

Developing Healthcare Infrastructure in Saudi Arabia Using Smart Technologies: Challenges and Opportunities

Amani Uraif

Saudi Ministry of Education, Jeddah, Saudi Arabia

Email: orf.amani1@gmail.com

How to cite this paper: Uraif, A. (2024) Developing Healthcare Infrastructure in Saudi Arabia Using Smart Technologies: Challenges and Opportunities. *Communications and Network*, 16, 51-73. <https://doi.org/10.4236/cn.2024.163003>

Received: June 15, 2024

Accepted: July 28, 2024

Published: July 31, 2024

Copyright © 2024 by author(s) and Scientific Research Publishing Inc. This work is licensed under the Creative Commons Attribution International License (CC BY 4.0).

<http://creativecommons.org/licenses/by/4.0/>



Open Access

Abstract

This study aims to explore the challenges and opportunities associated with developing healthcare infrastructure in Saudi Arabia through the implementation of smart technologies. The healthcare sector in Saudi Arabia is undergoing significant transformation, and the integration of smart technologies has the potential to revolutionize healthcare delivery, improve patient outcomes, and enhance the overall healthcare experience. However, several challenges need to be addressed in order to fully leverage the benefits of smart technologies in healthcare infrastructure development. This research identifies and analyzes these challenges while also highlighting the opportunities that arise from the adoption of smart technologies in the Saudi Arabian healthcare system. The findings contribute to the understanding of the current state of healthcare infrastructure in Saudi Arabia and provide insights into the strategies and policies required to overcome challenges and maximize the benefits of smart technologies in healthcare.

Keywords

Healthcare Infrastructure, Saudi Arabia, Smart Technologies, Challenges, Opportunities

1. Introduction

1.1. Background of Saudi Arabia's Healthcare Sector and Its Importance in Providing Quality Healthcare Services to Its Population

Saudi Arabia's healthcare sector plays a crucial role in ensuring the well-being and quality of life for its population. The Kingdom has made significant progress

in developing a comprehensive healthcare system that provides accessible and high-quality healthcare services to its citizens and residents. This article provides an overview of the background of Saudi Arabia's healthcare sector and highlights its importance in delivering quality healthcare services to the population [1].

The healthcare system in Saudi Arabia is a combination of public and private sectors. The Ministry of Health (MOH) serves as the primary regulatory authority responsible for overseeing healthcare services in the country. The government has invested heavily in healthcare infrastructure, resulting in the establishment of numerous hospitals, clinics, and specialized healthcare centers throughout the nation. This infrastructure development has significantly improved the accessibility of healthcare services for the population [2].

Providing quality healthcare services is of paramount importance in Saudi Arabia. The government recognizes that quality healthcare is essential for maintaining the well-being and improving the overall health outcomes of its population. Efforts have been made to enhance the quality of healthcare through various initiatives, including the implementation of rigorous quality assurance measures and the establishment of accreditation bodies such as the Saudi Central Board for Accreditation of Healthcare Institutions (CBAHI). These measures ensure that healthcare facilities meet predetermined standards of quality and patient safety, instilling trust and confidence in the healthcare system [3].

Saudi Arabia has experienced rapid population growth in recent years, further underscoring the importance of a robust healthcare sector. The population has increased significantly, with an estimated population of over 34 million in 2020 (World Bank, 2021). Additionally, the demographics of the country have been changing, characterized by a diverse age distribution. This includes a large youth population and an aging segment. These demographic shifts present unique challenges and demands on the healthcare sector, requiring a responsive and adaptable healthcare infrastructure to meet the evolving healthcare needs of the population [4].

The government of Saudi Arabia has demonstrated a strong commitment to healthcare. The Vision 2030 initiative, launched in 2016, identifies healthcare as a priority sector for development and reform. Vision 2030 aims to improve healthcare services, enhance healthcare outcomes, and promote innovation and research in the healthcare sector. This initiative reflects the government's dedication to continuously improving the healthcare system and addressing the emerging healthcare challenges in the Kingdom [3].

A well-trained healthcare workforce is crucial for delivering quality healthcare services. Saudi Arabia has invested in the development of its healthcare workforce through various initiatives, including the establishment of medical schools, specialized training programs, and scholarships for healthcare professionals. The government has also implemented policies to attract and retain skilled healthcare professionals, both domestically and internationally. These efforts ensure the availability of competent healthcare providers to meet the growing healthcare needs of the population [5].

1.2. Overview of Smart Technologies and Their Potential Applications in Healthcare Infrastructure Development

Smart technologies have emerged as transformative tools in various industries, and the healthcare sector is no exception. With advancements in technology, healthcare infrastructure development has witnessed a significant shift towards the integration of smart technologies. These technologies, including electronic health records, telemedicine, wearable devices, artificial intelligence (AI), big data analytics, and Internet of Things (IoT) devices, hold great potential for improving healthcare delivery, enhancing patient outcomes, and revolutionizing the healthcare system. This article provides an overview of smart technologies and explores their potential applications in healthcare infrastructure development [6].

Electronic health records (EHRs) have revolutionized the way healthcare information is managed and shared. EHRs enable the digitization and centralization of patient data, allowing healthcare providers to access comprehensive medical histories and make informed decisions. EHRs streamline administrative processes, reduce medical errors, and enhance coordination of care among healthcare professionals. They also facilitate data exchange between different healthcare facilities, ensuring continuity of care and improving patient safety [7].

Telemedicine, powered by advancements in communication technologies, has transformed the delivery of healthcare services. Telemedicine enables remote consultations, diagnosis, and treatment, eliminating geographical barriers and improving access to healthcare, especially in rural or underserved areas. Patients can connect with healthcare professionals through video calls, receive remote monitoring, and access virtual care platforms. Telemedicine not only enhances convenience for patients but also reduces healthcare costs and improves healthcare resource utilization [8].

Wearable devices, such as fitness trackers and smartwatches, have gained popularity for their ability to monitor vital signs and track health-related data. These devices enable individuals to take an active role in their healthcare by monitoring their physical activity, heart rate, sleep patterns, and other health indicators. Healthcare providers can leverage this data to gain insights into patient behavior, personalize treatment plans, and promote preventive care. Wearable devices also facilitate remote patient monitoring, enabling healthcare professionals to track patients' health in real-time and intervene when necessary [9].

Artificial intelligence (AI) has the potential to revolutionize healthcare in numerous ways. AI algorithms can analyze vast amounts of medical data, identify patterns, and provide accurate diagnoses. AI-powered tools can assist healthcare professionals in interpreting medical images, such as X-rays and MRIs, leading to faster and more precise diagnoses. AI can also automate administrative tasks, optimize resource allocation, and improve operational efficiency within healthcare facilities. Furthermore, AI-driven chatbots and virtual assistants can provide patients with personalized healthcare information, address their queries, and offer support [10].

Big data analytics plays a crucial role in extracting meaningful insights from large volumes of healthcare data. By analyzing patient records, treatment outcomes, and population health data, healthcare providers can identify trends, predict disease outbreaks, and develop evidence-based strategies for improving healthcare delivery. Big data analytics also facilitates population health management, enabling healthcare systems to identify high-risk individuals, implement preventive interventions, and allocate resources more effectively [11].

The Internet of Things (IoT) devices, interconnected through a network, can collect and transmit healthcare data in real-time. IoT devices, such as smart sensors and monitoring devices, enable continuous monitoring of patients' vital signs, medication adherence, and environmental factors. These devices can alert healthcare providers in case of emergencies, enable remote patient monitoring, and support the early detection of health issues. IoT devices also facilitate the integration of various healthcare systems, enabling seamless data exchange and interoperability [12].

The integration of smart technologies into healthcare infrastructure development offers several benefits. It enhances patient-centered care by empowering individuals to actively participate in their own healthcare and promoting personalized treatment plans. Smart technologies improve healthcare access, particularly for underserved populations, by overcoming geographical barriers and reducing healthcare disparities. They also optimize resource utilization, streamline administrative processes, and reduce healthcare costs [13].

However, the integration of smart technologies in healthcare infrastructure development also presents challenges. Interoperability and data security are crucial considerations to ensure the seamless exchange of healthcare information while safeguarding patient privacy. The implementation of these technologies requires a robust technological infrastructure, sufficient training for healthcare professionals, and the engagement of stakeholders at all levels. Financial implications, such as the cost of implementation and maintenance, should also be carefully evaluated.

1.3. Significance of Addressing Challenges and Leveraging Opportunities for the Successful Integration of Smart Technologies in Saudi Arabia's Healthcare System

The integration of smart technologies in Saudi Arabia's healthcare system holds immense potential for transforming healthcare delivery, improving patient outcomes, and enhancing the overall efficiency of the healthcare sector. However, several challenges need to be addressed and opportunities leveraged to ensure the successful integration and adoption of these technologies. This article highlights the significance of addressing these challenges and capitalizing on opportunities for the successful integration of smart technologies in Saudi Arabia's healthcare system [14].

1) Enhancing Healthcare Access and Equity

One of the key challenges in Saudi Arabia's healthcare system is ensuring eq-

uitable access to healthcare services, particularly in remote and underserved areas. Smart technologies, such as telemedicine and mobile health apps, can bridge the gap by enabling remote consultations, monitoring, and diagnosis. Addressing infrastructure gaps and promoting digital literacy among healthcare professionals and patients are essential for expanding access to healthcare services. By leveraging smart technologies, Saudi Arabia can overcome geographical barriers and ensure that all citizens have access to quality healthcare, regardless of their location [15].

2) Improving Healthcare Efficiency and Resource Utilization

Efficient utilization of healthcare resources is crucial for delivering timely and cost-effective care. Smart technologies offer opportunities to optimize resource allocation, streamline administrative processes, and reduce healthcare costs. For instance, electronic health records (EHRs) can eliminate the need for manual record-keeping, reduce paperwork, and enhance the accuracy and accessibility of patient information. Implementation of interoperable systems is necessary to enable seamless data exchange between healthcare facilities, ensuring continuity of care and avoiding duplication of tests or procedures. By addressing interoperability challenges and promoting the use of smart technologies, Saudi Arabia can enhance healthcare efficiency and improve resource management [16].

3) Enhancing Patient Engagement and Empowerment

Empowering patients and promoting their active participation in their healthcare is crucial for improving health outcomes. Smart technologies, such as wearable devices, mobile health apps, and patient portals, enable patients to monitor their health, access personalized health information, and engage in self-management. These technologies facilitate remote patient monitoring, medication adherence, and lifestyle tracking. By promoting patient engagement and providing individuals with tools to manage their health, Saudi Arabia can foster a culture of wellness and preventive healthcare, ultimately leading to improved health outcomes and reduced healthcare costs [17].

4) Ensuring Data Security and Privacy

The integration of smart technologies in healthcare brings forth concerns regarding data security and privacy. Protecting patient data from unauthorized access, ensuring data integrity, and maintaining patient privacy are critical considerations. It is essential to establish robust data security frameworks, implement encryption measures, and adhere to stringent data privacy regulations. By addressing these challenges and ensuring the confidentiality and security of patient information, Saudi Arabia can build trust among patients and healthcare professionals, encouraging the adoption of smart technologies [18].

5) Investing in Research and Development

Investing in research and development (R&D) is crucial for the successful integration of smart technologies in healthcare. R&D efforts can drive innovation, facilitate the development of locally tailored solutions, and address specific healthcare challenges faced by the Saudi Arabian population. Collaborations between academia, industry, and healthcare providers can foster innovation and

support the implementation of cutting-edge technologies. By investing in R&D and promoting a culture of innovation, Saudi Arabia can position itself as a leader in healthcare technology and promote economic growth [19].

6) Collaboration and Partnerships

Addressing the challenges and realizing the full potential of smart technologies in healthcare requires collaboration and partnerships among key stakeholders. Collaboration between the government, healthcare providers, technology companies, and regulatory bodies is essential for establishing a conducive ecosystem for the integration of smart technologies. Sharing best practices, knowledge, and experiences can accelerate the adoption process and facilitate the implementation of standardized protocols. By fostering collaboration and partnerships, Saudi Arabia can leverage the expertise and resources of various stakeholders, ensuring the successful integration of smart technologies in healthcare [20].

7) Continuous Training and Education

To fully harness the potential of smart technologies, healthcare professionals need to be equipped with the necessary skills and knowledge. Continuous training and education programs focused on smart technologies, data analytics, and digital healthcare are essential for healthcare professionals to adapt to the changing landscape. Providing training programs and continuing education opportunities will ensure that healthcare professionals are competent in utilizing smart technologies effectively and leveraging their full potential. This will ultimately enhance the quality of care provided and optimize patient outcomes [21].

1.4. The Role of Intelligent Technology in Improving the Efficiency of Medical Services, Medical Quality and Patient Experience

Intelligent technology plays a crucial role in improving the efficiency of medical services, enhancing medical quality, and enhancing the patient experience in several ways:

1) Data analysis and diagnosis: Intelligent technology can analyze vast amounts of medical data, including patient records, lab results, and research findings, to identify patterns and improve diagnosis accuracy. Machine learning algorithms can assist healthcare professionals in making more precise diagnoses and treatment plans, leading to better outcomes and reduced errors [22].

2) Remote monitoring and telemedicine: Intelligent technology enables remote monitoring of patients' vital signs and health conditions. Wearable devices and sensors can transmit real-time data to healthcare providers, allowing for early detection of abnormalities and timely interventions. Telemedicine platforms enable virtual consultations, reducing the need for in-person visits and improving access to healthcare, particularly for patients in remote areas [23].

3) Streamlined administrative processes: Intelligent technology automates administrative tasks such as appointment scheduling, billing, and medical record management. This automation reduces paperwork, minimizes errors, and frees up healthcare professionals' time, allowing them to focus more on patient care [24].

4) Predictive analytics and personalized medicine: By leveraging machine learning algorithms, intelligent technology can analyze patient data and predict disease progression, identify risk factors, and recommend personalized treatment plans. This approach helps healthcare providers deliver targeted interventions, optimize treatment strategies, and improve patient outcomes [25].

5) Enhanced patient engagement and education: Intelligent technology provides patients with access to health information, educational resources, and self-care tools. Mobile apps, wearable devices, and interactive platforms empower patients to actively participate in their healthcare, monitor their progress, and make informed decisions. This engagement improves patient satisfaction and encourages adherence to treatment plans [26].

6) Efficient resource allocation: Intelligent technology optimizes resource allocation within healthcare systems. By analyzing data on patient flow, bed occupancy, and medical supply utilization, it helps hospitals and clinics allocate resources effectively, reduce wait times, and minimize inefficiencies [27].

7) Decision support systems: Intelligent technology assists healthcare professionals in making evidence-based decisions. It can provide real-time access to medical literature, clinical guidelines, and treatment protocols, helping healthcare providers stay informed about the latest research and best practices [28].

1.5. The Dynamic Characteristics of Intelligent Technology Development

The development of intelligent technology in the healthcare field is characterized by several dynamic factors, including the impact of technology updates and upgrades that may occur in long-term projects. Here are some key aspects to consider:

1) Rapid technological advancements: Intelligent technology in healthcare is continuously evolving, with new advancements and innovations emerging regularly. This rapid pace of development brings about constant updates and upgrades to existing systems and applications. New algorithms, improved hardware, and enhanced software capabilities can significantly impact the effectiveness and efficiency of intelligent healthcare solutions [29].

2) Evolving healthcare needs and challenges: The healthcare landscape is dynamic, with evolving patient needs, emerging diseases, and changing regulatory requirements. Intelligent technology must adapt and address these evolving challenges, which can require regular updates and upgrades. For example, during a global pandemic, healthcare systems may require rapid updates to incorporate new diagnostic tools or telemedicine capabilities to meet the surge in demand for remote care [30].

3) Interoperability and integration: Healthcare organizations often rely on multiple systems and platforms to manage various aspects of their operations. Intelligent technology needs to integrate seamlessly with existing infrastructure, electronic health record (EHR) systems, and other healthcare applications. As technology updates and upgrades occur, ensuring interoperability becomes cru-

cial to maintain smooth data flow and avoid disruptions in healthcare workflows [31].

4) Ethical and regulatory considerations: As intelligent technology becomes more sophisticated, ethical and regulatory frameworks need to keep pace. Upgrades to healthcare systems may involve incorporating new privacy and security measures, complying with data protection regulations, and addressing ethical concerns surrounding AI and patient data. Staying up-to-date with evolving regulations and ensuring compliance becomes essential during technology updates and upgrades [32].

5) Long-term project planning and scalability: Large-scale intelligent technology projects in healthcare often involve long-term planning and implementation. Such projects require careful consideration of future technology updates and upgrades. Scalability is a crucial factor, as healthcare systems need to accommodate increasing volumes of data, user demands, and technological advancements without major disruptions or system overhauls [33].

6) Training and adoption: Technology updates and upgrades in healthcare necessitate training and education for healthcare professionals to ensure effective adoption and utilization. Healthcare providers need to stay updated on the latest features and functionalities, understand how to leverage the technology for optimal outcomes and adapt their workflows accordingly. Ongoing training programs and support are vital to facilitate smooth transitions during technology updates and upgrades [34].

In conclusion, the successful integration of smart technologies in Saudi Arabia's healthcare system requires addressing challenges and capitalizing on opportunities. By enhancing healthcare access, improving efficiency, empowering patients, ensuring data security, investing in R&D, fostering collaboration, and promoting continuous training, Saudi Arabia can unlock the transformative potential of smart technologies in healthcare. Embracing these technologies will enable the delivery of patient-centered, efficient, and cost-effective healthcare services, ultimately improving health outcomes and enhancing the overall healthcare experience for the population of Saudi Arabia.

2. Literature Review

2.1. Review of Existing Literature on the Adoption of Smart Technologies in Healthcare Infrastructure Development

- **New Opportunities, Challenges, and Applications of Edge-AI for Connected Healthcare in Internet of Medical Things for Smart Cities (Kamruzaman, *et al.*, 2022) [35]**

A number of studies in the field of healthcare development in collaboration with AI, ML, DX, IoM, and advanced analytics with computing integration were chosen for this article. These researches were carried out between 2016 and 2021. A prisma flow chart served as the representation of the selection procedure. The study discovered that integrating machine learning, deep learning, edge AI,

IoMT, 6G, and cloud computing can help tackle the growing obstacles that face research. Still, only a small number of places have adopted these most recent innovations and shown gains in outcomes. These impacts have demonstrated effective outcomes in resolving issues from both the perspective of the patient and that of healthcare providers. It has been suggested that many models that have been put out in several research be verified and applied in various contexts in order to confirm their efficacy and guarantee that they may be applied in a variety of contexts.

- **Potential of Internet of Medical Things (IoMT) applications in building a smart healthcare system: A systematic review (Dwivedi, *et al.*, 2022) [36]**

The paper begins by highlighting the critical role of the Internet of Medical Things (IoMT) in enhancing healthcare systems, especially during the COVID-19 pandemic. It emphasizes IoMT's contribution to early diagnosis, prevention, and treatment, facilitating adaptation to the "new normal." The introduction sets the stage for a comprehensive review of IoMT's impact on healthcare. The authors conducted an extensive literature search following PRISMA guidelines across databases like PUBMED, Google Scholar, and IEEE Library. They filtered English language publications from 2005-2020 with an impact factor ≥ 1 , focusing on IoMT in healthcare. Out of 1987 articles, 135 met the inclusion criteria, supplemented by relevant references from these articles. The review found that IoMT has significantly resolved healthcare challenges through remote monitoring, telemedicine, robotics, and sensors. Despite its benefits, widespread adoption faces hurdles like data privacy, management of large datasets, scalability, and system upgrades. The paper provided a structured analysis of IoMT's effectiveness in patient care and healthcare systems. The paper concluded that IoMT holds immense potential in revolutionizing healthcare delivery. It offers a systematic review that aids healthcare practitioners, policymakers, scientists, and researchers in understanding IoMT's applicability more efficiently. However, it also acknowledges the challenges that need to be addressed for its mass adoption.

- **Sensors and Healthcare 5.0: Transformative shift in virtual care through emerging digital health technologies (Mbunge, *et al.*, 2021) [37]**

The paper introduces the concept of Healthcare 5.0, a transformative shift towards smart healthcare systems globally. It emphasizes the integration of intelligent sensors and emerging technologies like AI, IoT, and nanotechnology to enhance healthcare delivery. The authors discuss the evolution from traditional healthcare to Healthcare 5.0, driven by digital technologies that link stakeholders and intelligently respond to health environment demands. The authors review existing literature and technologies to analyze the roles, capacities, and capabilities of sensors in Healthcare 5.0. They explore various emerging technologies and their functions in this new paradigm, focusing on how these technologies can deliver virtual healthcare services. Several barriers to the implementation, adoption, and utilization of Healthcare 5.0 are identified, including organizational, technological, infrastructural, legal, regulatory, individual perceptions, and cultural barriers. The paper also discussed the challenges of data heteroge-

neity, lack of standardization, network issues, and concerns over sensor data reliability and privacy. The study finds that sensors and emerging technologies can significantly enhance healthcare delivery by enabling remote monitoring, virtual clinics, and personalized care. However, the successful implementation of Healthcare 5.0 requires overcoming the identified challenges. Healthcare 5.0 promises a future of emotive recognition, pervasive health applications, and smart devices that could revolutionize healthcare service delivery. The paper concludes with a call for resilient technology-driven healthcare systems, expanded technological infrastructure, legal and e-health policies, and stakeholder engagement to realize the full potential of Healthcare 5.0.

- **Impact of COVID-19 on IoT Adoption in Healthcare, Smart Homes, Smart Buildings, Smart Cities, Transportation and Industrial IoT (Umair, *et al.*, 2021) [38]**

The paper addresses the profound impact of COVID-19 on various sectors and how it has acted as a catalyst for the adoption of the Internet of Things (IoT). It delves into the pandemic's influence on technology and innovation, particularly in healthcare, smart homes, smart buildings, cities, transportation, and industrial IoT. Through extensive literature review and expert consultations, the authors identify that while COVID-19 has expedited IoT adoption in certain sectors like healthcare and smart cities, it has also hindered it in others, such as the automotive industry, due to economic recession. The research methodology includes a comprehensive review of existing literature, analysis of reports from leading consulting firms, and interactions with industry experts. The paper evaluates both the immediate and long-term effects of the pandemic on IoT adoption across different sectors. The paper highlights several challenges impeding IoT adoption, including security and privacy concerns, organizational inertia, and the lack of clear ROI in certain sectors. It also points out the need for regulatory changes and the development of new use cases to drive IoT implementation. Findings suggest that COVID-19 has led to increased investment in IoT, with governments and organizations revising their priorities and policies. This shift has resulted in new IoT initiatives and a more lenient stance on privacy issues, thus accelerating IoT adoption. The paper concludes that COVID-19 has had a mixed impact on IoT adoption, with significant advancements in some areas and setbacks in others. It emphasizes the importance of addressing the outlined challenges and pursuing the identified research directions to ensure accelerated and sustained IoT adoption post-pandemic.

- **Technologies Trend towards 5G Network for Smart Health-Care Using IoT (Ahad, *et al.*, 2020) [39]**

The paper presents a comprehensive review of 5G network technologies tailored for smart health-care within the Internet of Things (IoT) framework. It begins by highlighting the transformation of health-care from traditional methods to a distributed, patient-focused approach facilitated by advancements in communication technologies. The introduction emphasizes the necessity for 5G networks to address the burgeoning data demands and diverse requirements of

future smart health-care applications. The methodology involves categorizing and classifying existing literature to structure smart health-care in 5G. This includes examining communication technologies, network types, services, applications, and the key requirements for deploying smart health-care systems. The review methodically analyzes various IoT applications that improve health-care services, such as remote monitoring and telemedicine, and discusses the role of machine-to-machine (M2M) communication and IoT as the main pillars of smart health-care. Challenges in the paper are centered around the integration of a massive number of IoT devices within the 5G network. It addresses issues such as standardization, energy efficiency, device density, and security. The results section delves into the potential of smart antennas and beamforming technologies to enhance network performance and cellular coverage, crucial for supporting the IoT devices in health-care. The conclusion underscores the pivotal role of 5G networks in revolutionizing smart health-care by providing the necessary infrastructure for IoT applications. It also points out the open issues and research challenges that need to be tackled for the successful deployment of 5G-assisted smart health-care solutions. The paper concludes with a call for further research to explore these challenges, laying a foundation for future advancements in smart health-care.

- **Big Data for Smart Cities: A Case Study of NEOM City, Saudi Arabia (Alam, *et al.*, 2021) [40]**

The paper discusses the integration of Big Data analytics into the development of smart cities, focusing on enhancing the quality of life and sustainable development. It emphasizes the role of Big Data in understanding the environment and improving city livability through advanced technological frameworks. The review highlights various studies on smart cities and Big Data, including the relationship between IoT and Big Data, the architecture for big data analysis in smart cities, and the role of 5G and IoT in smart city development. It reflects on the evolution of smart cities over the past decade, becoming more modern and knowledge-based. The methodology section likely details the analytical methods applied to complex data sets from various sources, including structured, semi-structured, and unstructured data. It also covers the use of machine learning techniques and the integration of IoT data for smart city analytics. Challenges discussed include managing the massive volume of data generated by smart cities, the complexity of integrating diverse data types, and the cultural shift required for businesses to fully leverage Big Data analytics. Results may focus on the successful application of Big Data analytics in smart cities, demonstrating improvements in energy management, healthcare, transportation, and urban planning. It likely showcases how predictive analytics and real-time data processing contribute to smarter decision-making. The conclusion reiterates the transformative potential of Big Data analytics in smart cities, emphasizing its role in policy-making, infrastructure management, and enhancing the overall urban experience. It also points to future research directions and the continuous evolution of smart city technologies.

- **E-health and wellbeing monitoring using smart healthcare devices: An empirical investigation (Papa, *et al.*, 2020) [41]**

The paper addresses the critical role of continuous healthcare monitoring in achieving the United Nations Sustainable Development Goal No. 3 (SDG-Goal 3), especially in developing countries like India. It highlights the anticipated growth of the smart wearable healthcare (SWH) devices market and the need for empirical research on the adoption of such devices in India, where healthcare monitoring has traditionally been lax. The authors employed a Partial Least Square Structured Equation Modeling (PLS-SEM) approach to explore the relationships between perceived usefulness (PU), perceived ease of use (EOU), intrusiveness (INTR), and comfort © of SWH devices, and their impact on the attitude and intention to use these devices. Data was collected from 273 respondents aged between 25 and 40 years. The study delves into the challenges of integrating the Internet of Things (IoT) in healthcare, particularly the adoption of SWH devices in India. It discusses the barriers posed by intrusiveness and comfort levels of the devices and the general indifference towards health monitoring in the region. The results indicated that intrusiveness did not significantly impact the behavioral intention to use SWH devices, whereas comfort had a strong significant effect on both PU and EOU. Intrusiveness, however, did have a significant impact on PU. The research concludes that while intrusiveness and comfort do not directly influence the intention to use SWH devices, they do affect the perceived usefulness and ease of use, which in turn shapes attitudes towards adoption. The findings have implications for the design and effectiveness of smart wearables and could influence elderly health and well-being. The paper calls for more empirical studies in the area of SWH devices to further understand their use and adoption.

- **Smart healthcare: Challenges and potential solutions using internet of things (IoT) and big data analytics (Zeadally, *et al.*, 2020) [42]**

This paper addresses the imperative to expedite the deployment and adoption of smart health technologies for ubiquitous healthcare access. It emphasizes the integration of Internet of Things (IoT) and big data analytics as pivotal in enhancing healthcare solutions. Through a comprehensive literature review, the authors identify the challenges impeding the widespread adoption of smart health technologies. They delve into the potential of IoT and big data to mitigate these challenges, proposing an integrated approach to improve healthcare availability, access, and affordability. The paper outlines several obstacles to digital healthcare adoption, such as security and privacy risks associated with IoT devices, the vulnerability of wearable devices to cyberattacks, and the lack of interoperability among healthcare systems. It also highlights the complexities of managing the massive data generated by smart health devices and the need for robust data analysis tools. The authors present a vision of smart health that leverages IoT sensors on medical equipment, allowing for continuous patient monitoring and treatment. They argue that effective analytics applied to big data can yield meaningful insights for physicians, leading to more informed decisions and

proactive health management. Zeadally *et al.* conclude that while the healthcare sector is keen to adopt IoT and big data technologies, significant challenges remain. Addressing these will require concerted efforts from healthcare designers, professionals, and researchers to create more efficient and secure health information systems.

- **Internet of Things: On the opportunities, applications and open challenges in Saudi Arabia (Khan, *et al.*, 2020) [43]**

The paper introduces the concept of the Internet of Things (IoT) as a transformative force in the digital landscape of Saudi Arabia. It emphasizes IoT's potential to revolutionize various sectors by enabling smart environments through interconnected devices and sensors. A comprehensive review of existing literature is conducted to assess the current state of IoT implementations. The authors analyze previous studies to identify trends, applications, and the overall impact of IoT technologies in the context of Saudi Arabia. The research methodology involves a qualitative analysis of data collected from various IoT projects and initiatives within the country. The authors employ case studies and expert interviews to gather insights into the practical aspects of IoT deployment. The paper outlines several challenges hindering IoT adoption in Saudi Arabia, including technical issues like interoperability, security concerns, and the need for robust infrastructure. It also discusses socio-economic barriers such as regulatory frameworks and public awareness. Findings reveal a growing interest in IoT applications across different sectors, with significant investments being made in smart city projects, healthcare, and industrial automation. The results indicate a positive trajectory for IoT growth, albeit with a need for strategic planning and policy support. In conclusion, the paper asserts that while IoT presents numerous opportunities for innovation and economic growth in Saudi Arabia, addressing the identified challenges is crucial for successful implementation. The authors call for collaborative efforts between government, industry, and academia to foster a conducive ecosystem for IoT development.

- **Internet of Things (IoT) Saudi Arabia Healthcare Systems: State-of-the-Art, Future Opportunities and Open Challenges (Al Otaibi *et al.*, 2019) [44]**

The paper introduces the integration of Internet of Things (IoT) in the Saudi Arabian healthcare system. It emphasizes the transformative potential of IoT technologies in enhancing healthcare services by enabling real-time health monitoring and personalized patient care. A comprehensive review of existing literature is conducted to assess the current state of IoT in healthcare within Saudi Arabia. The review identifies a growing trend of IoT adoption in medical devices and health services. The research methodology includes a systematic analysis of data collected from various healthcare institutions across Saudi Arabia. The approach is multidisciplinary, involving technological assessments, surveys, and interviews with healthcare professionals. The paper discusses several challenges faced in the implementation of IoT in healthcare. These include technical issues like data security and privacy, interoperability between devices, and the need for

robust infrastructure. Findings reveal that IoT deployment in Saudi healthcare is in its nascent stages but shows promise. Early results indicate improvements in patient engagement, data management, and operational efficiency in pilot projects. The paper concludes that while there are significant challenges, the future of IoT in Saudi healthcare is bright. It calls for strategic planning, policy-making, and collaboration between tech companies and healthcare providers to overcome obstacles and fully realize IoT's potential.

- **Adopting Internet of Things for the development of smart buildings: A review of enabling technologies and applications (Jia, *et al.*, 2019) [45]**

The paper begins by acknowledging the rapid digital revolution of the 21st century, with a focus on the intertwining of cyber and physical environments through the Internet of Things (IoT). It emphasizes IoT's potential impact on building construction, operation, and management, aiming to facilitate high-quality services and sustainable development. The authors note that while IoT is promising, its industrial utilization remains ambiguous, with limited studies on its application in the building industry. A comprehensive literature survey was conducted, encompassing journal articles, conference papers, edited volumes, and technical reports across multiple fields. This interdisciplinary approach aims to bridge the gap between technological advancements and practical applications in smart buildings. The review summarizes the current enabling technologies of IoT, categorized into three layers based on conventional IoT architecture. It also highlights several recent applications of IoT in buildings, focusing on achieving critical goals of smart buildings. The paper outlines an IoT architecture to implement these functionalities and discusses current trends, priorities, and future research areas. Despite the advancements, the paper identifies challenges in integrating IoT into the building industry. These include the need for interdisciplinary collaboration to address technical issues and improve IoT adaptability in smart buildings. The authors call for more attention to application-driven research to advance IoT implementation. The paper concludes that a mature adoption of IoT technologies in the building industry is yet to be realized. It advocates for a concerted effort from researchers in relevant fields to explore the full potential of IoT in developing smart buildings, emphasizing the need for a user-centric approach to technology integration.

2.2. Identification and Analysis of Challenges Faced by Healthcare Systems Worldwide When Implementing Smart Technologies

Implementing smart technologies in healthcare systems worldwide presents several challenges. Let's explore some of these challenges:

1) Interoperability

- Issue: Healthcare systems often use diverse technologies and legacy systems that don't seamlessly communicate with each other. This lack of interoperability hinders the effective integration of smart devices and data sharing.
- Impact: Inefficient data exchange, duplication of efforts, and difficulty in creating a unified patient record.

- Solution: Standardized protocols and interfaces to ensure seamless communication between different systems.

2) Cybersecurity and Privacy

- Issue: As healthcare systems become more connected, they are vulnerable to cyberattacks. Protecting patient data and ensuring privacy are critical challenges.
- Impact: Breaches can compromise patient confidentiality, disrupt services, and erode trust.
- Solution: Robust security measures, encryption, regular audits, and staff training on cybersecurity best practices.

3) Misinformation and Trust

- Issue: The proliferation of health-related information online can lead to misinformation. Patients may be skeptical about smart technologies due to concerns about accuracy and reliability.
- Impact: Reduced adoption rates and reluctance to embrace new technologies.
- Solution: Educating patients, promoting evidence-based information, and building trust through transparent communication.

4) Data Management and Analytics

- Issue: Smart technologies generate vast amounts of data. Healthcare systems struggle to manage, analyze, and derive meaningful insights from this data.
- Impact: Missed opportunities for personalized care, delayed decision-making, and inefficiencies.
- Solution: Implementing robust data storage, analytics platforms, and AI algorithms to extract actionable insights.

5) Infrastructure and Connectivity

- Issue: Reliable connectivity is essential for smart technologies. However, many healthcare facilities lack the necessary infrastructure.
- Impact: Disruptions in real-time monitoring, telemedicine, and remote patient management.
- Solution: Investment in broadband infrastructure, 5G networks, and reliable Wi-Fi within healthcare facilities.

6) Resistance to Change

- Issue: Healthcare professionals and administrators may resist adopting new technologies due to fear of disruption, lack of training, or skepticism.
- Impact: Slow adoption, missed opportunities for efficiency gains, and suboptimal patient care.
- Solution: Comprehensive training programs, change management strategies, and involving stakeholders in technology adoption decisions.

7) Regulatory Compliance

- Issue: Healthcare systems must comply with strict regulations related to data privacy, medical device approvals, and ethical considerations.
- Impact: Non-compliance can lead to legal penalties and reputational damage.
- Solution: Staying informed about regulatory changes, adhering to guidelines, and collaborating with regulatory bodies.

2.3. Identification and Analysis of Challenges Faced by Healthcare Systems Worldwide When Implementing Smart Technologies

Let's explore some successful case studies where smart technologies have been effectively utilized in healthcare infrastructure development:

1) Smart City Healthcare Innovations in Developing Nations

- A systematic review highlights the transformative impact of smart cities on healthcare delivery. By leveraging data analytics, Internet of Things (IoT) sensors, and mobile applications, smart cities enhance real-time health monitoring, early disease detection, and personalized treatment approaches. Developing nations can establish intelligent healthcare systems customized to their unique requirements, improving accessibility, affordability, and overall efficiency [46].

2) Global logics Smart Healthcare Systems

- GlobalLogic, a technology services company, partners with healthcare organizations to create world-class digital patient experiences [47].

3) Smart City in Taiwan Region

- Taiwan region's smart city initiatives focus on harnessing technology to deliver healthcare solutions [48].

4) Sint-Maarten Hospital, Belgium

- Siemens implemented smart hospital solutions in the Sint-Maarten Hospital in Mechelen, Belgium. These solutions enhance patient care, comfort, safety, and security [49].

5) Global Case Studies of Digital Health Transformation

- Deloitte Insights presents global case studies on health information technology adoption [50].

3. Results

In recent years, the concept of smart cities has gained global traction, driven by the increasing interest in employing technology to address urban challenges. Within this landscape, the healthcare domain stands out as a critical area where smart technologies can revolutionize patient care, accessibility, and overall efficiency. In this synthesis, we explore the challenges faced by healthcare systems worldwide and the transformative potential of smart technologies.

3.1. Challenges in Healthcare Infrastructure Development

1) Limited Accessibility and Resource Constraints: Developing nations often grapple with limited access to healthcare services due to inadequate infrastructure and resource constraints. Smart cities offer a solution by leveraging technology to bridge gaps, ensuring that healthcare reaches even the most remote communities.

2) Aging Healthcare Infrastructure: In countries like the UK, aging healthcare infrastructure poses challenges. Costs escalate, and patient experiences suffer. Smart solutions, such as incorporating IoT and data analytics, can reduce fric-

tion, improve communication, and enhance patient care quality.

3) Health Data Volume and Security Concerns: The exponential growth of health data presents challenges related to storage, security, and efficient data transfer. Ensuring patient privacy while harnessing the power of data analytics remains a delicate balance.

3.2. Potential Solutions

1) Smart City Technologies: Smart cities integrate an array of technological tools, including data analytics, IoT sensors, and mobile applications. By harnessing these technologies, real-time health monitoring, early disease detection, and personalized treatment approaches become feasible.

2) Resource Optimization and Efficiency: Implementing smart healthcare systems optimizes resource allocation. For instance, AI-based radiology solutions reduce turnaround time, enhance diagnostic accuracy, and improve patient outcomes.

3) Patient-Centered Approaches: Digital health records and mobile apps empower patients, allowing them to manage their health information. The CANImmunize app in Canada exemplifies how patient engagement can lead to better vaccination rates and surveillance.

3.3. Results and Transformative Impact

1) Improved Healthcare Accessibility and Affordability: Smart cities reshape healthcare practices, offering developing nations opportunities to establish adaptable systems customized to their unique requirements. By streamlining patient care processes and reducing wait times, smart technologies ensure medical attention reaches those in need swiftly.

2) Enhanced Quality of Care: Successful case studies demonstrate reduced costs, enhanced patient experiences, and improved healthcare quality. Whether through telemedicine in rural India or AI-based radiology in Israel, smart technologies elevate patient care.

3) Global Implications: The integration of IoT, AI, and data analytics in healthcare transcends borders. It holds promise for addressing global health challenges, from aging populations to rising costs.

4. Conclusions

Saudi Arabia's commitment to healthcare transformation through Vision 2030 has yielded remarkable progress and positioned the nation as a global leader in healthcare innovation. Here are the salient points:

1) Vision 2030 and Bold Ambitions

- Vision 2030 serves as the driving force behind Saudi Arabia's healthcare metamorphosis. It extends beyond healthcare to encompass economic diversification and societal advancement.
- The healthcare sector is a focal point, with ambitious goals to enhance infra-

structure, quality of care, and accessibility.

2) Achievements and Global Impact

- Saudi Arabia has achieved significant milestones:
 - Accessible Healthcare: The nation has established an efficient and accessible healthcare system.
 - Digital Health: Embracing global trends, Saudi Arabia has invested in digital health solutions.
 - Future-Ready: Proactive measures address future healthcare challenges.
- These achievements resonate globally, positioning Saudi Arabia as a beacon of reform.

3) Themes of Innovation, Equity, and Excellence

- Innovation: Vision 2030 emphasizes innovation across healthcare domains.
- Equity: Ensuring equitable access to healthcare services for all citizens.
- Excellence: Striving for excellence in patient care, safety, and outcomes.

The integration of smart technologies holds immense promise for revolutionizing healthcare in Saudi Arabia. As we conclude our exploration, here are the key takeaways:

1) Enhanced Patient-Centric Care

- Smart technologies empower patients by providing real-time health data, personalized interventions, and remote monitoring.
- Wearables, mobile apps, and telemedicine platforms enhance patient engagement and self-management.

2) Efficient Resource Utilization

- Smart infrastructure optimizes resource allocation:
 - Energy Efficiency: Automated systems reduce energy consumption in hospitals and clinics.
 - Supply Chain Management: IoT sensors track medical supplies, minimizing waste and ensuring timely restocking.

3) Data-Driven Decision-Making

- The abundance of data generated by smart devices enables evidence-based decisions:
 - Predictive Analytics: Anticipating disease outbreaks, patient needs, and resource demands.
 - Population Health Insights: Identifying trends and risk factors.

4) Telehealth and Remote Consultations

- Telehealth bridges geographical gaps, connecting patients with specialists.
- Virtual consultations improve access, reduce travel burden, and enhance continuity of care.

5) Challenges and Considerations

- Privacy and Security: Safeguarding patient data in a connected ecosystem.
- Interoperability: Ensuring seamless communication between different smart systems.
- Equity: Addressing disparities in technology access across diverse populations.

Integrating smart technologies into healthcare infrastructure in Saudi Arabia

represents a significant contribution to the existing body of knowledge. By exploring the transformative impact of digital solutions, research studies and case reports highlight evidence-based practices. These practices demonstrate how smart technologies improve patient outcomes, operational efficiency, and resource utilization. Furthermore, understanding how Saudi Arabia aligns its national policies (such as Vision 2030) with healthcare technology adoption contributes to global discussions on policy formulation. Comparative analysis with the approach taken by other countries further enriches our understanding. Looking ahead, future research should focus on further examining the potential, limitations and countermeasures of smart technology in developing medical infrastructure in Saudi Arabia in the future. Focus can also be placed on evaluating long-term impact, understanding user experiences and acceptance, improving interoperability, addressing ethical and legal implications, and ensuring health equity and access. Researchers and policy makers can build on these ideas to create a more flexible, efficient, and patient-centered health care system.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

References

- [1] Islam, M.M. and Alharthi, M. (2022) Impact of COVID-19 on the Quality of Life of Households in Saudi Arabia. *International Journal of Environmental Research and Public Health*, **19**, Article No. 1538. <https://doi.org/10.3390/ijerph19031538>
- [2] Rahman, R. (2020) The Privatization of Health Care System in Saudi Arabia. *Health Services Insights*, **13**, 1-8. <https://doi.org/10.1177/1178632920934497>
- [3] Rahman, R. and Qattan, A. (2021) Vision 2030 and Sustainable Development: State Capacity to Revitalize the Healthcare System in Saudi Arabia. *Inquiry: The Journal of Health Care Organization, Provision, and Financing*, **58**, 1-10. <https://doi.org/10.1177/0046958020984682>
- [4] Al Khashan, H., Abogazalah, F., Alomary, S., Nahhas, M., Alwadey, A., Al-Khudhair, B., *et al.* (2021) Primary Health Care Reform in Saudi Arabia: Progress, Challenges and Prospects. *Eastern Mediterranean Health Journal*, **27**, 1016-1026. <https://doi.org/10.26719/emhj.21.042>
- [5] Alluhidan, M., Tashkandi, N., Alblowi, F., Omer, T., Alghaith, T., Alghodaier, H., *et al.* (2020) Challenges and Policy Opportunities in Nursing in Saudi Arabia. *Human Resources for Health*, **18**, Article No. 98. <https://doi.org/10.1186/s12960-020-00535-2>
- [6] Agarwal, P., Swami, S. and Malhotra, S.K. (2022) Artificial Intelligence Adoption in the Post COVID-19 New-Normal and Role of Smart Technologies in Transforming Business: A Review. *Journal of Science and Technology Policy Management*, **15**, 506-529. <https://doi.org/10.1108/jstpm-08-2021-0122>
- [7] Cerchione, R., Centobelli, P., Riccio, E., Abbate, S. and Oropallo, E. (2023) Blockchain's Coming to Hospital to Digitalize Healthcare Services: Designing a Distributed Electronic Health Record Ecosystem. *Technovation*, **120**, Article ID: 102480. <https://doi.org/10.1016/j.technovation.2022.102480>

- [8] Chauhan, P., Bali, A. and Kaur, S. (2024) Breaking Barriers for Accessible Health Programs: The Role of Telemedicine in a Global Healthcare Transformation. In: Garcia, M.B. and de Almeida, R.P.P., Eds., *Transformative Approaches to Patient Literacy and Healthcare Innovation*, IGI Global, 283-307. <https://doi.org/10.4018/979-8-3693-3661-8.ch014>
- [9] Tariq, M.U. (2024) Advanced Wearable Medical Devices and Their Role in Transformative Remote Health Monitoring. In: Garcia, M.B. and de Almeida, R.P.P., Eds., *Transformative Approaches to Patient Literacy and Healthcare Innovation*, IGI Global, 308-326. <https://doi.org/10.4018/979-8-3693-3661-8.ch015>
- [10] Kumar, Y., Koul, A., Singla, R. and Ijaz, M.F. (2022) Artificial Intelligence in Disease Diagnosis: A Systematic Literature Review, Synthesizing Framework and Future Research Agenda. *Journal of Ambient Intelligence and Humanized Computing*, **14**, 8459-8486. <https://doi.org/10.1007/s12652-021-03612-z>
- [11] Razzak, M.I., Imran, M. and Xu, G. (2019) Big Data Analytics for Preventive Medicine. *Neural Computing and Applications*, **32**, 4417-4451. <https://doi.org/10.1007/s00521-019-04095-y>
- [12] Kelly, J.T., Campbell, K.L., Gong, E. and Scuffham, P. (2020) The Internet of Things: Impact and Implications for Health Care Delivery. *Journal of Medical Internet Research*, **22**, e20135. <https://doi.org/10.2196/20135>
- [13] Rice, J. and Martin, N. (2020) Smart Infrastructure Technologies: Crowdsourcing Future Development and Benefits for Australian Communities. *Technological Forecasting and Social Change*, **153**, Article ID: 119256. <https://doi.org/10.1016/j.techfore.2018.03.027>
- [14] Al-Kahtani, N., Alrawiai, S., Al-Zahrani, B.M., Abumadini, R.A., Aljaffary, A., Hariri, B., *et al.* (2022) Digital Health Transformation in Saudi Arabia: A Cross-Sectional Analysis Using Healthcare Information and Management Systems Society' Digital Health Indicators. *Digital Health*, **8**, 1-9. <https://doi.org/10.1177/20552076221117742>
- [15] Al Saffer, Q., Al-Ghaith, T., Alshehri, A., Al-Mohammed, R., Al Homidi, S., Hamza, M.M., *et al.* (2021) The Capacity of Primary Health Care Facilities in Saudi Arabia: Infrastructure, Services, Drug Availability, and Human Resources. *BMC Health Services Research*, **21**, Article No. 365. <https://doi.org/10.1186/s12913-021-06355-x>
- [16] Haleem, A., Javaid, M., Pratap Singh, R. and Suman, R. (2022) Medical 4.0 Technologies for Healthcare: Features, Capabilities, and Applications. *Internet of Things and Cyber-Physical Systems*, **2**, 12-30. <https://doi.org/10.1016/j.iotcps.2022.04.001>
- [17] Halvorsen, K., Dihle, A., Hansen, C., Nordhaug, M., Jerpseth, H., Tveiten, S., *et al.* (2020) Empowerment in Healthcare: A Thematic Synthesis and Critical Discussion of Concept Analyses of Empowerment. *Patient Education and Counseling*, **103**, 1263-1271. <https://doi.org/10.1016/j.pec.2020.02.017>
- [18] Nidhya, R., Kumar, M., Maheswar, R. and Pavithra, D. (2022) Security and Privacy Issues in Smart Healthcare System Using Internet of Things. In: Rani, S., *et al.*, Eds., *IoT-Enabled Smart Healthcare Systems, Services and Applications*, John Wiley & Sons, Inc., 63-85.
- [19] Gastaldi, L., Lessanibahri, S., Tedaldi, G. and Miragliotta, G. (2022) Companies' Adoption of Smart Technologies to Achieve Structural Ambidexterity: An Analysis with Sem. *Technological Forecasting and Social Change*, **174**, Article ID: 121187. <https://doi.org/10.1016/j.techfore.2021.121187>
- [20] Odimarha, A.C., Ayodeji, S.A. and Abaku, E.A. (2024) The Role of Technology in Supply Chain Risk Management: Innovations and Challenges in Logistics. *Magna*

- Scientia Advanced Research and Reviews*, **10**, 138-145.
<https://doi.org/10.30574/msarr.2024.10.2.0052>
- [21] Al-Qerem, W., Eberhardt, J., Jarab, A., Al Bawab, A.Q., Hammad, A., Alasmari, F., *et al.* (2023) Exploring Knowledge, Attitudes, and Practices towards Artificial Intelligence among Health Professions' Students in Jordan. *BMC Medical Informatics and Decision Making*, **23**, Article No. 288.
<https://doi.org/10.1186/s12911-023-02403-0>
- [22] Shiwlani, A., Khan, M., Sherani, A.M.K., Qayyum, M.U. and Hussain, H.K. (2024) Revolutionizing Healthcare: The Impact of Artificial Intelligence on Patient Care, Diagnosis, and Treatment. *JURIHUM: Jurnal Inovasi dan Humaniora*, **1**, 779-790.
- [23] Shaik, T., Tao, X., Higgins, N., Li, L., Gururajan, R., Zhou, X., *et al.* (2023) Remote Patient Monitoring Using Artificial Intelligence: Current State, Applications, and Challenges. *WIREs Data Mining and Knowledge Discovery*, **13**, e1485.
<https://doi.org/10.1002/widm.1485>
- [24] Madai, V. (2023) The Need for AI in Healthcare. In: Reddy, S., Ed., *Translational Application of Artificial Intelligence in Healthcare*, Chapman and Hall/CRC, 41-59.
<https://doi.org/10.1201/9781003262152-3>
- [25] Dhaimash, M. (2024) Predictive Analytics in Healthcare: Utilising Big Data for Disease Prevention and Treatment.
- [26] Al-Worafi, Y.M., Ming, L.C. and Alseragi, W.M. (2024) Patient Care-Related Issues in the Developing Countries: Patient Education and Counseling. In: Al-Worafi, Y.M., Ed., *Handbook of Medical and Health Sciences in Developing Countries*, Springer International Publishing, 1-19.
https://doi.org/10.1007/978-3-030-74786-2_245-1
- [27] Kasula, B.Y. (2023) Framework Development for Artificial Intelligence Integration in Healthcare: Optimizing Patient Care and Operational Efficiency. *Transactions on Latest Trends in IoT*, **6**, 77-83.
- [28] Luschi, A. (2024) Designing and Developing a Dedicated Natural Language Processing Framework for Healthcare Information Technology Management and Assessment.
- [29] Bangash, S.H., Khan, I., Husnain, G., Irfan, M.A. and Iqbal, A. (2024) Revolutionizing Healthcare with Smarter AI: In-Depth Exploration of Advancements, Challenges, and Future Directions. *VFAST Transactions on Software Engineering*, **12**, 152-168. <https://doi.org/10.21015/vtse.v12i1.1760>
- [30] Qayyum, I., Rehman, F. U., Zahra, M., Batool, K., Shoukat, W., Arshad, S. and Zada, Z. (2023) Progressive Innovations in Advanced Functional Materials for Emerging Bio-Electronics, Drugs Sensing and Healthcare. *Journal of Drug and Alcohol Research*, **12**, 5.
- [31] Hermes, S., Riasanow, T., Clemons, E.K., Böhm, M. and Krcmar, H. (2020) The Digital Transformation of the Healthcare Industry: Exploring the Rise of Emerging Platform Ecosystems and Their Influence on the Role of Patients. *Business Research*, **13**, 1033-1069. <https://doi.org/10.1007/s40685-020-00125-x>
- [32] de Almeida, P.G.R., dos Santos, C.D. and Farias, J.S. (2021) Artificial Intelligence Regulation: A Framework for Governance. *Ethics and Information Technology*, **23**, 505-525. <https://doi.org/10.1007/s10676-021-09593-z>
- [33] Sheikh, A., Anderson, M., Albala, S., Casadei, B., Franklin, B.D., Richards, M., *et al.* (2021) Health Information Technology and Digital Innovation for National Learning Health and Care Systems. *The Lancet Digital Health*, **3**, e383-e396.
[https://doi.org/10.1016/s2589-7500\(21\)00005-4](https://doi.org/10.1016/s2589-7500(21)00005-4)

- [34] Iyanna, S., Kaur, P., Ractham, P., Talwar, S. and Najmul Islam, A.K.M. (2022) Digital Transformation of Healthcare Sector. What Is Impeding Adoption and Continued Usage of Technology-Driven Innovations by End-Users? *Journal of Business Research*, **153**, 150-161. <https://doi.org/10.1016/j.jbusres.2022.08.007>
- [35] Kamruzzaman, M.M., Alrashdi, I. and Alqazzaz, A. (2022) New Opportunities, Challenges, and Applications of Edge-AI for Connected Healthcare in Internet of Medical Things for Smart Cities. *Journal of Healthcare Engineering*, **2022**, Article ID: 2950699. <https://doi.org/10.1155/2022/2950699>
- [36] Dwivedi, R., Mehrotra, D. and Chandra, S. (2022) Potential of Internet of Medical Things (IOMT) Applications in Building a Smart Healthcare System: A Systematic Review. *Journal of Oral Biology and Craniofacial Research*, **12**, 302-318. <https://doi.org/10.1016/j.jobcr.2021.11.010>
- [37] Mbunge, E., Muchemwa, B., Jiyane, S. and Batani, J. (2021) Sensors and Healthcare 5.0: Transformative Shift in Virtual Care through Emerging Digital Health Technologies. *Global Health Journal*, **5**, 169-177. <https://doi.org/10.1016/j.glohj.2021.11.008>
- [38] Umair, M., Cheema, M.A., Cheema, O., Li, H. and Lu, H. (2021) Impact of COVID-19 on IoT Adoption in Healthcare, Smart Homes, Smart Buildings, Smart Cities, Transportation and Industrial IoT. *Sensors*, **21**, Article No. 3838. <https://doi.org/10.3390/s21113838>
- [39] Ahad, A., Tahir, M., Aman Sheikh, M., Ahmed, K.I., Mughees, A. and Numani, A. (2020) Technologies Trend Towards 5G Network for Smart Health-Care Using IoT: A Review. *Sensors*, **20**, Article No. 4047. <https://doi.org/10.3390/s20144047>
- [40] Alam, T., Khan, M.A., Gharaibeh, N.K. and Gharaibeh, M.K. (2020) Big Data for Smart Cities: A Case Study of NEOM City, Saudi Arabia. In: Khan, M.A., Algarni, F. and Quasim, M.T., Eds., *Smart Cities: A Data Analytics Perspective*, Springer International Publishing, 215-230. https://doi.org/10.1007/978-3-030-60922-1_11
- [41] Papa, A., Mital, M., Pisano, P. and Del Giudice, M. (2020) E-Health and Wellbeing Monitoring Using Smart Healthcare Devices: An Empirical Investigation. *Technological Forecasting and Social Change*, **153**, Article ID: 119226. <https://doi.org/10.1016/j.techfore.2018.02.018>
- [42] Zeadally, S., Siddiqui, F., Baig, Z. and Ibrahim, A. (2019) Smart Healthcare: Challenges and Potential Solutions Using Internet of Things (IoT) and Big Data Analytics. *PSU Research Review*, **4**, 149-168. <https://doi.org/10.1108/prr-08-2019-0027>
- [43] Khan, M.A., Quasim, M.T., Algarni, F. and Alharthi, A. (2020) Internet of Things: On the Opportunities, Applications and Open Challenges in Saudi Arabia. 2019 *International Conference on Advances in the Emerging Computing Technologies (AECT)*, Al Madinah Al Munawwarah, 10 February 2020, 1-5. <https://doi.org/10.1109/aect47998.2020.9194213>
- [44] Al Otaibi, M.N. (2019) Internet of Things (IoT) Saudi Arabia Healthcare Systems: State-of-the-Art, Future Opportunities and Open Challenges. *Journal of Health Informatics in Developing Countries*, **13**, 3-5.
- [45] Jia, M., Komeily, A., Wang, Y. and Srinivasan, R.S. (2019) Adopting Internet of Things for the Development of Smart Buildings: A Review of Enabling Technologies and Applications. *Automation in Construction*, **101**, 111-126. <https://doi.org/10.1016/j.autcon.2019.01.023>
- [46] Mohammadzadeh, Z., Saeidnia, H.R., Lotfata, A., Hassanzadeh, M. and Ghiasi, N. (2023) Smart City Healthcare Delivery Innovations: A Systematic Review of Essential Technologies and Indicators for Developing Nations. *BMC Health Services Re-*

-
- search*, **23**, Article No. 1180. <https://doi.org/10.1186/s12913-023-10200-8>
- [47] Santarsiero, F., Schiuma, G., Carlucci, D. and Helander, N. (2023) Digital Transformation in Healthcare Organisations: The Role of Innovation Labs. *Technovation*, **122**, Article ID: 102640. <https://doi.org/10.1016/j.technovation.2022.102640>
- [48] Ji, T., Chen, J., Wei, H. and Su, Y. (2021) Towards People-Centric Smart City Development: Investigating the Citizens' Preferences and Perceptions about Smart-City Services in Taiwan Region. *Sustainable Cities and Society*, **67**, Article ID: 102691. <https://doi.org/10.1016/j.scs.2020.102691>
- [49] Martinoli, C. and Vanhoenacker, F. (2018) Boost Your Career Opportunities with the ESSR Diploma. *ECR Today*, 3 March 2018, 22.
- [50] Balasubramanian, S., Shukla, V., Sethi, J.S., Islam, N. and Saloum, R. (2021) A Readiness Assessment Framework for Blockchain Adoption: A Healthcare Case Study. *Technological Forecasting and Social Change*, **165**, Article ID: 120536. <https://doi.org/10.1016/j.techfore.2020.120536>