Leveraging Digital Transformation Technologies to Tackle COVID-19: Proposing a Privacy-First Holistic Framework

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Abstract The COVID-19 outbreak has caused unprecedented shocks to public health and economies around the world. The emergent technologies creating digital transformation across all industries have started to transform businesses in the last years. Although utilized by the healthcare industry before COVID-19, some of these technologies gained significant attention since they can alleviate the pandemic crisis. A holistic framework can still help (1) understand the relationship between fragmented technology solutions, (2) figure out how to combine fragmented solutions, (3) integrate data sources, and (4) introduce integrated digital solutions. Correspondingly, we explore the use of emergent technologies by proposing a privacy-first holistic framework by integrating digital transformation technologies to tackle the COVID-19 pandemic. The framework consists of data sources, technologies, users, applications for diagnosis, treatment, and prevention, and users. We then discuss the benefits and challenges of the framework. The proposed framework aims to provide a more efficient and dynamic healthcare system to reduce the death toll, the risk of virus transmission, and healthcare givers’ workload and stress levels.

Keywords COVID-19 · Digital transformation · Emerging technologies · Data science · Blockchain
1 Introduction

The COVID-19 is a respiratory disease caused by the recently discovered coronavirus attacking the respiratory system and causing fever, cough, breathlessness, and fatigue. The first case was reported in Wuhan City, China, in December 2019. After then, it has spread across the world in a short amount of time. On March 11, the World Health Organization (WHO) declared COVID-19 as a pandemic disease after reporting 118,000 cases and 4,300 deaths across 114 countries. According to the latest COVID-19 statistics published by WHO [1], the total number of cases has exceeded 20 million people, and the total number of COVID-19 deaths has reached 700,000, spread across 213 countries, with the US having the highest number cases.

The healthcare system would be overwhelmed by the pandemic in a short amount of time when the number of severe coronavirus cases spikes sharply, as seen in the case of Italy. The high rise of the novel coronavirus cases can cause a significant scarcity of resources, hospital beds, and healthcare professionals. To prevent these kinds of problems by reducing the spread of the virus and delaying the peak of hospitalization, there are some possible solutions, as lockdown and quarantine, which have some national and international drawbacks, such as the economic recession and mental problems of the population.

Since all organizations providing non-essential products and services are forced to shut down during lockdown, billions of people are at risk of losing their jobs. The estimated loss on the global economy caused by the COVID-19 is forecasted to exceed 5.5 trillion dollars in the next 18–24 months. This is the same as losing Japan.¹ There is still no specific treatment or vaccine found to alleviate this pandemic when this paper was written. The increase in the number of laboratory-confirmed COVID-19 cases at an alarming rate and shortcomings of lockdown has caused the need for urgent countermeasures to reduce the disastrous effects of this pandemic.

The emergent technologies creating digital transformation across all industries are the digital twin, the Internet of Things (IoT) and connected devices, artificial intelligence, cyber-physical systems, integration, social media and platforms, blockchain, everything-as-a-service (XaaS), robots and drones, and data analytics. It is forecast that, by 2022, more than 60% of the global gross domestic product will be digitized. By 2030 more than 70% of new value creation in the economy will be based on digitally-enabled platforms [2].

According to the WHO and the US Centers for Disease Control and Prevention (CDC), digital transformation technologies can play an essential role in fighting the COVID-19 pandemic.² For example, healthcare IoT, the Internet of Medical Things (IoMT) integrated into healthcare information technology (IT) systems, collects, analyzes, and transmits health data efficiently. Thus, it offers many services as

¹https://www.bloomberg.com/news/articles/2020-04-08/world-economy-faces-5-trillion-hit-that-is-like-losing-japan.
²https://www.who.int/news-room/detail/03-04-2020-digital-technology-for-covid-19-response.
monitoring patients by the concerned healthcare professionals in a real-time manner from a remote location.

Utilization of digital transformation technologies to alleviate COVID-19 has the potential to provide benefits, improving efficiency and effectiveness of diagnosis, treatment, and prevention processes. After realizing how versatile they are, digital transformation technologies have recently attracted intense attention from both industry and academia, many prototypes and applications have been developed and started to be used. Although there are fragmented cases, the integration of these technologies, which provides a significant impact on tackling COVID-19, is needed to achieve a more dynamic and efficient healthcare environment. The aim of this study is to propose an integrated framework consisting of digital transformation technologies and to provide innovative solutions to tackle COVID-19. Correspondingly, the research question of the chapter is that how an integrated framework consisting of digital transformation technologies can provide innovative solutions to tackle COVID-19.

The remaining of the paper is structured as follows: first, the background of the study is given, followed by the results of the literature review related to digital transformation technologies used for alleviating COVID-19. Then, the proposed conceptual integrated digital transformation framework is given, and the services provided through the framework are described. After analyzing the benefits and challenges of this system, we conclude the paper with final remarks.

2 Background of the Study

Some of the emerging technologies creating digital transformation across all industries, as digital twin [3], Internet of Things (IoT) and connected devices [4], Artificial Intelligence [5, 6], Cyber-Physical Systems [5–7], Integration [5, 8, 9] Social media and platforms, Blockchain [10], Everything-as-a-Service (XaaS) [11], Mobile computing [12–14], Cloud computing [15–17], Robots and drones, Data Analytics [18, 19] and 3D printing [11] are summarized in Table 1.

3 Literature Review

Although present before COVID-19, several technologies gained attention to cope with the pandemic. In this section, we will investigate data-driven solutions, digital contact tracing, robotics, and virtual clinics. These solutions are maturing, yet a holistic framework is necessary to (1) understand the relationship between fragmented solutions, (2) figure out ways to combine fragmented solutions, (3) integrate data sources, and (4) introduce integrated digital solutions to tackle COVID-19.
As of August 5, 2020, confirmed COVID-19 cases amount up to 18,965,479 [1]. Many organizations, including the WHO and the European Centre for Disease

| Technology                                      | Description                                                                 |
|------------------------------------------------|----------------------------------------------------------------------------|
| Digital Twin                                   | Compiling and formatting data of physical reality into the virtual world. It is used for creating simulation models to monitor, diagnose, and forecast |
| Internet of Things (IoT) and connected devices | Using and seamlessly integrating low-cost sensors and processors provides the generation of big data and ubiquitous environments throughout operations |
| Artificial Intelligence (AI)                   | The development of software for accessing, combining, analyzing data, and converting it into valuable information for learning, explaining, and forecasting the operations, events, and trends |
| Cyber-Physical Systems                         | Combination of real-time data collected from the physical systems, software modeling, and statistics to predict the behaviors of the system under different scenarios for making decisions in real-time |
| Blockchain                                     | Using distributed computers not owned by a single entity to manage immutable records of time-stamped data |
| Everything-as-a-Service (XaaS)                  | Tailoring the computing environments to reshape customer experiences |
| Social media and platforms                     | Bringing ecosystem parties together in a very accessible (low cost) way by providing interaction and giving feedback. I.e.: Uber |
| Robots and Drones                               | Using robotics technologies that have the capability of sensing and responding to the environment |
| Big Data Analytics                             | Collecting, storing, analyzing, and distributing big data to make better and faster decision making |
| 3D printing                                    | Printing the physical objects by using digital 3D models |
| Autonomous Vehicles                            | Developing vehicles that are driven utilizing built-in applications |
| Next-Generation Communication Network (5G)      | Wireless communication supported by mobile networks has a better performance than 4G |
| Cloud Computing                                | Availability of data centers to many-users over Internet |
| Image processing                               | Using algorithms for processing digital images |
| Mobile Computing                               | Chatbots: applications for an online chat conversation Mobile applications: a software application developed to run on mobile devices |
| Virtual Reality                                | Simulation of the real world or a completely different world |
| GIS                                            | Using spatial analytics, mapping, and location intelligence to determine the exact location |

### 3.1 Data-Driven Solutions

As of August 5, 2020, confirmed COVID-19 cases amount up to 18,965,479 [1]. Many organizations, including the WHO and the European Centre for Disease
Prevention and Control (ECDC), publish near real-time data to COVID-19 [20]. Dashboards and frequently updated figures provide exploratory and explanatory visual analysis capabilities by aggregating and cleaning these data sources. Among the exploratory ones, there are John Hopkins’ COVID-19 Dashboard [21] and Microsoft’s Bing COVID-19 Tracker [22]. On the other hand, to assist decision-makers, the Financial Times provides explanatory figures updated frequently [23]. However, we do not know the real number of cases since widespread population testing is still not available in most countries. Thus, some studies investigate prediction models. These models are either diagnostic or prognostic [24]. Diagnostic models predict the existence of the disease while prognostic models predict outcomes such as mortality risk, length of hospital stay, and the necessity of intensive care. For example, Menni et al. [25] used self-reported data from a free smartphone application available in the UK. They have generated a linear diagnostic prediction model that considers age, sex, loss of smell and taste, severe or significant persistent cough, severe fatigue, and skipped meals.

Despite the limited amount of data available, there is considerable effort to forecast new COVID-19 cases in real-time. Chakraborty and Ghosh [26] proposed a novel hybrid approach to obtain real-time ten-day forecasts for Canada, France, India, South Korea, and the UK Centers for Disease Control and Prevention (CDC) [27] publishes weekly forecasts of total deaths and hospitalization for the USA. These forecasts are produced by numerous modeling groups that include Carnegie Mellon University, Columbia University, and Georgia Institute of Technology.

### 3.2 Digital Contact Tracing

The pandemic stimulated the development of mobile-based digital contact tracing systems. By keeping a history of contact proximity and duration, these systems immediately send notifications to close contacts of diagnosed cases prompting them to self-isolate [28]. Various protocols emerged to help implement such systems, among which are Apple and Google’s combined Exposure Notification Framework [29, 30]. These protocols use Bluetooth or GPS technologies to track encounters between two devices. They differ in terms of their log processing and availability of specifications. Here, we only exemplify protocols that provide public specifications.

The majority of protocols respect the users’ privacy by exchanging non-personally identifiable messages that change frequently. The goal is to prevent third parties from identifying individuals. The usage of centralized log processing still raises privacy concerns. BlueTrace [31] and PEPP-PT [32] are example protocols where infected individuals share all their encounters with a health authority. The health authority can decrypt the encounter history and obtain personally-identifiable information.

Decentralized protocols delegate log processing to local devices. All encounter data remains local, but a central server still exists to observe anonymous identifiers.
of infected users. DP-3T [33] and TCN [34] are example protocols that implement decentralized log processing. In the case of TCN, a trusted health authority can maintain the integrity of the positive test results. Two implementations of TCN are CoEpi [35] and CovidWatch [36]. CoEpi allows users to self-report infection, while CovidWatch allows reports through a trusted authority.

3.3 Robotics

Robots take on tedious and dangerous jobs, some of which are not suitable for human workers. COVID-19 stimulated further research and investment in robotics to fight infectious diseases. We now use robots for surface disinfection, diagnosis and screening, and delivering medication [37]. Moreover, Kimmig et al. [38] argue that robot-assisted surgery reduces the number of medically exposed staff and contamination with body fluids and surgical gasses. It also makes room for COVID-19 patients by reducing hospital stay for patients who urgently need complex surgery.

3.4 Virtual Clinics

In response to COVID-19, virtual consultations are on the rise to prevent physical presence at clinics. Using smartphones or webcam-enabled computers, healthcare providers can efficiently screen patients before they arrive in hospitals [39]. The decision to intake a patient would depend on symptoms combined with local epidemiologic information, and detailed travel and exposure history. Gilbert et al. [40] rapidly implemented virtual clinics in response to the COVID-19 crisis and surveyed patients who undertook virtual consultations via telephone or video call. Patient satisfaction scores were high. Among the reasons for high satisfaction were reduced travel times, reduced waiting times, and reduced travel impact on symptoms.

As stated in [41], although the proliferation of telemedicine systems can alleviate COVID-19, a more efficient and dynamic healthcare system can be realized through consolidation with other digital transformation technologies, like mobile applications, drones, smart wearables, and other IoT devices. In summary, several digital transformation technologies currently address the critical problems of COVID-19. However, there is a need to manage these digital transformation technologies from a holistic point of view and use them in conjunction with other digital transformation technologies. This study aims to fill this gap by proposing a conceptual framework architecture, described in the next section.
4 The Proposed Integrated Digital Transformation Framework

As stated in [41], there is a lack of integration of data sources of existing digital transformation technologies. The aim of this framework is to demonstrate how innovative solutions can be generated by integrating these verified data sources via a holistic digital transformation framework.

As depicted in Fig. 1, the proposed holistic digital transformation framework consists of four main components: Data Sources, Digital Transformation Technologies, Applications, and Users.

4.1 Data Sources

With the recent technological advancements in IoT and cloud computing domains, we are able to collect data from an extensive array of data sources. These data sources may have different forms, including unstructured, semi-structured, and structured. The unstructured form includes image, audio, video, and text data, the semi-structured form includes XML and JSON data, and the structured form includes data stored in relational database management platforms. The proposed framework aims to collect and blend these data forms in a single platform and transfer these data to the digital environment for further use. The data sources may include governmental data, including citizen and health records and surveillance cameras, Internet of Things (IoT) devices. Moreover, there are also personal private data sources, including mobile and wearable devices, social media, and Internet of Medical Things (IoMT) devices. The proposed framework aims to gather and integrate these verified data sources from the external environment and provide a resilient data pipeline for digital transformation technologies.
4.2 Digital Transformation Technologies

Emerging digital technologies, including cloud computing, artificial intelligence, digital twin, virtual reality, image processing, big data, robotics, next-generation communication network, and 3D printing, are able to provide infrastructure for innovative applications to diagnose, treat and prevent pandemic by utilizing a wide range of data sources. However, these data sources may also include private information and health records, and there are strict government regulations and policies to transfer and share these data over the internet. The proposed framework needs to support data privacy by anonymization and encoding of private records such as name, surname, test results, and social security number. Hence, blockchain technology plays a crucial role in the proposed framework to transfer and share these private data anonymously and securely by using encryption and digital signs. Blockchain technology provides a solution for technical and social challenges, including privacy and quality of data. Accordingly, the utilization of blockchain technology in the healthcare domain presents promising solutions, including securing communications among stakeholders, efficient, accountable, transparent, and accurate delivery of private health records [42]. Moreover, blockchain technology enables us to integrate various kinds of private health records of individuals on a secure infrastructure. Even though some studies in the literature utilizes blockchain in the healthcare domain to solve a specific problem, including medical record management [43], medical [44], and financial transaction verification [45], these studies do not provide a comprehensive solution. To this end, the main focus of this study is proposing a holistic framework by integrating data sources and state-of-the-art digital transformation technologies on a blockchain-based secure infrastructure.

4.3 Applications

The proposed framework gathers and blends different various data sources in structured, semi-structured, and unstructured forms in a platform for interested parties, including researchers, healthcare professionals, and physicians. These interested parties may develop innovative applications by utilizing state-of-the-art digital transformation technologies. The result of these developed applications may be forwarded to interested parties in different forms to be used in diagnosis, treatment, and prevention applications for COVID-19.

4.3.1 Applications for Diagnosing COVID-19

With the state-of-the-art digital transformation technologies, we are enabled to develop applications for augmenting early diagnosis of COVID-19. The proposed
framework assists data scientists and researchers to analyze provided a vast amount of datasets to analyze and train novel Artificial Intelligence (AI) and machine learning (ML) models to present more accurate and rapid diagnosis applications. These diagnosis applications are listed below:

- identifying people who had exposure to infected individuals
- automating the clinical testing process by using robots and Cyber-Physical Systems (CPS)
- observing patients’ health indicators including stress level, cardiorespiratory variables, and daily activities in real-time with smart wearables, IoT devices, and mobile devices and notifying if there is any deviation from the baseline of the individual
- diagnosing COVID-19 via AI-powered medical imaging applications for analyzing computed tomography scans and X-rays
- supporting healthcare givers via telemedicine used in conjunction with AI, smart wearables, drones, and 5G cellular networks for evaluating, diagnosing and treating patients

4.3.2 Applications for Treating COVID-19

Developed treatment applications as a result of the utilization of emerging digital transformation technologies in the proposed framework are listed below:

- rapidly developing drugs and vaccines for COVID-19 by utilization of robots and CPS technologies
- helping hospitalized patients in transporting and serving food or medicines by robots
- developing unique treatment protocol for each patient and identifying patients with a higher possibility of developing severe symptoms based on their initial symptoms as a result of the utilization of AI and big data technology for analyzing patients’ historical health records and response to current treatment
- offering extensive healthcare services as monitoring patients’ health in a real-time manner and tracking their medicine use periodically by the integration of smart medical devices with IoMT technology.

4.3.3 Applications for Preventing COVID-19

These emerging digital transformation technologies and diverse set of data sources also enable us to develop prevention application for COVID-19 which are listed below;
• collecting proactive measures from the data sources and developing and using AI-powered applications for risk forecasting, simulation, and modeling of COVID-19 spread, to effectively manage it by the public health offices.
• tracing and warning people about social distancing and wearing masks by utilizing IoT, mobile, and surveillance camera data sources. These data sources can also be utilized to determine potentially infected individuals who had close contact with a person who diagnosed COVID-19 in the last few days and notify these potential patients about regulations and guidelines they should adhere.
• utilization of drones, robotics, and image processing technologies enables to determine crowded places, identifying high-risk zones according to social distancing and wearing mask rules.
• thermal imaging, crowd surveillance, and broadcasting announcements by drones without any human intervention.
• disinfecting surfaces by autonomous robots.
• helping patients with mild COVID-19 symptoms who are under strict isolation at home.
• preventing hospital-acquired infections by prompting alerts about any sanitation necessity risky for public safety by using IoT.
• providing effective contact tracing as a result of the utilization of the mobile app, Bluetooth, and GPS data, which can be collected with the consent of the users. The information gathered as follows;
  – The real-time location and the previous locations of the person diagnosed with COVID-19.
  – The list people exposed to the diagnosed person in the last few days to determine potentially infected people.
  – The list of individuals exposed any potential COVID-19 patient.
• notifying individuals immediately via the mobile application.
  – if they exposed a person who has later diagnosed with COVID-19 and notifies the guidelines they should follow.
  – when they enter the high-risk zone which assigned accurate risk scores to spaces.
• preventing misinformation, myths, and conspiracy theories about COVID-19 by using AI on social media. For example, there was a myth on social media about spreading coronavirus through 5G infrastructure.

4.4 Users

The developed applications with digital transformation technologies can be used for patients, caregivers, medical device manufacturers, researchers, hospitals, pharma companies, and government. Patients can use these applications to track their health...
condition and their health indicators, including stress level, cardiorespiratory variables, and daily activities in real-time. Caregivers can use telemedicine applications for evaluating, diagnosing, and treating patients. Moreover, they can rapidly diagnose COVID-19 via AI-powered medical imaging applications for analyzing computed tomography scans and X-rays. Medical device manufacturers and Pharma companies can utilize these applications to improve their products and develop drugs, vaccines, and medical devices for COVID-19 by utilization of robots and CPS technologies. Researchers may get benefit from standardized and unified data sources to improve and accelerate their COVID-19 related researches. The developed applications and their collected data can contribute to the improvement of health data quality and quantity for COVID-19 related researches. Hospitals may disinfect surfaces, measure body temperature with thermal imaging, and broadcast announcements by autonomous robots without human intervention. Governments can trace the pandemic process in their countries with different indicators and develop emerging solutions to prevent COVID-19 and trace patients with their consent for ensuring that patients with mild COVID-19 symptoms are under strict isolation at home. Moreover, governments are able to determine crowded places to identify people who do not obey the rules, as social distancing and wearing a mask.

5 Benefits and Challenges of the Proposed System

Following the introduction of the proposed holistic framework and the analysis of principal components, we first discuss the benefits of producing integrated digital technologies to deal with contemporary problems caused by COVID-19. We then examine the challenges associated with building, maintaining, and exploiting the proposed framework.

5.1 Benefits of the Proposed Framework Architecture

5.1.1 Effective Strategic Management of COVID-19 Crisis

Public health agencies are responsible for making strategic decisions for tackling COVID-19 for their countries. Feeding integrated data from a multitude of sources to AI-powered applications yields better models, forecasts, and simulations. More reliable data products enhance the decision-making capability for public health agencies to manage the crisis effectively.
5.1.2 Reducing the Risk of Virus Transmission

After assigning accurate and real-time risk scores to zones, preventative applications can notify individuals immediately when entering a high-risk zone. Real-time detection of high-risk zones also enables local authorities to focus their efforts and take immediate action. Particularly in these zones and hospitals, autonomous robots can disinfect surfaces reducing the probability of staff members contracting the virus.

5.1.3 Detecting COVID-19 Carriers as Early as Possible

Since widespread population testing is not available in most countries, we do not know and thus isolate COVID-19 carriers if we do not implement strict lockdowns. A diagnosis application in the framework can combine user-reported symptoms, data from smart wearables, and travel and exposure history on smartphones. Telemedicine, together with remote testing or automated clinical testing procedures, can identify individuals who must self-isolate as early as possible.

5.1.4 Decreasing the Workload and the Stress Level of the Hospital Staff

The proposed framework supports healthcare givers to diagnose, treat, and prevent COVID-19 cases. It is possible to use telemedicine systems in conjunction with AI, smart wearables, remote testing, and autonomous robots. By reducing the workload and risk of virus contraction, integrated digital technologies also decrease the stress level of the hospital staff.

5.1.5 Reducing the Risk of an Overwhelmed Healthcare System

Early detection of carriers and decreased risk of virus transmission lead to a significant reduction in new case numbers, which require hospitalization. Moreover, better forecasts and simulations guide authorities’ decisions on prioritizing healthcare investments and regions to send a limited amount of medical supplies (e.g., test kits and respirators). As a result, the risk of an overwhelmed healthcare system goes down.

5.1.6 Decreasing the Mortality Rates and Increasing the Treatment Success Rates

The use of AI, together with big data technologies, facilitate the development of unique treatment protocols for each patient. Treatment applications can accurately
identify patients with a higher possibility of developing severe symptoms analyzing initial symptoms, response to current treatment, and historical health records. Predicting the necessity of intensive care early on would decrease mortality rates.

5.1.7 Reducing the Negative Impact of COVID-19 on the Economy

Digital transformation technologies can eliminate the need for lockdowns preventing economic shrinkage when they utilized in integrated forms. Furthermore, effectively preventing the spread would decrease the cost of treating patients.

5.1.8 Decreasing the Stress Level of People

There has been an abundance of misinformation, myths, and conspiracy theories about COVID-19 since the outbreak began. Combined with lockdowns, the inadequate response by public authorities, and overwhelmed states of hospitals, people’s stress level spiked. As public health agencies can present better models and forecasts, we can expect an increase in trust and a decrease in misinformation.

5.2 Challenges of the Proposed Framework Architecture

5.2.1 Data Acquisition and Integration

In the proposed framework, heterogeneous data sources transmit data in different forms, such as text, image, audio, and video. This heterogeneity is a significant challenge since it can negatively affect the time necessary to develop AI-powered applications [46].

With the help of blockchain, disparate systems store patient health records. Every member of the chain is connected, and data is updated in all of the computers at once. Therefore, blockchain solves the inconsistency problem in which patients encounter inaccuracies in their health records, or their medical history is not available to all stakeholders. On the other hand, the proposed framework relies on trusted authorities to maintain data integrity. Selecting and keeping up with verified sources still create data accuracy and reliability challenges.

5.2.2 Privacy

Although blockchain technology highlights security through encryption, managing databases that contain having private health records, even in encrypted form, is a critical issue. Thus, the implementation of the proposed framework must adequately address access control.
5.2.3 The Lack of Historical Data

The lack of a substantial amount of unbiased training data affects the performance of the data analysis model. As a result of the unprecedented nature of the pandemic, the lack of historical data to train the models causes inefficient results.

5.2.4 Governance

In order for fragmented digital transformation technologies to work together, standards, protocols, and agreements need to emerge. Coordination can prove to be a challenge.

5.2.5 Expertise

There need to be people who have IT-skills to develop, implement, and maintain the components of this framework. Besides, for real-time scenarios to work out, domain experts and data scientists should be knowledgable of real-time big data processing platforms. The lack of people having expertise in these fields is a significant challenge for the effective implementation of the proposed framework.

5.2.6 Scalability

Since the framework uses a blockchain-based platform to manage digital transformation technologies, scalability stands as a challenge for the maintainability of the proposed framework.

5.2.7 Lack of Legislation

Appropriate legislation for governance rights, ownership of records, and distributed storage structure of the blockchain should be carefully defined. Since there are many stakeholders, data ownership is also an important issue needed to be solved.

5.2.8 The Lack of Infrastructure for 5G Network

A cellular network with a high bandwidth capability is necessary to maintain the implementation of the framework efficiently. The next-generation 5G networks can provide high-speed data transmission needed for the dynamic structure of the transactions performed through the system, such as collecting data via mobile applications or smart wearables, monitoring crowds via drones, or performing advanced data analytics. However, 5G networks have many challenges: still at the
infancy stage, high cost of maintenance, and security issues for data confidentiality [47].

5.2.9 Cost of Setup and Operation

Since the proposed structure is a conceptual framework, setup and operation costs are not yet known. The decreased cost of IoT and storage devices and the availability of open-source technologies can reduce costs. Further cost reduction is possible if the implementation can use the present but fragmented technology solutions. We have an idea of the cost of lockdowns and the overwhelmed healthcare system, which can justify the implementation of the framework. Furthermore, the framework would continue to show benefits in a post-COVID-19 world.

5.2.10 Adoption and Trust

Blockchain-based infrastructures require a network of inter-connected computers for supplying the required computing power. Incentive mechanisms are necessary to encourage participants for adoption.

Most digital contact tracing apps fail because of the inability to build a critical mass of engaged users. If these applications fail to build a critical mass, they show highly inaccurate results. As suggested by Farronato et al. [48–50], the implementations can first provide immediate value to smaller communities to increase user engagement. Incentives might be necessary to increase adoption for other communities. Any implementation must consider the cultural context to minimize user resistance. Even so, the social implications of this framework should be managed effectively.

6 Conclusion

COVID-19 pandemic disease has cost lives and jobs. It has changed how we communicate, work, and socialize. Digital transformation technologies can play a crucial role in alleviating the COVID-19 outbreak. Although fragmented digital technologies try to address some of the contemporary problems created by the pandemic, a much more effective and dynamic healthcare system must use a combination of the digital transformation technologies in which data is integrated, private, and anonymized. In order to satisfy this necessity, a holistic digital transformation framework architecture is proposed in this study.

One of the main contributions of this study is to propose a privacy-first holistic digital transformation framework and its components. The second contribution is to identify innovative digital solutions developed for diagnosis, treatment, and
prevention of the COVID-19 pandemic as a result of integrating data sources and state-of-art digital transformation technologies. The third contribution is to analyze the benefits and challenges of such a holistic digital transformation framework architecture developed for alleviating COVID-19. The proposed framework aims to provide a more efficient and dynamic healthcare system to reduce the negative impact on the economy, the risk of an overwhelmed healthcare system, the death toll, the risk of virus transmission, and healthcare givers’ workload and stress levels.

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