Data-Driven Technologies for Global Healthcare Practices and COVID-19: Opportunities and Challenges

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Abstract

This paper discusses the applications of data-driven technologies in managing healthcare data services and information systems, as well as how they stimulate innovations to bring major improvements in the industry. The study explores the novel applications of digital technologies such Big Data, AI, 3D Printing, and Blockchain and the most challenging parts of data security, privacy, and interoperability in healthcare organisations. Whilst the number of articles on this subject have been steadily increasing owing to the sweeping health crisis of COVID-19 Pandemic, there is absence of systematic literature review that comprehensively explored the existing and potential applications of these digital data-driven innovations in response to the pandemic, and in handling healthcare data services. The review outlined six principal facets namely: hospitals practices, clinical services, patients' home, nursing homes, rural areas, and anywhere, which provided the useful insights and the journey involved in the emergence of data-driven technologies for healthcare Practices. These facets are built across the multiple levels and unique conceptual standpoints indicated by 10 sub-themes. These themes were generated based on 77 articles (2010-2022) drawn from 40 leading Journals. Overall, there is a considerable consensus across current literature that digital data-driven technologies extend far beyond mitigating the significant impacts of coronavirus on healthcare industry. They have the potential to support and provide more responsive digital solutions to the data management crises that industry has been characterised, such as high demands of rising aging populations with chronic diseases, child mortality and potential impacts of pandemics.

Keywords: Data-Driven technologies; Healthcare data management; Industry 4.0; Internet of Things; Ethical issues; COVID-19 Pandemic.

1. Introduction

Healthcare is becoming increasingly a difficult sector to manage due to insufficient and less effective healthcare services. The industry has also been characterised with high demands of rising aging populations with chronic diseases, child mortality and frequent impacts of pandemics like the recent COVID-19 (Farahani et al., 2017). According to Manero et al. (2020), coronavirus pandemic has provided a unique set of global supply chain limitations with an exponential growing surge of patients requiring care and Personal Protective Equipment (PPE) for hospital staff and doctors.

Besides the significant impacts of coronavirus on Healthcare industry, the pandemic had devastating effects that cut across industries and businesses, and the effects are still evolving. Chamola et al. (2020; cited by Ogbuke et al.,2020) confirm that COVID-19 pandemic has adversely impacted several industries, ranging from automotive sector, tourism industry, aviation industry, oil and gas industry, construction industry, telecom sector, food industry, to healthcare industry. In fact, 94% of the Fortune 1000 companies were reported to have experienced coronavirus-driven SC disruptions (Dun and Bradstreet, 2020; Ivanov and Dolgui, 2020; cited by Ogbuke et al., 2020).

Moreover, the issue of data management in the global healthcare practices has become more challenging, with the recent pandemic outbreak. This novel virus is unprecedented and quite tragic, especially in tracking and tracing of the data, as patients infected by this virus may either be asymptomatic (no detectable sign of symptoms) or symptomatic - with mild fever, sore throat and cough, as well as severe clinical symptoms like pneumonia, respiratory failure and, ultimately death. Likewise, Sayi et al. (2019) have highlighted that healthcare industry is a data-intensive clinical environment where a huge amount of data is generated, accessed, disseminated on regulated basis, and shared for essential clinical decision making.

Therefore, the authors argued that hospitals are becoming bigger with little resources to admit, treat, operate, or monitor the increasing number of patients. And worse still, the numbers of old adults (over 60 years of age) are expected to grow globally more than double, from 841 million individuals in 2013 to more than 2 billion by 2050 (Miorandi et al., 2012; cited by Farahani et al., 2017). Yet, we still live in the traditional model of hospital-centric care, in which citizens visit doctors when they are sick - A model that is more reactive and less proactive, and do not involve patients as an active part of the medical process.

However, there is an emerging model for healthcare services that is Patient-Centred (PCC) and Data-Driven, which ensures smooth operations of the industry. This model focuses on the patients and their individual healthcare needs. The model is also dependent on Smart and Digital Data-Driven technologies like Big Data Analytics, Artificial intelligence (IA), 3D Printing, Internet of things (IoT), Blockchain, as well as the miniature wearable bio-sensors for personalised Electronic Health Records (EHR) and services (Manero et al., 2020). More importantly, the supply chain shocks and adaptations amid the covid-19 pandemic and post-pandemic recoveries provided indisputable evidence for the urgent needs of digital techniques for mapping supply chain networks and ensure visibility (Ivanov and Dolgui, 2020; cited by Ogbuke et al., 2020).

According to Sayi et al. (2019), researchers have tried in the past couple of years to implement applications of internet of things, artificial intelligence, machine learning and computer vision to facilitate doctors and clinical practitioners in the diagnosis and treatment of various chronic diseases. The scholars have also suggested how healthcare services can collect, transport, shared and process different types of patient's health data including heartbeats, blood pressure, and glucose level through smart devices or wearable sensors and store them in the cloud or wireless networks layers. Several other scholars (Zhang et al., 2016; Azaria et al., 2016; Kuo et al., 2017; Angraal et al., 2017; cited by Sayi et al., 2019) have also explored with remarkable interest the utilization and applications of blockchains for the delivery of safe and secure healthcare data and biomedical for e-health data sharing.

Recently, Yaqoob et al. (2021) have confirm the emerging roles of blockchain technology and how it can be leveraged for healthcare data management systems and employed to stimulate innovations, and bring major improvement in the industry. The authors suggest that this emerging technology offers unprecedented data efficiency and transparency, provides decentralized storage, immutability, and authentication, as well as data access, flexibility, interconnection, and data security and privacy for the general healthcare service users. Similarly, Big data analytics is an emerging field where innovative technology offers new ways of extracting value from the massive new information. In facts, the continuous increase in the volume and details of data captured by organisations, through social media, Internet of Things, Cloud Computing, Cyber-Physical Systems, Machine-learning, 3D printing, and Multimedia, health information and product recalls have produced enormous flow of data in either structured or unstructured format (Musa and Dabo, 2016; cited by Ogbuke et al., 2020). In healthcare domain, big data emanate from Electronic Healthcare Records such as hospital records, medical records of patients, results of medical examinations, demographics, call records, prescriptions, Pharmaceutical and R&D records, queries from patients, billing records, laboratory test results, and devices that are part of the internet of things (Dash et al, 2019). Zhang et al., (2015) emphasise that in healthcare practices, big data has gradually becoming the trend for healthcare innovation (Zhang et al., 2015).

Maria' Cavanillas et al. (2016) corroborated that big data is the 'New Oil' that now fuel innovations. The authors estimated that applications of big data in healthcare services have potential of 90 billion euros saved expenditure. Although, some scholars have contended that most of the big data studies in healthcare sector merely concentrate on technological understanding of big data rather than the analytics aspect of healthcare data services for decision making skills (Senthilkumar et al., 2018). They believe that the healthcare industry has not been quick enough to adapt to the big data movement compare to other leading sectors like Financial services, High tech and communication, Transportation, and logistics (SAP, 2018). Hence big data usage and applications in the healthcare sector remain in the infancy stage.

Another emerging data-driven innovation is the Internet of Things (IoT-based) medical devices which can help to collect invaluable patient's data, automate workflows, provide insights on diseases symptoms, facilitate remote caring, and provide patients more control over their lives and treatments (Tao et al., 2018; Ali et al., 2020; cited by Yaqoob et al., 2021). With the IoT devices, patients can be monitored real-time, thereby reducing the need for visiting hospitals for routine health check-ups. More so, connected home health monitoring systems can help to reduce hospital stays or readmission costs. And more importantly, the IoT-enabled medical devices can assist in diagnosis through alerts and can trigger notifications before it becomes an emergency health situation. In addition, installed sensors and wearables on various parts of patient's medical apparatus could be gathered and the data sent to the hospitals, where clinicians will analyse them for possible abnormalities.

Artificial intelligence (AI) and its subfield machine learning (ML) are another key innovative technology. Their applications cut across industries, including Healthcare industry. Kaplan and Haenlain (2019) described AI in the context of its ability to independently interpret and learn from external data to achieve specific outcomes via flexibility adaptation. For example, AI systems are already helping oncologist to identify cancerous tumours. More interestingly, the recent COVID-19 Pandemic was detected by a digital firm called, Blue Dot, a Toronto-based start-up that uses AI-enhanced surveillance systems. The detection was carried out several hours the insurgence was reported in Wuhan, the epic centre, well ahead of the Chinese authorities and other international institutions and agencies (Bragazzi et al.,2020; cited by Ogbuke et al., 2020). The timely detection of this deadly virus demonstrates the capacity of AI and Big Data Analytics in monitoring and detection of disease outbreak in real-time.

Additionally, the applications of these disruptive techniques have also enabled institutions such as John Hopkins University, USA, in its efforts in visualisation in real-time and tracking the spreading of this virus across the world. Again, AI/ML medicine and healthcare initiatives can be developed strategically from in-silico to in-patient paediatric care (Drysdale et al., 2019). This initiative, according to the authors will deliver data-driven and personalised paediatric healthcare-for paediatric patients, as well as facilitate the implementations of clinical practices.

On the other hand, there is an overwhelming demand for personal protective equipment (PPE) for hospital staff and doctors, due to COVID-19 driven global supply chain disruptions. Consequently, this has led to the switching of production lines by businesses to manufacture essential items like mechanical ventilators, Hand Sanitizers etc., needed to curtail the spread of the virus and save life. This trend has resulted in a call for additive manufacturing (3D printing) equipment to fill the gap between traditional manufacturing cycles (Manero et al, 2020). 3D printing can be used to produce a variety of equipment for hospitals including face shields, mask, and even mechanical ventilator to handle the upsurge. Although 3D printing innovation, rapid and crowed sourced, it is very costly and required innovative design and production skills.

Despite the benefits of these innovative digital applications, there are clear issues and challenges of regulations, transparency, scalability, liability, data leakage and distributions. Additionally, handling and streamlining the e-Health records in a secure manner will pose a challenge since the data is spread across medical facilities. Some scholars have contended that most of the big data studies in healthcare sector merely concentrate on technological understanding of big data rather than the analytics aspect of healthcare data services for decision making skills (Senthilkumar et al., 2018). The authors also believe that the healthcare industry has not been quick enough to adapt to the big data movement compare to other industries. Sengupta et al. (2020) have maintain that the current electronic health and medical records fall short in providing transparency, trustful traceability and ethical considerations, and any leakage or failure of patients' personal information can constitute serious health implications.

In the same vein, only a limited fraction of artificial intelligence and machine learning (AI/ML) described in research papers find their way into medical and healthcare practices (Drysdale et al., 2019). The authors maintain that healthcare academic researchers generally focus on factors required for successful data science and statistical analysis of ML algorithms. Consequently, there are limited or less emphasises on implementation, digital applications, and operational research in medical and healthcare data management, which by no means are quite emerging.

Therefore, this paper will comprehensively review the previous, existing and the latest developments in applications of digital tools for healthcare management. Against this background, the study will therefore, seeks to address the following research questions:

RQ1. What are the Operational challenges in healthcare data-driven innovations and management?

RQ2. How far can data be extracted from Hospital's Electronic Healthcare Record system and evaluated in real-time through digital technologies?

RQ3. How will feedback and clinical contexts be enabled and incorporated into healthcare data practices in response to COVID-19 Pandemic?

In general, there is interesting evidence that researches conducted in healthcare industry particularly in data-driven technology, are quite limited and have fluctuated tremendously. For example, the number of articles published have decrease from 134, 000 in Year 2011 to 75,000 in Year 2014, and they have surge again to 97,000 publications in Year 2015 (Farahani et al., 2017). We have also, observed within the literature space that very limited articles have been published in data-driven technology since 2015. In fact, the latest article accepted for publications at the time of this study, is titled: ‘’Blockchain for Healthcare Data management: Opportunities, Challenges, and Future Recommendations (Yaqoob et al., 2021).’’ This clearly shows that there are still lots of demand to increase research outputs in Healthcare data-driven Innovations. And we believed we have responded to these clarion calls, and this review paper will set the pace and lead further discussion in this emerging healthcare operational research.

The rest of the study is organised a follow: In section 2 we analyse the recent literature information, related work done in the healthcare practices, challenges, opportunities, various applications of the emerging digital technologies in healthcare and medical field, and how they relate to COVID-19 pandemic. Section 3 explains the methodology of the research. In section 4, we discuss data analysis. In section 5 we explain the results of the study, and Section 6 carried out the discussion. Section 7 draw the summary of the conclusion from the entire overview including theoretical contributions, managerial implications, future of the research and its limitations.

2. Literature Review

The interactions in supply chain for vast majority of enterprises are going unmonitored, and have created silos along the operations processes, resulting in businesses inefficiency. Similarly, the usage and exploitation of these unmonitored and unstructured massive data information by digital technologies may have also illustrated the value creating possibilities of data-driven innovations for business decision-making skills. Likewise, the adoption of these digital technologies by organisations has boosted their business models and marketing strategies globally, as well as creating opportunities for better understanding of ways to automate and optimise, collect and analyse data, make predictions and offer added value to corresponding market (Ramon Saura et a., 2022).

Several academics (Trabuchi and Buganza, 2019; Adamides and Karacapilidis, 2020; Ramon Saura et al., 2022) also support the views that Artificial Intelligence (AI), Blockchain Technology, Cloud Computer, and Internet of Things (IoT) enable organisations to develop business models that is focused on what is known as Data-Driven Innovations (DDI). Therefore, these perspectives have provided the conceptual background and the overview of Data-Drive Innovations, as well as highlighting other factors and challenges associated with their diffusion, uptake, and sustainability initiatives in the society and across industries, particularly in the healthcare sector.

According to Ivanov et al. (2020), disruptive innovations such as Artificial Intelligence (AI), Internet of Things (IoT), 3D Printing, Blockchain Technology and Big Data Analytics influence the development of new paradigms, principles, and models in supply chain management (SCM). More so, they facilitate the development of digital supply chain (SCs) and smart operations (Qu et al., 2017; Yang, Pan, and Ballot, 2017; Minner, Battini, and Celebi, 2018; cited by Ivanov et al., 2020). In the same vein, AI and big data analytics can be deployed in managing supply chain disruptions to enhance firm's resiliency, cost effectiveness, and improve agility and adaptability. Arter et al. (2022) believed that the adoption and application of these advanced systems such as the IoT, Blockchain Technology (BCT), Cloud Computing, Data Analytics and AI, are fundamental for the digital transformations of businesses. For example, the market value of AI in the food and beverages industry is expected to reach US$29.94 billion by 2026, at Compound-Annual Growth Rate (CAGR) of 45.8 percent. Also, the global market size for BCT in agriculture and food sector is projected to reach US$948 million by 2025, at CAGR of 48.1 percent (MarketsAnd Markets, 2020).

Ivanov and Dolgui (2020) have emphasised that these disruptive technologies have the capacity to enhance predictive and reactive decisions, utilize the advantages of SC visualisation, historical disruption of data analysis, end-to-end visibility, as well as business continuity in global companies, particularly the healthcare organisation. Tsolakis et al. (2022) in their study agreed that digitalisation is expected to transform end-to end supply chain operations by leveraging the technical capabilities of advance technology applications. Weill and Woerner (2018) also corroborated the importance of these innovations in business operations and advantages they offer to traditional enterprises to competing in the digital economy.

Several researchers (Ben-Daya et al., 2018; Nguyen et al., 2017; Hofmann and Rusch, 2017; Choi et al., 2018; cited by Gunasekaran et al., 2018) have identified classifications of different digital technologies and their impacts on SC management (SCM). These digital technologies include big data analytics (BDA), advanced manufacturing technologies with sensors, decentralised agent-driven control, advanced robotics, augmented reality, advanced tracking and tracing technologies, and additive manufacturing. Moreover, these evolutions have now prompted Operational researchers and SC Practitioners to explored various ways to better manage the data information and leverage them for better business decision-making skills.

Furthermore, Samad et al. (2022) in their study identified the roles of Blockchain Technology in aiding Logistics Supply Chain Managers to understand the appropriate decision-making framework, as well as implementing strategic recommendations to overcome the challenges faced by Logistics Supply Chain Organisations. Notwithstanding the operations-wise merits associated with the implementation of these digital technologies, individually, the challenge for the future is that their combined effect has been overlooked due to limited real-world evidence. In this context, this research explores the prospect of their integration and future challenges in healthcare data management.

2.1. Global healthcare data management and COVID-19

Healthcare Industry is one of the world's biggest and constantly involving industries. In recent years, the industry is changing from disease centre to a patient-centred model, volume based to a value-based healthcare delivery model (Cortada et al., 2012). Similarly, in terms of its data management and operations, there are high demands and adoption of digital data-driven innovations (Yaqoob et al., 2021). The recent research conducted by IDC (2019), predicted that the worldwide big data expenditure in the healthcare business has progress towards CAGR of 42 percent between the year 2014 – 2019. Rahaman Masudur (2020) confirm that global healthcare supply chain is expected to hit $3 billion by 2025. The author classified the global supply chain into diverse range of segments, including pharmaceuticals, information technology, medical devices, and several other services, all of which are growing exponentially.

Several studies have also, suggested that technologies such as 3D printing, Big data, AI, and industry 4.0 can be used to manage the impact of COVID-19 pandemic, particularly in the healthcare sector. In fact, these studies confirm that such technologies can help the healthcare supply chain immediately to ramp up the production of Personal Protective Equipment (PPE), Mechanical Ventilators, and other essential items (Chowdhury et al., 2021). Kazancuglu et al. (2022) in their study emphasised the importance of sustainability of supply chain in rapidly changing business conditions, such as the recent COVID-19 pandemic that caused unexpected disruptions in the global value chain, and the need for further improvement of its resiliency for future events. The authors agreed that the use of emerging disruptive digital techniques including blockchain, industry 4.0 analytics model, robotics technology, IoT and AI driven methods are aimed at enhancing the sustainability and resilience of supply chains, particularly in an uncertain environment. The studies encouraged healthcare researchers to investigate the prospects of these data-driven innovations in healthcare data management and practices. These research gaps are completely in line with research questions as outlined in introductory section, which this review seeks to explore, including the associated challenges.

To envision the roles of digital data-driven technologies, smart devices, as well as IoT, in healthcare data management, it is important to identify the operations and classification of the industry. The healthcare industry is classified into three areas: large healthcare organisations such as hospitals; small clinics and dispensaries; and non-clinical environments such as patients' homes, communities, nursing home, and rural areas without any medical support. According to Farahani (2017), healthcare professionals across the globe are connected via IoT eHealth ecosystem to enable patients have more access to international facilities at their fingerprints (anywhere and any times). Moreover, there is also an increasing interest in mobile healthcare clinics across the globe. For example, in African and most developing countries, mobile clinics have proven to offer a low-cost, high-quality care for vulnerable populations in remote areas where citizen have no access to basic medical facilities (Farahani., et al., 2017). Mobile clinics are vehicles with limited medical facilities, therefore, IoT could make a big difference in enhancing the infrastructure of the mobile clinics that could partner with large hospitals to remotely communicate for diagnosis and decision support. As such, mobile clinics could scale up their capabilities for care services.

Senthil Kumar et al. (2018) stated that the volume, demand, the usefulness and need for data in healthcare organisations are growing in leaps and bounds. They emphasise that to provide effective patient-centred care, it is essential to manage and analyse huge health data. The outdated data management is insufficient to analyse big data, especially now that variety and volume of data sources have increased tremendously in the last two decades, and skyrocketed by Covid-19 pandemic. Schiopoiu and Ferhati (2020) acknowledged that the recent crisis of COVID-19 has also forced all organisations, including public and private sector, to rethink their policies and strategies. The rapid evolution of the virus requires collective and global strategies towards ensuring the health of the populations, as well as continuous assessment of the events to give priority to the future needs. Panhuis et al. (2018) have also acknowledged that decisions in global health populations can affect the lives of millions of people and can change the future of entire communities. For example, the decision to declare a particular viral disease a pandemic, like the recent COVID-19, gives the government and its advisers the opportunity to design some form of restriction measures to curtail the spread of the virus. A case in point is the different tiers of restrictions and lockdown measures introduced by Government of several nations in the ongoing Coronavirus Pandemic. Certain strategic business decisions were taken by leaders of nations, even in area of stockpiling of Personal Protective Equipment (PPE).

Firms that were resilient and agile enough, made sacrifices by switching their production line to manufacture some of the essential materials - a patriotic move in support of their country and humanity. For example, the following manufacturers namely: Tesla, General Motors, Ford, Dyson, and Roll-Royce switched their production lines to manufacture essential items that were in short supply, including mechanical ventilators (Bhaskar et al., 2020). Moreover, Government leaders initiated Public Private Partnership arrangements (PPP) with Pharmaceutical companies to massively produce vaccine. There were also some economic incentives and safety-net that most Head of States put in place in support of businesses and their workforce, as well as to mitigate the looming massive unemployment, orchestrated by the deadly virus. Other sources also contended that billions of dollars could also be wasted if decision to announce the pandemic outbreaks was based on false alarm and not data driven. Panhuis et al. (2018) also, recognised that decision making in global health is often made under some degree of uncertainty and with incomplete information. But, with emergence of data-driven innovations coming from mobile technology, electronic health records, social media platform, and remote sensing, there are now golden opportunities for data-driven decision making in global healthcare industry.

However, there are multiple layers of challenges, ranging from technical to ethical barriers, that can limit the effective use of data in global healthcare practices (Drysdale et al., 2019). The authors support the views that composing an epidemic model to inform decisions about vaccine stockpiling requires the integration of existing data from a wide range of data sources, such as population census, disease surveillance, environmental monitoring, and research studies. Integrating data sources can be a daunting task, especially since global health data are often stored in domain-specific data silos that each uses different formats and content standards, that are semantically heterogenous. The heterogeneity of data in global health can slow down scientific progress, and so researchers must spend much time on data discovery and curation (Forbes Magazine, 2016). On the other hand, Drysdale et al. (2019) also highlighted the ethical challenges posed to digital technologies including machine learning, data security, and privacy concerns, as well scalability. They maintain that in order to address each of these issues, there should be a discussion among stakeholders and experts around establishing general frameworks. The study outlined the some of the major applications of Big Data, 3D Printing, IoT, AI and Blockchain in healthcare data management, as well as their mitigating measures for Covid-19 related health pandemic (see table 1).

Table 1. AI, Big Data, 3D Printing, IoT and Blockchain Influence on COVID-19 Pandemic and other health crises

Applications	**Functions**	**Authors**
Detecting and Diagnosis of infection	IoT provides insights on disease symptoms and trends, facilities in terms of remote caring, and provide patients more control over their lives and treatments	Saura et al. (2022)
	Blockchain-based tele-monitoring healthcare framework for the diagnosis and treatment of cancer tumours for remote patients. it can also be used to ensure the validity and security of patient's data specialised medical centres, as well as in patients' homes.	Samad et al. (2022); Kazancoglu et al. (2022); Tsolakis et al. (2022)
	AI is helping in developing a new diagnosis and management system for the COVID-19 case, through useful algorithms	Kazancoglu et al. (2022); Tsolakis et al. (2022); Javid et al. (2020); Modgil et al. (2021)

	Blockchain is deployed in applications of IoT, AI, ML, Computer vision to facilitate doctors and clinical practitioners in the diagnosis and treatment of various chronic diseases.	Samad et al. (2022); Kazancoglu et al. (2022)
	3D printing plays a relevant role in clinical preoperative evaluation.	Aimar et al. (2019); Manero et al. (2020)
	Big Data application in proteomics will have a major role in predicting and preventing human cancer	Ji et al. (2022)
	AI is also helpful in diagnosis of the infected cases through medical imagery technologies like computed tomography, magnetic resonance imagery (MRI) scan of human body parts.	Kazancoglu et al. (2022); Tsolakis et al. (2022); Javid et al. (2020); Modgil et al. (2021)
	A neutral network can also be developed to extract the visual features of this disease, and this would help in proper monitoring and treatment of the effected individuals.	Kazancoglu et al. (2022); Tsolakis et al. (2022); Javid et al. (2020); Modgil et al. (2021)
Monitor the treatment	Big Data application in genomics will help to prevent or cure diseases and delivery personalised care to each patient.	Ji et al. (2022)
	Blockchain is used in storing, transferring, sharing, as well as maintaining the most sensitive electronic health and medical records of patients' health history. For example, health record of patients fighting for chronic disease such as HIV and Cancer.	Samad et al. (2022); Kazancoglu et al. (2022); Tsolakis et al. (2022)
	Blockchain based strategy can facilitate, secure real-time remote monitoring, thus allowing practitioners to track the healthcare status of other patients from distant locations, while also maintaining a safe, secure, and up-to-date history of patients.	Samad et al. (2022) Kazancoglu et al. (2022); Tsolakis et al. (2022)
	3D printing is used in paediatric congenial heart disease treatment is a study reported in the literature based on the development of a 3D heart model of a 15-years-old boy to improve interventional simulation and planning in patient with aortic arch hypoplasia.	Aimar et al. (2019); Manero et al. (2020)
	AI can build an intelligent platform for automatic monitoring and prediction of the spread of the virus features of these diseases. It has the capacity of providing day-to-day updates of the patients and provide solutions in COVID-19 pandemic.	Kazancoglu et al. (2022); Tsolakis et al. (2022); Javid et al. (2020); Modgil et al. (2021)
	IoT convergence and interconnectivity of Sensors, Wearables, Actuators, Telecommunications, Cloud computing and Big Data provides goal-oriented services by using wearable wrist watches and sensors by the patients to monitor and detect heart rate, glucose level and blood pressure, and thereby providing easy analysis, diagnosis and treatment by health professionals and clinicians	Saura et al. (2022)

Contact tracing of the individuals	IoT-based medical devices can help to collect invaluable patient's data, and automate workflows	Saura et al. (2022)
	AI helped to analyse the level of infection of virus by identifying the clusters and hot spots and can be usefully contact tracing of the individuals and monitor them.	Kazancoglu et al. (2022); Tsolakis et al. (2022); Javid et al. (2020); Modgil et al. (2021)
	Blockchain is utilised for delivery of safe and secure healthcare data, biomedical and e-health data sharing, brain simulation and thinking.	Samad et al. (2022); Kazancoglu et al. (2022); Tsolakis et al. (2022)
	3D Printing is used in producing a variety of equipment for hospitals including face shields, masks, and even, ventilator for components to handle the surg.	Aimar et al. (2019); Manero et al. (2020)
	Patient-specific 3D printing anatomical models are becoming increasingly useful for tools in today's practices of precision medicine.	Aimar et al. (2019)
Projection of cases and mortality	Digital techniques like Big Data and AI help in understanding prediction of pandemic outbreaks.	Kazancoglu et al. (2022); Tsolakis et al. (2022)
	AI technologies can track and forecast the nature of the virus from the available data, including social media platforms. It can also predict the number of positive cases and death in any region.	Kazancoglu et al. (2022); Tsolakis et al. (2022); Javid et al. (2020); Modgil et al. (2021)
Development of Drug	The growth of IoT has increased the applicability and transformation of Big Data Analytics in pharmaceutical and drug prescriptions.	Ji et al. (2022)
	AI is used for drug research by analysing the available data on COVID-19. Big data AI are used for drug delivery design, development, testing in real-time.	Kazancoglu et al. (2022); Tsolakis et al. (2022); Javid et al. (2020)
	Vaccine manufacturing firm (e.g., MERCK) implemented Hadoop (AI) to utilise huge amount of data in producing vaccines faster.	Samad et al. (2022); Javid et al. (2020); Modgil et al. (2021)
	Pfizer has recently initiated Precision Medicine Analytics Environment program to identify innovative medicines for patient populations.	Senthilkumar et al. (2018)
	Blockchain is a fit technology for evaluating, monitoring, and ensuring the production process of potential drugs. It plays a major role in inspecting and fighting the production of counterfeit drugs. Blockchain is used to improve the traceability of falsified drugs, security of drug supply system, and guarantee the quality of drugs supplied to consumers or end-users.	Samad et al. (2022); Kazancoglu et al. (2022); Tsolakis et al. (2022)

	Blockchain made it possible for pharmaceutical industries, drug manufacturers, and biomedical researchers to use DNA data stored to conduct advance transnational research at genomic level.	Samad et al. (2022); Kazancoglu et al. (2022); Tsolakis et al. (2022)
	3D Printing technology represents a big opportunity to help pharmaceutical and medical companies to create more specific drugs, enabling a rapid production of medical implants and changing the way that doctors and surgeons plan procedures.	Aimar et al. (2019); Manero et al. (2020)
Reducing the workload of healthcare workers	IoT could further augment telemedicine by networking sensors to facilitate tele-screening. In this way, the hospital could cope with a smaller number of health workers by increasing the virtual care services.	Saura et al. (2022)
	Through digital approaches and data science, AI can impact future patient care and address more potential challenges which reduce the workload of the doctors, through digital applications	Kazancoglu et al. (2022); Tsolakis et al. (2022)
	Because Blockchain is not easy to manipulate, it can provide a safe platform that eliminate fraudulent and vulnerable attack, and in some cases, prevent fraud occurrence, as well as introducing higher data transparency and improve product traceability.	Samad et al. (2022); Kazancoglu et al. (2022); Tsolakis et al. (2022)
Prevention of the disease	Data-drive technologies like IoT, Big data, and AI could make a difference in enhancing the infrastructure of the mobile clinics, which could partner with large hospitals to remotely communicate for diagnosis and decision support in disease control and prevention	Kazancoglu et al. (2022); Tsolakis et al. (2022); Saura et al. (2022)
	With the help of real-time data analytics, AI can provide updated information which is helpful in the prevention of disease. It can also be used in predicting probable sites of infection, influx of the virus, for healthcare professional during this crisis.	Kazancoglu et al. (2022); Tsolakis et al. (2022)
	AI identifies traits, causes, and reasons for the spread of infections. In future, it would become more important technology to fight against other chronic illness.	Kazancoglu et al. (2022); Tsolakis et al. (2022); Javid et al. (2020)
	3D Printing is deployed in surgical planning, prosthesis, tissue construct, and drug printing	Aimar et al. (2019); Manero et al. (2020)

2.2. Applications of data-driven technologies for healthcare services

In recent years, healthcare has gone through technology advancement and has become an important part of our daily life. Likewise, it has been very challenging for the practitioners to deliver high-quality care with limited resources (Stromeo et al., 2013; cited by Vali et al., 2022). The industry has also, seen tremendous growth of data, both in value and in the number of data users and they are expected to increase even more rapidly in the near future.

The influence of the COVID-19 disruption has worsened the situation, resulting in the global imbalance between the supply and demand of ant-epidemic materials such as marks, disinfectants, googles, gloves, and protective clothing. This situation has also led to people, including doctors, nurses, and patients, not having sufficient anti-epidemic materials, thus resulting in the prioritization of healthcare services, and eventually the shutting down of the healthcare centres (Song et al., 2022). Therefore, collecting, maintaining, and leveraging data assets to support decision making and daily operations have become an important target in healthcare data services (Zhang and Koru, 2019).

The growth of Industrial Internet of Things (IIoT) has increased the applicability and transformation of big data analytics across industries such as healthcare sector (Abaker et al., 2014; Biajian et al., 2018). Ji et al. (2022) in their paper emphasised that data-driven innovation enables organisations to design products that are more responsive to market needs, which significantly will reduce the risk of innovation. The study focuses on the influence of big data analytics capability of the firms. A good example is in pharmaceutical sector, where big data and mobile health are starting to transform the healthcare and diagnostics in a significant way, with new players such as Apple and Google acting as increasingly disruptive catalyst (Gautam and Pan, 2016; Giuseppe et al., 2018; cited by Ogbuke et al, 2020). Likewise, vaccine manufacturing firm, MERCK implemented Hadoop to utilise huge amount of data in producing vaccines faster and reduce the discard rates (Henschen, 2014; cited by Lamba and Singh, 2017).

Senthilkumar et al. (2018) have also, noted that big data is used during all pharmaceutical development, particularly for drug delivery. The authors gave example of how Pfizer has recently initiated Precision Medicine Analytics Environment program that associates the dots among electronic medical record data, clinical trials, and genomic to identify chances to rapidly convey innovative medicines for particular patient populations. Another example of big data application is the utilisation of enormous volume of information from patient data by scientist to detect drug interactions, design, and implementation of optimal drug therapies (healthworkscollective.com, 2014; Smolan and Erwitt, 2012). Yang et al. (2014; cited by Senthilkumar et al., 2018)) in his research predicted that in near future that big data-derived influences, will prompt suitable updates of diagnostic assistance, clinical guidelines and patient triage that permit more particular modified treatment, and advance medical results for patients. Similarly, Yalamanchili et al. (2012) predicted that big data application in proteomics will have a major role in predicting and preventing human cancer. A study conducted by Oracle indicated that healthcare providers experience on the average of $70.2 million annually, about 15% of potential revenue per hospital, because of their inability to interpret and translate data into actionable insights, as well as due to poor quality of the large volumes of data they collected (Lewis, 2019).

Although, in recent time, the industry is now benefiting from the progress of data-driven innovations of extracting information and translating the information into knowledge. Hospital flows has also benefited from the technology progress of information systems and the emergence of new IT tools with high added value such as Radio Frequency Identification (RFID), Enterprise Resource Planning (ERP) and Mobile applications. Healthcare sector has also benefited significantly from telemedicine. Telemedicine is one the first and famous stakeholders of IoT today. According to recent reports by Trends and Forecast (2019), the global market for telemedicine is worth around $23,224 million and is expected to go up to $66,606 million in 2021, with estimated growth rate of 18.8%. IoT has a lot to offer data management because of a large portion of world’s population that owns cellphones and smartphones, which are not mere communication devices, but are deployed for connecting with other sensors (Farahani et al., 2015). In fact, healthcare organisations have seized the opportunity offered by ICTs to move towards a new management based on the control of financial, administrative, and medical aspects. Several studies have focused on the trajectory of intra-site patients, and proposed innovative practices to optimise their circulation and ensure the safety of their stay in care units or medical-technical services (Shen et al., 2007; cited by Ageron et al., 2018). Other scholars (Chaerul, Tanaka, and Shekdar 2007; Narayana, Pati, and Vrat 2014; Bentahar, Benzidia, and Fabbri, 2016), have analyse the circulation of physical flows by focusing on other issues related on traceability of blood flows and elimination of pharmaceutical flows.

According to Ageron et al. (2018), patient information flows are a source of improvement for medical practices. The authors further maintain that tools such as electronic patient record play a key role in recording the data, and thereby providing detailed information about the history of patients’ file. Moreover, the e-healthcare record also constitutes a medium of communication between the service of the organisation and information sharing, as well as the partner institutions like laboratory, hospital. blood transfusion centre, etc. Shah et al. (2018) also highlighted key insights for the top application categories, which include wearables connectivity, disease detection and treatment, patient care, and sensor networks. The authors identify gaps and future research directions related to technology design and acceptance, regulations for data security and privacy, and system efficacy and safety. More so, the IoT devices such as smart pills, wearables monitors, and sensors allow healthcare practitioners to continuously collect data, and AI systems.

Also several scholars (Daecher et al., 2018; Verweij et al., 2017; cited by Shah et al., 2018) have the suggested that AI systems can help analyse this data to detect changes in a patient’s conditions, suggest treatment options, and identify trends, thus supporting patient adherence, as well as improving patient outcomes and accelerating discovery of access to new treatment. More so, the development of medical information including the increase volume of medical data, and promotion of wearables health devices, have accelerated the explosion of healthcare data (Chen et al. (2013; cited by Zhang et al., 2015). Some other healthcare researchers (Chen et al., 2014; Chen et al., 2015; Zhang et al., 2013) categorised healthcare developments into three stages: rapid generation, various structure, and deep value. For rapid generation, most medical equipment like wearable devices are deployed to collect, generate, and process data needed for prompt response to emergency concerns. Whilst various structure category, is for clinical examination, treatment, monitoring, and other healthcare devices that generate complex and heterogenous data (e.g. text, image, audio, or video). And deep value is a hidden and an isolated data source fusion of eHealth records and electronic medical records (EMRs), which can maximise the deep value from healthcare data such as personalised health guidance to public health warning.

Zhang et al. (2015) proposed a cyber-physical system for patients-centre healthcare application and services, called Health-CPS, built on cloud and big data analytics technologies. The results of the study indicate that the technologies of cloud and big data can be used by humans to enhance the performance of various smart healthcare application services. Lin et al. (2014) proposed a NoSOL-based approach for rapid processing, storage, indexing, and analysis of healthcare data, to overcome the limitation of a national database. In another study, Takeuchi and Kodama (2014; cited by Zhang et al., 2015) presented a personal dynamic health system based on cloud computing and big data to store daily healthcare-related information collected by mobile devices.

In facts, they believe big data can help fight the spread of communicable diseases. For example, a retrospective analysis of the 2010 cholera outbreak in Haiti indicated that mining data from Twitter and online news reports could have given the country's health officials an accurate indication of the disease's spread with lead time of two weeks (Chunara et al.,2012; cited by Kshetri (2014). Additionally, with the scenario of mobile applications, particularly in intensive care, sudden disease detection, vital signs monitoring, and data changing, will reflects the individual health status in real-time. In such circumstances, data will be processed rapidly, and the analysis of results will be expected to return quickly in response to emergency situations. In the end, with this memory analysis framework, hotspot data such as heat rate, blood pressure, and other relevant data, will be kept in memory for improving the efficiency of e-Healthcare records.

Furthermore, digital applications have the highest technical complexity and greatest commercial value. For instance, individual eating habits can be deduced through retail records, using big data and AI. Other potential health risks can also be predicted particularly, diet-related disease such as obesity and high blood pressure (Zhang et al., 2015). Likewise, Robot assisted user interface plays key roles in healthcare operations. For example, Health-CPS provides a robot with healthcare services supported by a cloud-assisted system, for communication to the doctor, family, and in emergency. Singh et al. (2020) conceptualised a Truck-drone hybrid delivery system that will administer relief materials in a high-rising building quarantine zone. The study helps in curtailing the spread of diseases in virus-prone environment like the recent COVID-19, using drone technology to minimize human to human contacts.

However, there are ethical and security challenges posed by these emerging digital data-driven technologies. Every single digital tool present risk that could be exploited to either harm the end-users of jeopardise their privacy (Suciu et al.,2015). For example, in IoT, when security is comprised, end-user's information can be accessed through unauthorised authentication. This can lead to creating risks to personal safety. Moreso, coordination, integration, and management of global supply chain using digital technologies will be needed to mitigate the impacts of both current and future pandemics.

Recent studies have reviewed the healthcare operations data management and its accelerated adoption of data-driven technologies, particularly in personalised eHealth services. Essentially, handling and streamlining of e-Health and Medical Records (HER/EMR) in a secure manner has become very challenging, since the new data-driven information is spread across various medical facilities. There are concerns on how to address most of the challenging issues created by these advance technologies particularly, in eHealth data management, ranging from scalability, regulation, interoperability, device-network-human interface, data security, privacy, to ethical issues. For example, data is becoming more in variety, volume, and velocity. And as such, network infrastructure needs to be scalable in different devices and data. More so, the interfaces need to be simple and genuine enough, making them accessible for everybody from children to elderly people. Again, other challenges of data management come with data volume and velocity, associated with the capabilities to receive, process, store, and communicate the high-fidelity, high-resolution data coming from medical devices that could be with patients or in hospital.

In proffering solutions to these data management challenges, Chen et al. (2012; cited by Ogbuke et al., 2020) in his explorative research described Big Data Analytics as the datasets and analytical application tool that are so large (from terabytes to exabytes) and complex (from sensor to social media data), which require advanced and unique data storage, management, analysis, and visualisation technologies. Other sources have also recommended that in order to ensure cloud less vulnerable attack, network cloud and acting agents must be enhanced by secure hardware, as well as adequate training of people that handle the secure data. Moreover, security and privacy of IoT eHealth spans the whole life of the system starting from specification generation, to implementation and deployment. In fact, Suciu et al. (2015) believe that every single digital technology might present a potential risk that could be exploited to either harm the end-users of jeopardise their privacy (Suciu et al., 2015). Hence protecting the IoT ecosystem is a sophisticated and challenging task.

Furthermore, there are other concerns in area of standardization in application of digital data-driven technologies, as various organisations developed different standards of regulations for integrating, exchanging, and retrieving electronic and medical healthcare records. The standardisation complexity lies in the fact that IoT aims to capture a wide range of disciplines that are, in general, regulated by different regulatory affairs. In the case of IoT eHealth, the complexity even increases due to the strict regulations mandated by medical standards. This implies that companies must precisely consider the policies and rules mandated by the regulators. For IoT, eHealth will have to navigate through a complex multi-agency regulatory structure before we start to see the IoT eHealth products in the market. The facility can also be scale up to the entire hospital, so that patients can use medical services, check updates and health status monitoring by their smartphones.

Overall, society is yet to fully grasp with many of the ethical and economic considerations associated with IoT, AI and Big Data, 3D printing, Blockchain technologies and their wider implications on human life, culture, sustainability, and technological transformation. To this end, healthcare organisations and tech companies are now at a crucial juncture in determining how to effectively deploy these disruptive technologies in a manner that promote the duty of care for service users, as well as upholding other values such as freedom, equality, and transparency.

Table 2. Research questions and step approaches

Questions	**Steps**
What are the Operational challenges in healthcare data-driven innovations and management?	Identify all the associated challenges ranging from, security, privacy to issues of scalability, regulations, and interoperability.
How far can data be extracted from Hospital's Electronic Healthcare Record system and evaluated in real-time through digital technologies?	Define the concept of data-driven technologies and applications for healthcare data practices
How will feedback and clinical context be enabled and incorporated into healthcare data practices in response to COVID-19 Pandemic?	Outlined the current and future perspectives of digital technologies in healthcare data service.

3. Methodological Approach

A comprehensive literature analysis of the article deals with Big Data, AI, 3D printing, Blockchain and IoT, in Electronic and Medical Healthcare Records data practices, as well as the impacts of these digital tools in mitigating Covid-19 pandemic health-related concerns. The review also explored the associated challenges of the data-driven innovations. To answer the research questions, the study identified three research questions as described in 3-step approaches (see table 2). Furthermore, the paper adopted a systematic literature review process that involves structured and transparent assessment of the articles from mainstream journals. The review demonstrates both the present and future perspectives of data digital solutions and management in healthcare and medical field. The research also discussed the associated challenges of data-driven innovations, including the issues of scalability, security, privacy, ethical and interoperability and regulations confronting the healthcare organisations.

Table 3. Review protocol

Research Variables	Description
Database	The study selected Scopus because it offers integrated results from diverse databases, including Tailor and Francis, Elsevier, Science Direct, Emerald, and Ebsco.
Article quality	This paper addressed the issues by considering articles that originate from ABS Journal ranking and SSCI index (impact factor).
Review scope	The year, 2010 is selected as the baseline for the literature search. This will support the objective of the present research. Therefore, review considers the timeline from 2010– 2022.
Keywords	Data-driven technologies; Healthcare data management; Industry 4.0; Internet of Things; Ethical Issues; Covid-19 pandemic.
Article selection criteria	The principal criteria include articles with good empirical characteristics, including quantitative survey, case study and conceptual model development, reviews that focused on data-driven technologies, and application, and associated security, privacy, and ethical challenges.
Article de-selection criteria	In line with objectives and review scope of this research, the articles are restricted towards a manageable level. We review article with conceptual underpinnings inherent in the research questions. However, papers based on stochastic mathematical models were excluded from the review. The articles of interest must also have management implications for healthcare data services and operations applications. Articles that do not address the challenges of data-driven innovations were also excluded.

It became significant to broaden the research with the inclusion of relevant articles, given the nature of the research topic. Therefore, the key stages of SLR comprises planning, execution, and reporting (Tranfield et al., 2003; cited by Vivek et al., 2018).

Table 4: Classification of the Reviewed Articles

Journal (SSCI and ABS ranking)	**Article Count**	**Journal (SSCI and ABS ranking)**	**Article count**
Journal of the American Medical Informatics Association	4	American Journal of Theoretical and Applied Business	1
Neural Computing and Applications	1	Journal of Big Data	2
Journal of Production Planning and Control	2	IEEE Systems Journal	2
Journal of Healthcare	1	Digital Technology	1
Supply Chain Forum: An International Journal	4	AI in Medical for Kids	2
Annals of Operations Research	9	Computer and Biomedical Engineering	1
Research and Applications	1	Journal of Healthcare Engineering	3
Journal of Cryptography	1	Public Policy	2
International Journal of Environmental Research and Public Health	3	New Horizons for a Data-Driven Economy	2
Bioscience Trend	2	Journal of International Business Policy	1
Frontiers in Public Health	2	Issues in Information Systems	2
Information Fusion	2	Transportation Research Part E	1
Innovations in Care Delivery	2	Big Data Analytics in Healthcare	2
IEEE Internet of Things	1	Neural Computing and Applications	1
Business Process Management Journal	1	American Journal of Theoretical and Apple Business	1
Journal of Marketing Management	1	Communications for development	2
Analytics in Healthcare	4	Journal of medical systems	1
International Journal of Production Research	2	Healthcare	1
Future Healthcare Journals	2	Journal of Cryptography	1
Waste Management Journal	2	PwC	1

The approach prompted this study to focus on a review scope of at least 11 years. Following the example of the extant comprehensive literature reviews, the study believed the data-driven technologies have become increasingly an enabling tool that provide useful insights for healthcare industries post- 2010. The paper also employed a diverse set of keywords for the literature search. The entire research team agreed on these keywords since they gave us a clue and clear direction of the review protocol (See table 3). The analysis uncovers journals that have extensively publish research on the data-driven innovations and Covid-19 pandemic in healthcare practices and data management. The research papers were extracted from the prominent databases like Tailor and Francis, Emerald, Science direct, Elsevier, Ebsco, and Google Scholar. Articles considered in this study were published in the duration of 2010 – 2021. The keywords employed for searching for the databases were outlined in Table 3.

Initially, 1900 articles were obtained using the keywords from leading journal articles (see table 3). A preliminary screening was performed on articles by assessing title and abstract of the articles to filter the articles based on the relevance to this research. It synthesizes the main themes investigated in these studies, including the methodologies, contexts, and theoretical underpinnings. The articles in non-English language were discarded. The screening generated 310 articles and rigorous analysis of these articles were performed to limit the system boundary of the articles to Data-driven technologies, Healthcare data management, Industry 4.0, Internet of Things, Ethical Issues, and Covid-19 pandemic. Repetitive and similarity articles were removed in their findings, leading to 77 most relevant articles from 40 leading Journals as shown in Table 4.

3.1. The thematic landscape of DDTHP

The 76 articles were classified in thematic landscape across the 40 mainstream Journals. The thematic landscape provided the useful insights and the journey involved in the emergence of data-driven technologies for healthcare practices (DDIHP). Additionally, thematic landscape is designed and developed around a conceptual framework along 6 levels themes, namely: Hospitals practices, Clinical services, Patients' home, Nursing homes, Rural areas, and Anywhere. Each level contains article stream that characterised the group sub-themes. Following this was the selected articles with the full lists of the authors. These segments give the descriptions of the authors, as well as their viewpoints around the discourse. The summary of these points are outlined in Table 5.

Furthermore, the matrix level was explored based on broad theme and sub-themes. This was done in way that shows a progressing expansion of conceptual framework, from bottom-up to top-down approach. The bottom-up approach is the beginning of the extraction of sub-themes, as individual research articles in the review were determined inductively. The coding was designed in a manner that allowed the capturing of the most dominant conceptual standpoints in the articles towards the main issues of data-driven innovations for healthcare data management, as well as how digital techniques can enhance costs efficiency. The concept was also designed to improve access to data services, increase innovative platform for information and communications, as well as explore other security, privacy, ethical and regulatory challenges. Moreover, to ensure validity and reliability of the coding, the research team read the articles in chronological order starting from 2010 to 2022. Separate lists were generated and cross-validated.

There were discussions among the research team about the classification of the themes and sub-themes and consensus were reach. In general, the reconciliation of the useful insights arising from the top-bottom and bottom-up approaches were achieved within the research team and the team adopted the six principal facets of DDIHP operations, namely: Hospitals practices, Clinical services, Patients' home, Nursing homes, Rural areas, and Anywhere - for representing the conceptual matrix at the top-most level. The next section explained the results in detail.

4. Analysis and Results

This research conceptualised, developed, and validated the dimensions of data-driven innovations for healthcare data applications management, and data security, data privacy, as well as interoperability and regulatory challenges in 77 articles. The results reveal that the largest number of articles (50 out of 96) relied on researchers' opinions as their main methods of investigations. The researchers specifically, provided their perspectives and opinions on the potential impacts of Covid-19 pandemic and data-driven innovations for healthcare data operations. Some parts of the articles used the viewpoints of the researchers themselves, whilst the rest were discussions, conceptual papers and three review papers. The articles were filtered from 40 mainstream Journals as listed in table 4. The study embraced a systematic approach to established rigor throughout the

Review. This was based on a similar approach used by Vaithianathan (2010; cited by Shahria and Wamba, 2016) in e-commerce and Benedettini and Neely (2012) in service system research. The study adopted a protocol that described the criteria, scope, and methodology at each step (Ogbuke et al., 2020). Additionally, the thematic landscape is designed around the conceptual standpoints along top categories including Hospitals practices, Clinical services, Patients' home, Nursing homes, Rural areas, and Anywhere. The thematic landscape was further expanded into broad level themes and sub-themes as shown in Table 5 and 6. As such, total number of 6 broad themes and 10 sub-themes were identified. The tables were designed to provide a clear understanding of the specific conceptual underpinnings as contained in the thematic landscape.

Table 5. Thematic landscape in terms of broad themes and sub-themes (article streams).

DDIHP (Functions): reflecting the focus	Articles streams (Operations): showing the conceptual underpinning of the sub-theme focus	Conceptual standpoints of selective articles (Applications): full list of the authors
Hospital practices (1): There is an increasing need from clinic-centric healthcare. Digital tool is expected to be a strong enabler that provide a seamless connection of devices and cloud storage, as well as an acting agent for patient hospital, analysis labs and emergency services.	**Article streams (1):** A typical Internet of Things (IoT) electronic Health Records system integrate, offer networking skills, support, and transfer data in wired and wireless network. More so, IoT paradigm have revolutionized healthcare industries by bringing major improvements in term of e-health/medical records (HER/EMR).	Yaqoob et al. (2021) present recent on-going projects and case studies to show the practicality of blockchain technology for various healthcare applications. In the research, the authors confirm that IoT-based medical devices can help to collect invaluable patients data, automate workflows, provide insights on disease symptoms and trends, facilities in terms of remote caring, and provide patients more control over their lives and treatments. Farahani et al. (2015) presented a complete survey of various published papers on IoT eHealth and proposed a holistic eHealth ecosystem covering those layers where various applications can be mapped, which include mobile health, assisted living, e-medicine and implants, early warning systems, and populations monitoring.
Hospital practices (2): The outdated data management implements in healthcare are not sufficient to analyse big data as variety and volume of data sources have increase in the past two decades.	**Article streams (2):** The practices of advance techniques enhance the prospective of the upcoming markets needs and trends in healthcare establishments. Likewise, digital technologies provide great opportunity for epidemiologist, physicians, and health policy experts to make data-driven judgements that will eventually develops the patient care	Sessler (2015; cited by Senthilkumar et al., 2018) in his research employed Google trends for analysing big data in healthcare between 2010 - 2015.The authors maintained that big data provides a great opportunity and intelligent workflow management tools for hospital preparations, which might include an operating room for surgeons. According to Belle et al. (2015), application of big data in genomics will help to prevent or cure diseases and delivery personalised care to each patient.
Hospital practices (3): Hospitals are becoming bigger with limited resources to admit, treat, operate, or monitor increasing numbers of patients.	**Article streams (3):** For easy, flexible, and smooth operations of the industry and for cost savings, the healthcare organisations now rely on advance and smart technologies particularly in ICU and Emergency department.	Farahani et al. (2015) envision the role of IoT in other divisions of the hospital care practices such as intensive care unit (ICU), primary care unit, and specialised units. The authors also suggest that smart Ambulances could perform on-fleet diagnosis such that medical staff can make possible arrangements before the arrival of the patients in ICU or A&E department. Smart ambulances will need a set of reliable medical sensors for diagnosis, a secure communication link with hospital. Siyal et al. (2019) proposed a blockchain-based tele-monitoring healthcare framework for the diagnosis and treatment of cancer tumours for remote patients. it can also be used to ensure the validity and security of patient's data specialised

		medical centres, as well as in patients' homes. The authors suggest that blockchain could be used in storing, transferring, sharing, as well as maintaining the most sensitive electronic health and medical records of patients' health history. For example, health record of patients fighting for chronic disease such as HIV and Cancer.
Clinical services (1): Healthcare industry is facing challenging concerns of increasing aging population, individuals with chronic conditions and frequent outbursts of disease epidemics and rising populations.	**Articles streams(4):** Healthcare organisations employ new technology for scheduling and managing epidemic outbreaks, chronic disease, patients make frequent visits to hospital or clinics for the doctors to make observations that include monitoring disease progression and to make clinical decisions that lead to treatment adjustments. Moreover, big cities will become a centre of epidemic outburst of contagious diseases that will spread easily across dense populations. In facts, big data can help fight the spread of communicable diseases.	According to Javid et al. (2020), AI helped to analyse the level of infection of any epidemic virus by identifying the clusters and hot spots, as well as in through contact tracing of the individuals and monitoring them. Likewise, Farahani et al. (2015), confirm that IoT could play significant roles to make the medical processes and procedures more cost effective, timely, reliable, and easy. WHO predicted in 2015 that 70% of the world's populations will live in urban environment. This implies that big cities will demand more healthcare infrastructure to serve rising populations. According to Yaqoob et al. (2021), blockchain is deployed in applications of IoT, AI, ML, Computer vision to facilitate doctors and clinical practitioners in the diagnosis and treatment of various chronic diseases.
	Article streams (5): Digital techniques like Big data and AI help in understanding prediction pandemic outbreaks and the same predict consumers' purchasing behaviours during pandemic crises.	Chunara et al. (2014; cited by Kshetri, 2014) carried out retrospective analysis of the 2010 cholera outbreak in Haiti indicated that mining data from Twitter and online news reports could have given the country's health officials an accurate indication of the disease's spread with lead time of two weeks.

Table 5. Thematic landscape in terms of broad themes and sub-themes (article streams).

DDIHP (Functions): reflecting the main focus	**Articles streams (Operations): showing the conceptual underpinning of the sub-theme focus**	**Conceptual standpoints of selective articles (Applications): full list of the authors**
Clinical services (2): Healthcare operations is utilisation the enormous volume of information from patient data by Scientist to detect drug interactions, design and implement optimal drug therapies	**Article streams (6): T**he growth of Industrial Internet of Things (IIoT) has increased the applicability and transformation of big data analytics in pharmaceutical sand drug prescriptions, as well as across healthcare industry.	Several researchers (Abaker et al., 2014; Biajian et al. 2018) acknowledged the application of big data in pharmaceutical sector. Similarly, other scholars (Gautam and Pan., 2016; Giuseppe et al., 2018; cited by Ogbuke et al., 2020) confirm that mobile health are starting to transform the healthcare and diagnostics in a significant way, with new players such as Apple and Google acting as

		increasingly disruptive catalyst. According to Henschen, (2014; cited by Lamba and Singh, 2017), Vaccine manufacturing firm, MERCK implemented Hadoop to utilise huge amount of data in producing vaccines faster and reduce the discard rates. According to Senthilkumar et al. (2018) have noted that big data is used during all pharmaceutical development, particularly for drug delivery. The authors gave example of how Pfizer has recently initiated Precision Medicine Analytics Environment program that associates the dots among electronic medical record data, clinical trials, and genomic to identify chances to rapidly convey innovative medicines for patient populations. Aimar et al. (2019) In his study proposes that 3D printing plays relevant range of role consistent in clinical preoperative evaluation.
Patients' homes (1): One of the emerging models for healthcare today is Patient-Centre Care (PPC). This model focuses on the patients and their individual healthcare needs.	**Article streams (7):** This model was not designed to eliminate hospital and clinics. Instead it leverages them in the share model for patient care. To integrate hospital or clinics with patients in PCC, there is a need to utilise the powerful ecosystems of IoT, both in smart homes and in self-testing.	Senthilkumar et al. (2018) in their research paper review the definition, process, and use of big data in healthcare management. The authors analysed the effective tools used for visualization of big data and suggesting new visualization tools to manage the big data in healthcare industry. Farahani et al. (2015) stated that IoT is a convergence of sensors, wearables, actuators, telecommunications, cloud computing and big data, interconnecting them through the internet to provide goal-oriented services. The applications of these digital tools include using wearable wrist watches and sensors by the patients to monitor and to detect heart rate, glucose level and blood pressure, and integrating the information into the Electronic Health and Medical records for easy analysis, diagnosis and treatment by health professionals and clinicians.
Nursing Homes (2): One of the first and famous stakeholders of digital techniques for Healthcare electronic data management practices is telemedicine. This health service is very vital for elderly patients with chronic disease, as well as disable individuals	**Article streams (8):** In telemedicine, IoT, has a lot to offer since a large portion of the world population owns cellophanes and smartphones. These digital tools are not just mere communication devices, but they are useful for connecting with other sensors	Chowdhury et al. (2021) in his studies confirm that such technologies can help the healthcare supply chain immediately to ramp up the production of Personal Protective Equipment (PPE), Mechanical Ventilators, and other essential items (Chowdhury et al., 2021). Other studies also acknowledge that smart phones played a vital role in medical field in enabling patients to self-test their own health, particularly now that self-test data have become important predictors of health and diseases. Additionally, physicians and medical staff have ways of seeing their patients virtually

		via teleconferencing. More so, IoT could further augment telemedicine by networking sensors to facilitate tele-screening. In this way, the hospital still could cope with a smaller number of health workers by increasing the virtual care services.
Rural Areas (1): There is an increasing demand and adoption of Mobile Clinics in healthcare services, particularly, in most developing countries	**Article streams (9):** In African for example, mobile clinics are proved to over a low-cost, high quality care for vulnerable populations in remote areas where citizens have no access to basic medical facilities. Mobile clinics are vehicles with limited medical facilities that could partner with large.	Yang et al. (2014; cited by Senthilkumar et al., 2018)) in his research predicted that in near future, fresh big data-derived influences will prompt suitable updates of diagnostic assistance, clinical guidelines and patient triage that permit more particular modified treatment, and advance medical results for patients. Data-drive technologies like IoT, Big data, and AI could make a difference in enhancing the infrastructure of the mobile clinics, which could partner with large hospitals to remotely communicate for diagnosis and decision support.
Anywhere (1): Since telemedicine services can reduce the number of visits to hospital and clinics, especially for patients who are elderly with chronic conditions or disabilities, it become crucial to establish a technical infrastructure in their homes. In that regards, there is need for smart homes and environment that will provide an enabling support system to assist citizens to experience independence, activity, quality of wellbeing.	**Article streams (10):** Digital technologies have penetrated the market of home automation to provide interactive capabilities for residents to control the appliances using smartphones and remote controls. Smart homes could adjust lights and sound to avoid sensory overloads for individuals with autism who then could live better quality life	Yalamanchili et al. (2012) predicted that big data application in proteomics will have a major role in predicting and preventing human cancer. Other literature sources maintain that IoT and smart sensors could be customised to fulfil specific healthcare needs of elderly individuals. Smart toilet could execute urine testing on regular basis for preventive and primary care. Another example on how IoT-driven smart cities can make the healthcare more efficient is the convergence of smart traffic lights and ambulance routing to save lives with the cooperation of transportation infrastructure. Shah et al. (2018) in his also highlighted key insights for the top applications, which include wearables connectivity, disease detection and treatment, patient care, and sensor networks. The authors identify gaps and future research directions related to technology design and acceptance, regulations for data security and privacy, and system efficacy and safety. Aimar et al. (2019) have noted that 3D Printing technology represent a big opportunity to help pharmaceutical and medical companies to create more specific drugs, enabling a rapid production of medical implants and changing the way that doctors and surgeons plan procedures.

		Manero et al. (2020) emphasis that 3D Printing is used in producing a variety of equipment for hospitals including face shields, masks, and even, ventilator for components to handle the surg.

4.1. National and geographical contexts

Furthermore, the articles were categorised according to the national and geographical contexts. National and geographical context are important factors for developing customised strategy for dealing with covid-19, given that different countries have experienced different infection rates and adopted different lockdown strategies to manage the pandemic situations (Chowdhury et al., 2021).

Table 7. Detailed timeline of DDIHP

Article Streams (AS)	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	Total
Hospital Practices														
AS1						1	2		1		2	1	1	8
AS2	1	1			1	1		1		1	1			8
AS3			1			1	1		1		3		1	8
Clinical Services														
AS4						1			1	3	1			6
AS5	1		1			1	1	2	1		1	1	1	10
AS6					1	1	1	1	2	2	1	1		10
Patients' Homes														
AS7			1			2			1		1	1	1	7
Nursing Homes														
AS8			1		1		1		1		1	2	1	8
Rural Areas														
AS9		1				1	1		1		1		1	6
Anywhere														
AS10			1			1			1		1	1	1	6
Total														**77**

We also adopted this novel classification with interesting evidence that constant pandemic crises like the recent Covid-19 has exacerbated data management crises in healthcare data services. Hence the need and rapid adoption of digital data-driven technologies as solution enablers. In line with this objective, the reviewed articles focused mostly on digital applications in healthcare environment across nations and countries ranging from Advance (A) countries, Emerging (E) countries, to Developing (D) countries (see table 8). Furthermore, the top medical problems discussed in the papers include health monitoring, diseases detection/treatment, system accuracy/security, and data collection/management. Other fewer problems covered in the papers include smart hospitals and medical specialisation, as well as research/innovations and emergency response.

Table 8: The national and geographical contexts on which the reviewed articles focused

Country	**Economy**	**Number of Articles**	**References**
Central European countries	A	3	Ogbuke et al. (2020); Dash et al. (2019); Mathy et al. (2020); Suara et al. (2022); Vali et al. (2022); Tsolakis et al. (2022), Ji et al. (2022); Modgil et al. (2022)
South Asian countries	E	3	Zhang et al. (2015); Bhaskar et al. (2020); Wang et al. (2019); Song et al. (2022)
Multiple countries from various continents	A, E, D	9	Bourlakis et al. (2016); Daecher et al. (2018); Miorandi et al. (2012); Suciu et al. (2015); Tao et. (2018); Ali et al. (2020); Bhaskar et al. (2020); Aimar et al. (2019); Angraal et al. (2017); Kazancoglu et al. (2022)
Canada	A	2	Ageron et al. (2018); Drysdale et al. (2020)
Algeria	D	1	Schiopoiu et al. (2020)
India	E	1	Senthilkumar et al. (2018)
Ireland	A	2	Farahani et al. (2015); Cavanillas et al. (2016)
United State	A	5	Shah et al. (2018); Davenport and Kalakota (2019); Manero et al. (2020); Zhang and Koru (2020); Panhuis et al. (2018)
Australia	A	1	Chowdhury et al. (2021)
UAE	E	2	Zobbi et al. (2020); Yaqoob et al. (2021); Samad et al. (2022)
Italy	A	1	Aimar et al. (2019)
Greece	A	1	Siyal et al. (2018)

Sweden	A	1	Rahaman Mohammad (2020)
Germany	A	1	Ivanov and Dolgui (2020)

5. Discussion

This study presents a comprehensive and systematic review of existing and future research perspectives in data-driven technology for healthcare practices and operations. The paper also explored the most challenging parts of digital technology applications in healthcare data privacy, data leakage, data security, scalability in terms of efficient handling of large volume of electronic health and medical data records, as well as interoperability and regulatory concerns, not only to healthcare organisations but the vulnerable populations. We also assessed the novel applications of digital technologies such Big Data, AI, 3D Printing, and Blockchain technology, and provided the conceptual background and overview of these innovations, highlighting other factors associated with their diffusion, uptake, and sustainability initiatives in the society and across the healthcare industries. Additionally, the review outlined six principle facets namely: hospitals practices, clinical services, patients' home, nursing homes, rural areas, and anywhere, which provided the useful insights and the journey involved in the emergence of data-driven technologies for healthcare practices.

These principle facets are built across the multiple levels and unique conceptual standpoints indicated by 10 sub-themes. These themes were generated based on 77 articles (2010 -2022) drawn from 40 leading Journals. This research is very novel and is one of first studies, to the best of our knowledge, which systematically synthesized and analysed both the prior and most recent discussions on electronic health and medical data records, as well as digital applications in response to the sweeping crisis of Covid-19 pandemic. This paper comprehensively explored the current digital applications, as well as the potential prospects, including the industry 4.0, following a well-designed thematic landscape and conceptual articles streams. Again, most of the existing research work focused more on the traditional healthcare data practices, with limited information on today's emerging models for healthcare - Patient-Centre Care (PPC). The model focuses on the patients and their individual healthcare needs, with potentials to integrate hospital and clinics with patients in PCC, thereby utilizing the powerful ecosystems of IoT, digital tools, both in smart homes and in self-testing.

Most reviewed research work often justified the traditional approach, because of the associated data security, data leakage, and data privacy challenges of digital innovations on the vulnerable individuals. Other justifiable factors include cost implications posed to healthcare organisations, in terms of maintenance and managing the electronic health and medical records. Other scholars have also noted that the interactions in supply chain for vast majority of enterprises are going unmonitored, and have created silos along the operations processes, resulting in businesses inefficiency. They argue that the usage and exploitation of these unmonitored and unstructured massive data information by digital technologies may have also illustrated the value creating possibilities of data-driven innovations for business decision-making skills. In general, the systematic rigor adopted in this study is more evident, particularly in clear recognition of these most challenging issues of data security, data privacy and their impact on individuals' freedom, transparency, and the ramifications to the entire society. More so, the comprehensive review demonstrates clarity, and brought to bear what the issues are, that these emerging innovations will offer proactive and useful data management insights for healthcare organisation's decision-making and better performance.

6. Conclusion

The issue of data management in the global healthcare practices has become a more challenging concern with the recent pandemic outbreak. Prior to COVID-19 disruption, firms were known for their just-in-time capabilities and souring strategies. But post-Covid-19 recovery has broadened the conversation around mitigating supply shocks, sustainability, and resiliency of supply chain networks through the application of digital techniques. Our findings have indicated considerable consensus across recent literature that digital data-driven technologies mitigate the impacts of coronavirus on healthcare operations. Literature evidence has also shown that these digital techniques have the potential to provide more responsive digital solutions to the data management crises that characterised the industry, such as high demands of rising aging populations with chronic diseases, child mortality and frequent impacts of pandemics.

Overall, the idea among both the practitioners and academics that COVID-19 pandemic is a practical experiment to text the capabilities of industry 4.0 technologies, and to understand their limit within the systems has been validated in this study. In fact, our findings have not only validated this assession but have shown it with empirical evidence as demonstrated in the theoretical and managerial contributions of the study.

6.1. Contributions

In this paper, we presented insightful discussions on the integration of digital data-driven technologies with healthcare systems, and highlighted other factors and challenges associated with their diffusion and uptake across the industries. We formulated six thematic landscapes, namely, Hospitals Practices, Clinical Services, Patients' Home, Nursing Homes, Rural Areas, and Anywhere, which focused on the patients and their individual healthcare needs, with potentials to integrate hospital and clinics with patients in PCC. The review also showed that the number of articles on this subject have been steadily increasing owing to the sweeping health crisis of Covid-19 Pandemic.

Through a systematic rigor, we comprehensively identified research gaps in the domain of this inquiry and suggested unique research questions and proffered step approaches that addressed the concerns. Moreover, the reviewed articles were categorised according to the national and geographical contexts. National and geographical context are important factors for developing customised strategy for dealing with covid-19, given that different countries have experienced different infection rates and adopted different lockdown strategies to manage the pandemic situations (Chowdhury et al., 2021).

6.2. Theoretical implications

The main theoretical contribution of this study is that: (1) Previous research has focused the capabilities of supply chain on just-in-time, inventory management, route optimisations and sourcing strategies (Song et al., 2022; Ivanov, 2020; Van Hoek, 2020; Modgil et al., 2021). This review paper has broadened the conversation from pre-COVID-19 pandemic to post-COVID-19 recovery, discussing mitigating supply shocks, sustainability and resiliency of global supply value chains, through the applications of industry 4.0 digital technologies.

(2) The paper also investigated the most challenging parts of digital technology applications in healthcare data privacy, data leakage, data security, scalability in terms of efficient handling of large volume of electronic health and medical data records, as well as interoperability and regulatory concerns, not only to healthcare organisations but the vulnerable populations. We embraced a systematic approach to established rigor throughout, and the articles were filtered from 40 mainstream Journals as listed in table 4. This was based on a similar approach used by Vaithianathan (2010; cited by Shahria and Wamba, 2016) in e-commerce and Benedettini and Neely (2012) in service system research.

(3) Furthermore, the reviewed articles focused mostly on digital applications in healthcare environment across nations and countries ranging from Advance (A) countries, Emerging (E) countries, to Developing (D) countries (see table 8). The study adopted a protocol that described the criteria, scope, and methodology at each step (Ogbuke et al., 2020). Additionally, the thematic landscape was designed around the conceptual standpoints along top categories including Hospitals Practices, Clinical Services, Patients' Home, Nursing Homes, Rural Areas, and Anywhere. The thematic landscape was further expanded into broad level themes and sub-themes as shown in Table 5 and 6. As such, total number of 6 broad themes and 10 sub-themes were identified. The tables were designed to provide a clear understanding of the specific conceptual underpinnings as contained in the thematic landscape. (4) In this study, we offer a threefold contribution to the recent literatures, and the consensus among most scholars (Song et al., 2022; Saura et al., 2022; Kazancoglu et al., 2022; Tsolakis et al., 2022; Vali et al., 2022; Samad et al., 2022) that digital data-driven technologies mitigate the impacts of coronavirus on healthcare operations.

6.3. Managerial implications

According to the conclusions, this study has some managerial contributions. (1) Most existing research work focused more on the traditional healthcare data practices, with limited information on today's emerging models for healthcare - Patient-Centre Care (PPC). Our model focuses on the patients and their individual healthcare needs, with potentials to integrate hospital and clinics with patients in PCC, thereby utilizing the powerful ecosystems of IoT, digital tools, both in smart homes and in self-testing. We designed the thematic landscape around the conceptual standpoint top categories, ranging from Hospitals Practices, Clinical Services, Patients' Home, Nursing Homes, Rural Areas, and Anywhere. Therefore, firms should focus on fostering digital technology capabilities and strengthening of data infrastructures, as well as recruitment of analysis technical personnel to improve data value for independent innovation decisions (Ji et al., 202). For example, telemedicine services can reduce the number of visits to hospital and clinics, especially for patients who are elderly with chronic conditions or disabilities. It will become crucial to establish a technical infrastructure in their homes. In this regard, there would be need for smart homes and environment that will provide an enabling support system to assist citizens to experience independence activity, and quality of wellbeing.

(2) However, most reviewed research work often justified the traditional approach, because of the associated data security, data leakage, and data privacy challenges of digital innovations on the vulnerable individuals, particularly in the rural developing nations. But this study combined digital analytics capabilities to organisational processes. Afterall, there is an increasing demand and adoption of Mobile Clinics in healthcare services, particularly, in most developing countries. For example, in African for example, mobile clinics are proved to over a low-cost, high-quality care for vulnerable populations in remote areas where citizens have no access to basic medical facilities. Mobile clinics are vehicles with limited medical facilities that could partner with large. Data-driven technologies like IoT, Big data, and AI could make a difference in enhancing the infrastructure of the mobile clinics, which could partner with large hospitals to remotely communicate for diagnosis and decision support (Yang et al., 2014; cited by Senthilkumar et al., 2018).

(3) Other justifiable factors include cost implications posed to healthcare organisations, in terms of maintenance and managing the electronic health and medical records. Notwithstanding, our findings have enriched the data-driven innovations literature by demonstrating how data resources can be achieved through cooperation and the advantages healthcare enterprises can gain through this innovation activities. For example, in clinical services, healthcare operations are utilisation the enormous volume of information from patient data by scientist to detect drug interactions, design and implement optimal drug therapies. Additionally, the growth of Industrial Internet of Things (IIoT) has increased the applicability and

transformation of big data analytics in pharmaceutical sand drug prescriptions, as well as across healthcare industry. Other scholars (Gautam and Pan., 2016; Giuseppe et al., 2018; cited by Ogbuke et al., 2020) have confirmed that mobile health is starting to transform the healthcare and diagnostics in a significant way, with new players such as Apple and Google acting as increasingly disruptive catalyst. Henschen, (2014; cited by Lamba and Singh, 2017) corroborated that Vaccine manufacturing firm, MERCK has implemented Hadoop to utilise huge amount of data in producing vaccines faster and reduce the discard rates.

6.4. Limitations and future research directions

Whilst our study offers clear theoretical and managerial implications, it is not without limitations. For example, the developing nations are underrepresented in this research review as evidence in the national and geographical contexts as outlined in table 8, and therefore, more research is needed in this context. More so, we have noticed that there are quite limited publications that are available on digital technologies and integration within the healthcare systems. There is also interesting evidence that research conducted in healthcare industry particularly in data-driven technologies, are quite limited and have fluctuated tremendously. We have also, observed that limited articles have been published in data-driven technology since 2015. This clearly shows that there are still lots of demand to increase research outputs in healthcare data management. Finally, we strongly recommend this review paper, and believed it will set the pace and lead further discussion in this emerging healthcare operational research.

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