, AI-based diagnostics, electronic health record systems, etc.) Many professionals want to avoid using new technologies for lack of knowledge or inability[12],[34].

Lack of Data Science and AI Experts

As AI and big data become increasingly essential in healthcare, so does proficiency in the areas of data science, machine learning andAI. India is facing a skills shortage of professionals who can develop, deploy and maintain such advanced systems.

Importance of Continuous Learning & Up-skilling

An ever-changing environment is given, hence, it demands eternal learning. However, digital health or AI training is rarely incorporated into the structured curricula of medical or paramedical courses across India, thus helping to prepare the majority of these professionals for the digital paradigm shift.

4. Legal and Standardization Issues

Due to a lack of clear policies and standardization frameworks, the digital healthcare sector in India is riddled with regulatory uncertainty.

Lack of Uniform Standards

There are no national standards for electronic health records that most providers in the United States would adopt, which has led to diverse and incompatible data formats[18],[38]. Without having a unified format for information, sharing health data from one provider to another becomes difficult with the current Healthcare devices and platforms that each uses its technical framework.

Regulatory Uncertainty

The Telemedicine Practice Guidelines (2020) have helped India with the regulation around telemedicine. However, legislation considering the nature of AI-derived health care, digital therapeutics, and blockchain-based health data management remains in its early stages of development, leaving lingering uncertainty for health care providers and technology vendors.

Legal Liability in Telemedicine

Interesting points in telemedicine consultations are raised concerning misdiagnosis, medical malpractice, and liability. Limited patient history and self-reported symptoms make it more complicated to determine responsibility if adverse events occur in a given case.

Cross-Border Healthcare Challenges

The challenges that arise at the international level in respect of telemedicine services relate to the potential regulations governing cross-border healthcare[24],[36]. Preserving compliance with internationally established health data regulations, coupled with affordability and accessibility, prove to be quite complex.

5. Privacy and Security Concerns

Given that digital healthcare solutions depend on huge amounts of sensitive patient data, data security and privacy should be of the utmost importance.

Risk of Data Breaches

The storage of sensitive personal health information in healthcare organizations draws various cyber attacks. Numerous data breaches of healthcare institutions in India, such as the ones mentioned above, indicate that data protection is highly vulnerable.

Absence of an exhaustive Data Protection legislation

At present, there is no law in India solely addressing the protection of health data. While the Digital Personal Data Protection Act (2023) gives some guidelines, there is a need for a more sector-specific law to ensure the safety of patients' data[25],[37].

Issues of Consent and Ownership

A whole ecosystem controls patients' health data, with hospitals, insurance companies and technology providers collecting and using this information, often with none of the consent measures patients have grown used to. Patients need to empower themselves with clear articulation on data ownership, consent, and usage.

Risks of AI and Data Bias

Whether it be AI-based tools or programs, enormous quantities of data are needed. When there is bias or a lack of data, the predictions from these models may be wrong and lead to misdiagnosis. Fairness and transparency of algorithms become essential to maintaining a fair health-care delivery to various sectors.

DIGITAL HEALTHCARE AND SUSTAINABLE HEALTHCARE

Modern Healthcare are supported by various Information Technology and Computing components and some of them are dedicated in bringing of sustainable healthcare.

1. Towards a Resilient Future

The design, provision, and administration of health systems that satisfy current demands without endangering the capacity of future generations to satisfy their own is known as sustainable healthcare[32],[42]. This idea highlights how healthcare procedures should strike a balance between social justice, economic viability, and environmental sustainability. In a time when population increase, resource depletion, and climate change present serious obstacles, sustainable healthcare has become a crucial paradigm to guarantee the robustness and effectiveness of international health systems.

2. Healthcare's Environmental Responsibilities

The environmental impact of the healthcare industry is significant. In addition to producing hazardous waste and using a lot of energy and water, hospitals, clinics, and the pharmaceutical industry all contribute to greenhouse gas emissions. Adopting green construction standards, cutting energy use, and supporting renewable energy sources are all part of the transition to sustainable practices. For instance, energy-efficient medical equipment and solar-powered hospitals can lower carbon emissions without sacrificing quality of care. Another crucial element is waste management. Ecosystems and human health may be harmed by the inappropriate disposal of medical waste, which includes old needles, outdated drugs, and chemical byproducts. Recycling, safe disposal techniques including autoclaving and cremation with pollution control, and waste segregation at the source are all components of sustainable waste management systems[43],[48].

3. Financial Viability

Sustainable healthcare systems must strike a balance between economic and environmental objectives. Digital health technology and telemedicine are examples of cost-effective solutions that minimize emissions related to travel and lessen the demand for physical infrastructure. These solutions increase access to disadvantaged communities while significantly reducing operating costs. Another strategy that is economically viable is preventive care. The long-term burden of chronic diseases can be decreased by healthcare systems through the implementation of immunization programs, early diagnosis, and lifestyle changes. These actions enhance community health outcomes while reducing treatment costs. Investing in regional production of generic medications and medical supplies promotes economic sustainability[39],[47]. Healthcare systems can reduce costs and carbon footprints while mitigating disruption risks by decreasing their reliance on global supply networks.

4. Healthcare Social Equity

A key component of sustainable healthcare is equity. All people will have access to high-quality care in a system that places a high priority on inclusivity, regardless of their financial situation, gender, or place of residence. In distant and underserved locations, community-based healthcare models—like mobile clinics and community health workers—provide vital services. Campaigns for education and awareness are essential for enabling people to take control of their health. In order to promote confidence and involvement in healthcare programs, sustainable healthcare places a strong emphasis on culturally relevant interventions that complement regional customs and beliefs.

5. Support for Innovation and Policy

Sustainability in healthcare is driven by innovation. Biotechnology innovations like biodegradable implants and environmentally friendly medicine packaging help to lessen their negative effects on the environment. Predictive healthcare planning and effective resource allocation are made possible by artificial intelligence and big data analytics, which save waste and enhance results. Frameworks for policies are essential for encouraging sustainable activities. Governments and regulatory agencies need to set rules for environmentally friendly healthcare facilities, encourage the use of renewable energy sources, and enforce stringent waste disposal regulations. Addressing global health issues like pandemics and diseases brought on by climate change need equal amounts of international cooperation.

CORE OBSERVATION AND FUTURE PROSPECTS

- ***Digital Divide:*** Rural areas still face internet connectivity issues, limiting access to telemedicine and digital health services.
- ***Data Privacy Concerns:*** With increased digitalization, securing patient data against cyber threats is a critical challenge.
- ***Interoperability Issues:*** Different healthcare institutions use different software, making seamless data exchange difficult[28],[44].
- ***Regulatory Framework:*** The lack of strong regulatory policies for AI and digital health solutions could lead to ethical and legal complications.
- ***Expansion of AI and ML in Diagnostics:*** The integration of AI in imaging, pathology, and predictive analytics will enhance disease detection.
- ***5G in Healthcare:*** Faster internet speeds will improve telemedicine services and enable remote robotic surgeries.
- ***Wearable Health Tech:*** Smart wearables will provide real-time health monitoring, reducing hospital visits.
- ***Genomic and Precision Medicine:*** AI-driven genomic research will help in personalized treatment plans.

HEALTHCARE 5.0: NEW TRENDS IN DIGITAL HEALTHCARE WITH SUSTAINABILITY

Transitioning to sustainable practices includes adopting green building standards, reducing energy consumption, and investing in renewable energy sources. For example, using energy-efficient medical devices and implementing solar energy in hospitals can significantly lower carbon emissions while maintaining high-quality care. And there were steps in reaching new heights of Healthcare systems as depicted below.

1. Evolution from Healthcare 4.0 to 5.0

The foundation for intelligent and networked healthcare systems was established by Healthcare 4.0, which is defined by the digitization of healthcare through IoMT and electronic health records (EHRs). However, it frequently ignored the human element of care in favor of automation and data-driven decision-making. Sustainable healthcare refers to the thoughtful design, delivery, and management of health systems that meet today's needs while ensuring that future generations can address their own health requirements. This concept emphasizes the importance of balancing social equity, economic feasibility, and environmental stewardship in healthcare practices. The healthcare sector has a considerable ecological footprint. Hospitals, clinics, and pharmaceutical companies generate hazardous waste and consume vast amounts of energy and water, contributing to greenhouse gas emissions.

To achieve sustainability, healthcare systems must integrate economic and environmental goals. Innovations like digital health technologies and telemedicine not only provide cost-effective care but also reduce travel-related emissions and lessen the need for expansive physical infrastructure. These approaches enhance accessibility for underserved populations while lowering operational expenses. Preventive care is another economically sound strategy. By focusing on immunization initiatives, early detection, and promoting healthier lifestyles, healthcare systems can diminish the long-term impact of chronic diseases, resulting in improved health outcomes and reduced treatment expenditures[42],[46]. Additionally, fostering local production of generic medications and medical supplies supports economic sustainability. By lessening reliance on global supply chains, healthcare systems can cut costs and shrink their carbon footprints, while also minimizing the risks associated with disruptions. The healthcare sector is experiencing a profound transformation thanks to the technological advancements heralded by Industry 5.0. This new section, termed Healthcare 5.0, builds upon the framework established by its predecessor, Healthcare 4.0, by embedding human-centric principles alongside innovative technologies such as artificial intelligence (AI), the Internet of Medical Things (IoMT), robotics, big data, and blockchain. The primary objectives of this transition focus on enhancing patient care, streamlining healthcare delivery, and fostering a more personalized and effective medical system. The fundamental components of Healthcare 5.0 encompass:

- ❒ Artificial Intelligence and Machine Learning
- ❒ Internet of Medical Things (IoMT)
- ❒ Robotics and Automation
- ❒ Blockchain Technology
- ❒ Personalized Medicine
- ❒ Ethics and Empathy

Healthcare 4.0 laid the groundwork for interconnected and intelligent health systems, characterized by the digitization of services via IoMT and electronic health records (EHRs). However, this phase often overlooked the critical human aspect of care in favor of automation and data-centric decision-making.

2. Key Pillars of Healthcare 5.0

Artificial Intelligence and Machine Learning: AI is essential to Healthcare 5.0 because it makes early

diagnosis, individualized treatment plans, and predictive analytics possible. In order to improve preventive treatment, machine learning algorithms examine enormous databases to find trends and forecast illness outbreaks. AI-powered imaging technologies, for example, let radiologists identify abnormalities more accurately.

Internet of Medical Things (IoMT): IoMT links medical equipment, wearable technology, and sensors to track patient health in real time[13],[21]. By enabling preventive interventions and facilitating remote patient monitoring, these interconnected systems lower hospital readmission rates. Smart wearables, for instance, can monitor vital signs and notify medical professionals of possible problems.

Robotics and Automation: Beyond surgical support, robotics in healthcare 5.0 encompasses drug delivery systems, patient rehabilitation, and senior care. Collaboration between humans and robots guarantees accuracy in intricate processes while preserving a human touch in care giving tasks.

Blockchain Technology: Blockchain solves issues with data privacy and interoperability by ensuring safe and transparent health data management. By giving people authority over their medical records, decentralized ledgers promote accountability and confidence throughout the healthcare system.

Personalized Medicine: Customized therapy regimens based on each patient's genetic profile, lifestyle, and environmental circumstances are made possible by developments in genomics and artificial intelligence. This method reduces side effects while increasing treatment efficacy.

Ethics and Empathy: Healthcare 5.0 is distinguished by its focus on moral behavior and compassion in the provision of healthcare. Healthcare workers' empathy and intuition are meant to be enhanced by technologies, not replaced[17],[33].

Among the many advantages of healthcare 5.0 are better patient outcomes, lower expenses, and easier access to care. In underprivileged areas, remote healthcare solutions help close gaps and guarantee fair treatment. To reach its full potential, though, issues like data security, moral dilemmas, and the digital divide must be resolved.

CONCLUSION

Healthcare is one of the many industries that have been significantly impacted by the new era of technology developments brought about by Industry 5.0. By focusing on the integration of human-centric approaches with cutting-edge technologies like artificial intelligence (AI), the Internet of Medical Things (IoMT), robotics, big data, and blockchain, Healthcare 5.0 expands on its predecessor, Healthcare 4.0. The goals of this paradigm shift are to improve patient outcomes, expedite the delivery of healthcare, and advance a more individualized and effective healthcare system. While digital health has the potential to revolutionize medical access, efficiency, and patient outcomes in India, it can create certain roadblocks for which solutions must be found. Digital infrastructure development entails programs to close the digital divide, capacity building, legal frameworks and standardization, and protection of data privacy, all seen as imperatives for a virtuous digital health ecosystem. Government initiatives like Ayushman Bharat Digital Mission (ABDM) and the National Digital Health Mission (NDHM) are encouraging steps towards this. If so, long term investment, regulatory clarity and progressive digital literacy campaigns will need to be continued to address the existing barriers to achieving digital healthcare for all Indians.

REFERENCES

1. Agrawal, R. and Prabakaran, S. 2020. Big data in digital healthcare: lessons learnt and recommendations for general practice. *Heredity,* **124**(4): 525-534.

2. Behkami, N.A. and Daim, T.U. 2012. Research forecasting for health information technology (HIT), using technology intelligence. *Technological Forecasting and Social Change,* **79**(3): 498-508.

3. Bhambere, H.S.S., Abhishek, B. and Sumit, H. 2021. Rapid digitisation of healthcare: a review of COVID-19 impact on our health systems. *Int. J. All Res. Educ. Sci. Methods,* **9**: 1457-1459.

4. Bhattacharya, I. and Ramachandran, A. 2015. A path analysis study of retention of healthcare professionals in urban India using health information technology. *Human Resources for Health,* **13**(1): 1-14.

5. Chandra, M., Kumar, K., Thakur, P., Chattopadhyaya, S., Alam, F. and Kumar, S. 2022. Digital technologies, healthcare and Covid-19: insights from developing and emerging nations. *Health and Technology,* **12**(2): 547-568.

6. Chopra, H., Choudhary, O.P. and Emran, T.B. 2024. G20 summit in India: unveiling the digital health initiative with *'Vasudhaiva Kutumbakam'. International Journal of Surgery,* **110**(1): 591-593.

7. Dasgupta, A. and Deb, S. 2008. Telemedicine: A new horizon in public health in India. *Indian Journal of Community Medicine: official publication of Indian Association of Preventive & Social Medicine,* **33**(1): 3.

8. Dash, S.P. 2020. The impact of IoT in healthcare: global technological change & the roadmap to a networked architecture in India. *Journal of the Indian Institute of Science,* **100**(4): 773-785.

9. Dey, A., Nandi, S. and Sarkar, M. 2018. Security measures in IOT based 5G networks. In 2018 3rd International Conference on Inventive Computation Technologies (ICICT), pp. 561-566, IEEE.

10. Habes, M., Alghizzawi, M., Ali, S., Salih Alnaser, A. and Salloum, S.A. 2020. The Relation among Marketing ads, via Digital Media and mitigate (COVID-19) pandemic in Jordan. *International Journal of Advanced Science and Technology,* **29**(7): 12326-12348.

11. Itumalla, R. 2012. Information Technology and Service Quality in HealthCare: An Empirical Study of Private Hospital in India. *International Journal of Innovation, Management and Technology,* **3**(4): 433.

12. Jain, D. 2023. Regulation of digital healthcare in India: Ethical and legal challenges. *Healthcare (Basel)*, **11**(6): 911.

13. Jain, E. 2020. Digital Employability Skills and Training Needs for the Indian Healthcare Industry. In Opportunities and Challenges in Digital Healthcare Innovation (pp. 113-130). IGI Global.

14. Kapadia-Kundu, N., Sullivan, T.M., Safi, B., Trivedi, G. and Velu, S. 2012. Understanding health information needs and gaps in the health care system in Uttar Pradesh, India. *Journal of Health Communication,* **17**(sup2): 30-45.

15. Kar, S.K., Saxena, S.K. and Kabir, R. 2020. The relevance of digital mental healthcare during COVID-19: Need for innovations. *Nepal Journal of Epidemiology,* **10**(4): 928.

16. Karthikeyan, N. and Sukanesh, R. 2012. Cloud based emergency health care information service in India. *Journal of Medical Systems,* **36**(6): 4031-4036.

17. Kasoju, N., Remya, N.S., Sasi, R., Sujesh, S., Soman, B., Kesavadas, C., Muraleedharan, C.V., Varma, P.R.H. and Behari, S. 2023. Digital health: Trends, opportunities, and challenges in medical devices, pharma, and biotechnology. *CSIT*, **11**(1): 11-30.

18. King, J.L., Gurbaxani, V., Kraemer, K.L., McFarlan, F.W., Raman, K.S. and Yap, C.S. 1994. Institutional factors in information technology innovation. *Information Systems Research,* **5**(2): 139-169.

19. Kumar, A., Mahajan, P., Mohan, D. and Varghese, M. 2001. IT—information technology and the human interface: tractor vibration severity and driver health: a study from rural India. *Journal of Agricultural Engineering Research,* **80**(4): 313-328.

20. Kumar, P. and Reddy, K.S. 2019. Challenges and Opportunities for Implementing Digital Health Information Systems in India: A Review. *Health Policy and Technology,* **8**(4): 392-399.

21. Kumari, T. 2019. A study on knowledge and attitude towards digital health of rural population of India-Innovations in practice to improve healthcare in the rural population. *International Journal of Emerging Multidisciplinary Research,* **3**(3): 13-21.

22. Lee, D. and Yoon, S.N. 2021. Application of artificial intelligence-based technologies in the healthcare industry: Opportunities and challenges. *International Journal of Environmental Research and Public Health,* **18**(1): 271.

23. Madon, S., Sahay, S. and Sudan, R. 2007. E-government policy and health information systems implementation in Andhra Pradesh, India: need for articulation of linkages between the macro and the micro. *The Information Society,* **23**(5): 327-344.

24. Maita, K.C., Maniaci, M.J., Haider, C.R., Avila, F.R., Torres-Guzman, R.A., Borna, S., Lunde, J.J., Coffey, J.D., Demaerschalk, B.M. and Forte, A.J. 2024. The impact of digital health solutions on bridging the healthcare gap in rural areas: A scoping review. *Perm Journal*, **28**(3): 130-143.

25. Malhotra, S., Chakrabarti, S. and Shah, R. 2019. A model for digital mental healthcare: Its usefulness and potential for service delivery in low-and middle-income countries. *Indian Journal of Psychiatry,* **61**(1): 27.

26. Mehta, S. and Jain, P. 2022. Role of Digital Health Information Systems in Addressing Healthcare Disparities: Insights from Urban and Rural Settings in India. *Journal of Public Health Management and Practice,* **28**(1): 12-19.

27. Mennella, C., Maniscalco, U., De Pietro, G. and Esposito, M. 2024. Ethical and regulatory challenges of AI technologies in healthcare: A narrative review. *Heliyon*, **10**(4): e26297.

28. Mishra, S.K., Kapoor, L. and Singh, I.P. 2009. Telemedicine in India: current scenario and the future. *Telemedicine and e-Health,* **15**(6): 568-575.

29. Mishra, S.K., Singh, I.P. and Chand, R.D. 2012. Current status of telemedicine network in India and future perspective. *Proceedings of the Asia-Pacific Advanced Network,* **32**(1): 151-163.

30. Modgil, S., Dwivedi, Y.K., Rana, N.P., Gupta, S. and Kamble, S. 2022. Has Covid-19 accelerated opportunities for digital entrepreneurship? An Indian perspective. *Technological Forecasting and Social Change,* **175**: 121415.

31. Mony, P.K. and Nagaraj, C. 2007. Health information management: An introduction to disease classification and coding. *National Medical Journal of India,* **20**(6): 307.

32. Mumtaz, H., Riaz, M. H., Wajid, H., Saqib, M., Zeeshan, M.H., Khan, S.E., Chauhan, Y.R., Sohail, H. and Vohra, L.I. 2023. Current challenges and potential solutions to the use of digital health technologies in evidence generation: A narrative review. *Frontiers in Digital Health*, **5**: 1203945.

33. Orlikowski, W.J. and Robey, D. 1991. Information technology and the structuring of organisations. *Information Systems Research,* **2**(2): 143-169.

34. Pai, R.R. and Alathur, S. 2019. Assessing awareness and use of mobile phone technology for health and wellness: Insights from India. *Health Policy and Technology,* **8**(3): 221-227.

35. Pandey, P. and Litoriya, R. 2020. Implementing healthcare services on a large scale: challenges and remedies based on blockchain technology. *Health Policy and Technology,* **9**(1): 69-78.

36. Paul, P.K., Aithal, P.S. and Bhuimali, A. 2018. Health Information Science and its growing popularities in Indian self financed universities: Emphasising Private Universities—A Study. *International Journal of Scientific Research in Biological Sciences,* **5**(1): 1-11.

37. Paul, P.K., Bhuimali, A. and Aithal, P.S. 2017. Allied Medical and Health Science and Advanced Telecommunications: Emerging Utilisations and its Need in Indian Healthcare System. *Current Trends in Biotechnology and Chemical Research,* **7**(1-2): 27-30.

38. Paul, P.K., Chatterjee, D. and Ghosh, M. 2012. Medical information science: Emerging domain of information science and technology (IST) for sophisticated health & medical infrastructure building-an overview. *International Scientific Journal of Sport Sciences,* **1**(2): 97.

39. Paul, P.K., Chatterjee, D. and Ghosh, M. 2012. Neural Networks: Emphasising its Application in the World of Health and Medical Sciences. *Journal of Advances in Medicine,* **1**(2): 93-99.

40. Paul, P.K., Sinha, R.K., Ganguly, J. and Ghosh, M. 2015. Health and Medical Information Science and its potentiality in Indian Education Sector. *Journal of Advances in Medicine,* **4**(1&2): 21-37.

41. Rana, N.P., Luthra, S. and Rao, H.R. 2020. Key challenges to digital financial services in emerging economies: the Indian context. *Information Technology & People,* **33**(1): 198-229.

42. Role of Digital India Program in Strengthening Good Governance: A Study of Jammu Municipal Corporation. Ilkogretim Online- Elementary Education Online. 2021. Vol. 20, Issue 1, Retrieved from www.ilkogretim-online.org

43. Safi, S., Thiessen, T. and Schmailzl, K.J. 2018. Acceptance and resistance of new digital technologies in medicine: Qualitative study. *JMIR Research Protocols*, **7**(12): e11072.

44. Sahay, S., Monteiro, E. and Aanestad, M. 2009. Toward a political perspective of integration in information systems research: the case of health information systems in India. *Information Technology for Development,* **15**(2): 83-94.

45. Saraswat, D., Bhattacharya, P., Verma, A., Prasad, V. K., Tanwar, S., Sharma, G. ... and Sharma, R. 2022. Explainable AI for healthcare 5.0: opportunities and challenges. *IEEE Access,* **10**: 84486-84517.

46. Sharma, S. and Gupta, R. 2021. Assessing the Socio-economic Impact of Digital Health Information Systems: A Case Study of Rural India. *International Journal of Medical Informatics,* **132**: 104066.

47. Srivastava, S.K. 2016. Adoption of electronic health records: a roadmap for India. *Healthcare Informatics Research,* **22**(4): 261-269.

48. Tegegne, M.D., Tilahun, B., Mamuye, A., Kerie, H., Nurhussien, F., Zemen, E., Mebratu, A., Sisay, G., Getachew, R., Gebeyehu, H., Seyoum, A., Tesfaye, S. and Yilma, T.M. 2023. Digital literacy level and associated factors among health professionals in a referral and teaching hospital: An implication for future digital health systems implementation. *Frontiers in Public Health*, **11**: 1130894.

49. Vijai, C. and Wisetsri, W. 2021. Rise of Artificial Intelligence in Healthcare Startups in India. *Advances in Management,* **14**(1): 48-52.