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Ethics for integrating emerging technologies to contain COVID-19 in Zimbabwe

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Abstract

Zimbabwe is among the countries affected with the coronavirus disease (COVID-19) and implemented several infection control and measures such as social distancing, contact tracing, regular temperature checking in strategic entry and exit points, face masking among others. The country also implemented recursive national lockdowns and curfews to reduce the virus transmission rate and its catastrophic impact. These large-scale measures are not easy to implement, adhere to and subsequently difficult to practice and maintain which lead to imperfect public compliance, especially if there is a significant impact on social and political norms, economy, and psychological wellbeing of the affected population. Also, emerging COVID-19 variants, porous borders, regular movement of informal traders and sale of fake vaccination certificates continue to threaten impressive progress made towards virus containment. Therefore, several emerging technologies have been adopted to strengthen the health system and health services delivery, improve compliance, adherence and maintain social distancing. These technologies use health data, symptoms monitoring, mobility, location and proximity data for contact tracing, self-isolation, and quarantine compliance. However, the use of emerging technologies has been debatable and contentious because of the potential violation of ethical values such as security and privacy, data format and management, synchronization, over-tracking, over-surveillance and lack of proper development and implementation guidelines which impact their efficacy, adoption and ultimately influence public trust. Therefore, the study proposes ethical framework for using emerging technologies to contain the COVID-19 pandemic. The framework is centered on ethical practices such as security, privacy, justice, human dignity, autonomy, solidarity, beneficence, and non-maleficence.

KEYWORDS
artificial intelligence, COVID-19, digital technologies, ethical values, internet of medical things, social distancing monitoring tools

1 | INTRODUCTION

The outbreak of the novel coronavirus disease (COVID-19) poses unprecedented challenges and threatened to profoundly affect developing countries. World Health Organization (WHO) declared COVID-19 a global pandemic on January 30th, 2020 (Malik et al., 2020), and many countries swiftly announced stern restrictions and WHO infection control measures and guidelines to facilitate social distancing and health system preparedness. The infection control and preventive measures include social distancing, masking,

quarantine of suspected and infected persons, self-isolation to reduce the catastrophic impact and spread of the virus. Similar policies were swiftly implemented in sub-Saharan Africa countries like Zimbabwe. In addition, some countries announced restrictions such as national lockdown, curfews, travel restrictions, closing public places, physical distancing, and closing of borders. These restrictions presented acute challenges in developing countries where weakened infrastructure, overstretched health systems, insufficient funding and limited public health surveillance compromised their potential efficacy (Mackworth-Young et al., 2021). Also, several scholars including (Coroiu et al., 2020; Masters et al., 2020; Mbunge, Fashoto, Akinnuwesi, Gurajena, & Metfula, 2020; Suppawittaya et al., 2020) noted that such large-scale measures are not easy to implement, adhere to and subsequently difficult to practice and maintain which lead to imperfect public compliance, especially if there is a significant impact on social and political norms, economy and psychological wellbeing of the affected population. Notably, the attention is now shifting towards the vaccination of populations after the successful development of vaccines. However, emerging COVID-19 variants, porous borders, regular movement of informal traders and sale of fake vaccination certificates continue to threaten impressive progress made towards virus containment in some countries. In exceptional circumstances like this, the need for incorporating emerging technologies including technology-based social distancing apps (Mbunge, 2020b), contact tracing apps and smart devices to strengthen health systems and improve health services delivery and adherence is imminent (Nguyen et al., 2020; Ranisch et al., 2020). For instance, emerging technologies such as digital contact tracing apps, social distancing systems and smart devices significantly assist to monitor populations' adherence and compliance to the COVID-19 guidelines and restrictions, monitor suspected cases in isolation and quarantine centers, monitoring vaccination progress, verification of vaccination or immunity certificates. Hence, these advanced emerging technologies can significantly improve compliance, adherence to maintain social distancing and reduce the upsurge of COVID-19. These technologies use health data, symptoms monitoring, mobility, location and proximity data for contact tracing, self-isolation, quarantine compliance, maintaining physical distance and monitor adherence to stay-at-home guidelines. However, the use of emerging technologies has been debatable and contentious because of security and privacy, data format and management, synchronization, over-tracking, and lack of proper development and implementation guidelines which impact their efficacy and adoption (Ahmed et al., 2020). Also, the use of emerging technologies without observing ethical values may cause greater levels of surveillance and potentially violate the security and privacy of users leading to legal and ethical issues. This is generally exacerbated by hasty, poor user engagement, ill-prepared or badly communicated implementation of digital tools especially contact tracing apps which ultimately influence public trust, uptake (Ranisch et al., 2020) and consequently risk impeding their general effectiveness. Therefore, we propose ethical framework for integrating emerging technologies to contain the pandemic.

2 | COVID-19 SITUATION ANALYSIS IN ZIMBABWE

After WHO declared COVID-19 a global pandemic on 11 March 2020, Zimbabwe's Ministry of Health and Child Care adopted several measures in response to the COVID-19 outbreak after the government declared COVID-19 a national disaster on 19 March 2020 to curb transmission and reducing the catastrophic impact of the pandemic on both population and the already overburdened health system (Nhapi & Dhemba, 2020). These measures include social distancing, self-isolation and quarantine of returnees from other countries, face masking (Chitungo et al., 2021), banning of all public gatherings and sporting fixtures, dusk-to-dawn curfew, closure of non-essential business, stay-at-home, regular temperature checking and testing (Mbunge, Fashoto, Akinnuwesi, Gurajena, Metfula, & Mashwama, 2020) among others. Like many countries in Africa, Zimbabwe has an under-resourced healthcare system, high unemployment, densely populated urban areas and shortages of basic commodities (Mackworth-Young et al., 2021), which make lockdowns difficult to adhere to and enforce. The lockdowns came with unintended consequences, such as widening economic inequalities, mental health problems, and exacerbating poor medical outcomes that are not COVID-19 related (Dzinamarira et al., 2021). As of 19 June 2021, Zimbabwe recorded 42,195 confirmed COVID-19 cases, 37,200 recoveries and 1685 deaths.

The increased number of infections is exacerbated by several factors including poor testing capacity, the dearth of personal protective equipment (Dzobo et al., 2020), limited humanitarian and social support, poor health system, corruption (Makoni, 2020), lack of funding, perennial economic challenges (Dandara et al., 2020), dilapidated health care infrastructure, illegal immigration and porous borders (especially South Africa and Zimbabwe border), limited intensive care unit beds and ventilators, ignorance, and lack of digital contact tracing systems (Makoni, 2020). Also, most of the populations rely on informal sectors for their livelihoods, which means, recursive national lockdowns and dusk-to-dawn curfews would mean hunger or potential violation of COVID-19 measures, especially compliance with social distancing guidelines. Notably, hand-washing basins were installed in various strategic points in major towns, recently launched the national COVID-19 hotline, and also opened a National Microbiology Reference Laboratory in addition to two infectious disease hospitals to support and strengthening COVID-19 testing capacity (Dandara et al., 2020). Also, some organizations (but not yet rolled out country-wide) started utilizing infrared digital thermometers, smart disinfection tunnels and wearable smart devices including smartwatches, smart hand band and smart helmets (especially in the mining sector) to thwart a recent swell in COVID-19. Owing to the weak health system, socio-economic problems (Mbunge, Millham, et al., 2021), and sustainability of COVID-19 measures, it is therefore imperative to integrate digital technologies to monitor, track and trace people in self-isolation and quarantine facilities and their close contacts. However, there is limited literature, guidelines and published framework designed to integrate digital tools such as smart devices and social distancing apps

suited for socioeconomic structure of the country and ethical values of the citizens to contain the pandemic.

The following section provides a comprehensive analysis of emerging technologies for contact tracing, symptoms monitoring, self-isolation and quarantine compliance, maintaining physical distance and monitor adherence to stay-at-home guidelines during the COVID-19 pandemic. Section 3 proposes a framework for integrating digital technologies to contain the COVID-19 pandemic. Finally, Section 4 and 5 present the concluding remarks and future work.

2.1 | Related work

Since the outbreak of the COVID-19 pandemic, several emerging technologies such as artificial intelligence (AI), Internet of Things (IoT), Blockchain, big data, cloud computing, geographical information systems (GIS), virtual reality, robotics, 5G technology and IoMT have been implemented to tackle the pandemic (Ahmed et al., 2020). Globally, researchers, scientists and technologists have been applying artificial intelligence techniques such as deep learning (DL) and machine learning models to screen suspected cases, identify and detect COVID-19, and diagnose patients (Mbunge, Akinnuwesi, Fashoto, Metfula, & Mashwama, 2020) as well as vaccines development (Nguyen et al., 2020), prediction of cases and mortality (Vaishya et al., 2020) and ethics for rolling out vaccines as well as the issuance of digital vaccination or immunity certificates (Mbunge, Dzinamarira, et al., 2021). For instance, Albahri et al. (2020), Enughwure and Febaide (2020), Ghimire et al. (2020), Lalmuanawma et al. (2020), Raza (2020) and Sengar (2020) conducted reviews on the application of artificial intelligence models for detecting, identification and modeling COVID-19 using chest computed tomography (CT) or X-ray images. Besides, applying artificial intelligence techniques to tack COVID-19 pandemic, several scholars including Ahmed et al. (2020), Kumar et al. (2020), Nguyen et al. (2020), Tayarani (2020) and Yao et al. (2020) conducted reviews of social distancing apps developed using various emerging digital technologies for enhancing stay-at-home guidelines, self-isolation and quarantine compliance, self-isolation adherence, symptoms monitoring, movement tracking, contact tracing activities as well as maintaining social and physical distancing. Social distancing monitoring apps differ extensively on data collection format and usage, data sources, data management and handling, data reporting and data protection (Ranisch et al., 2020). These apps perform various functions including creating awareness by providing users with COVID-19-related information, monitoring people in self-isolation and quarantine facilities, tracing close-contacts, tracking people who tested positive for COVID-19. Such apps play a tremendous role to enforce COVID-19 regulations. For instance, Aquino et al. (2020), Mbunge (2020a), Ölcer et al. (2020) and Vaishya et al. (2020) state that many people violate WHO COVID-19 regulations especially social distancing guidelines as well as self-isolation and quarantine compliance and guidelines. This is exacerbated by the lack of real-time COVID-19 monitoring tracing apps (Fischer et al., 2020) and well-synchronized social distancing apps and Internet

of Medical Things devices that provide real-time data of the COVID-19 suspected cases and positive tested individuals (Nasajpour et al., 2020).

The high penetration and usage of digital technologies provide tremendous opportunities to tackle the COVID-19 pandemic. For instance, as of 2019, there were 3.8 billion people active on social media platforms and 204 billion mobile apps were downloaded in the various app store, also, 67% of the world's population subscribed to mobile devices, of which 65% were smartphones (Budd et al., 2020). Also, social media platforms such as Facebook, Twitter, Weibo and WhatsApp among others have been used to share COVID-19 information including new cases, mortalities, and prevention measures. Such data amassed in these platforms could be utilized to map COVID-19 hotspots, migration patterns, tracing and tracking close contacts and positive cases (Mbunge, 2020b). Also, telecommunication companies have been playing a pivotal role in providing location-based services, mobile satellite pinging data and mobility trends of suspected and positive individuals for COVID-19 tracing purposes. Besides COVID-19, these digital technologies including smart applications were successfully applied to fight other pandemics such as Ebola, human immunodeficiency virus/acquired immunodeficiency syndrome (HIV/AIDS), and Swine Flu among others that prompt technological companies in partnership with health regulators, researchers and governments to develop and rollout COVID-19 apps for self-isolation, monitoring, tracking cases, tracing, self-isolation and maintain social distancing guidelines.

However, in some low-income economies, the integration of information and communication technologies (ICTs) into health systems is still nascent (Chandrasekhar & Ghosh, 2001) leading to the absence of e-health framework and guiding policy for inclusion and integration of technology-based solutions to improve health service delivery. Also, many countries including Singapore, Israel and China initiated mandatory use of social distancing apps to effectively monitor and tracing the affected populace (Ahmed et al., 2020; Mbunge, 2020b; Nguyen et al., 2020). This is not always the case as evidenced in some COVID-19 hard-hit countries like the United States of America, Brazil and India, they are still battling with security and privacy issues which raise legal and ethical problems and eventually influence public trust towards the use of social distancing apps (McGrail et al., 2020). However, like other low-income countries, the use of digital technologies in Zimbabwe face some impending challenges such as limited access to ICTs, limited internet access and poor signal strength, inadequate infrastructural support, poor ICT culture among healthcare professionals and patients, digital illiteracy, digital divide, poor electricity supply, high cost of internet data and insufficient equipment (Chowdhury et al., 2020).

2.2 | Wireless technologies that connect digital technologies

To ensure the effective connection of smart devices and social distancing apps, wireless technologies can be adopted such as Bluetooth technology, wireless fidelity (Wi-Fi) technology, global navigation

satellite system, cellular technology. The available smart devices and social distancing apps rely on wireless technologies to trace, track, and monitoring adherence to social distance guidelines. These technologies widely differ in terms of data handling, processing data source, handling data security and privacy as well as data gathering and usage (Ranisch et al., 2020). For instance, social distance apps can collect anonymized or pseudonymized proximity or geo-location data using either Bluetooth technology or the global navigation satellite system and store that data in either a centralized or decentralized database for further processing or warning of potential exposure. To effectively maintain adherence and compliance with social distancing guidelines, these technologies use wireless technologies such as Bluetooth technology, Wi-Fi technology, global navigation satellite system, radio technology, and cellular technology. The description, functions and limitations of wireless technologies to connect digital technologies are shown in Table 1.

2.3 | Artificial intelligence-based social distancing tools

The recent developments of artificial intelligence-based social distancing tools have been used to reduce the catastrophic impact of the COVID-19 pandemic. AI is used for maintaining social distancing and monitoring people in quarantine. If these are not maintained, AI obtains information of involved individuals especially people in close-proximity and recommends further screening and test. Table 2 shows a few selected AI-enabled social distancing tools and their respective functions and ethical issues.

These available AI-based social distancing tools shown in Table 2 operate independently and effectively work when connected and communicate with a similar device of the same brand. This poses interoperability, standardization and synchronization challenges when using a different brand. Also, these social distancing tools and contact tracing face implementation challenges such as privacy protection issues, security challenges, scalability, internet access, limited connectivity, legal and regulatory issues as well as ethical issues (Mbunge, Akinnuwesi, Fashoto, Metfula, & Mashwama, 2020). Even though some proximity apps have been used in market analysis, workplace, retail locations, transit stations, grocery stores, parks, and residences pre-COVID-19 their usage was much on a smaller scale and for different purposes such as in-store tracking and improving services delivery. However, due to COVID-19 restrictions and guidelines, the development and deployment of different social distancing apps lacked sufficient time to consult public and private partners and relevant authorities to standardize the development process, protocols, data format and semantics regardless of ethical issues (Meinert et al., 2020).

2.4 | Smart social distancing monitoring through IoMT smart devices

Wearable smart devices have been used to enhance symptoms monitoring, stay-at-home and social distancing guidelines and also ensuring

quarantine compliance during the outbreak (Swayamsiddha & Mohanty, 2020). Internet of Medical Things is a disruptive technology that plays an imperative role in the containment of the pandemic by using artificial intelligence-based mobile health tools connected via the Internet (Mohd Aman et al., 2020). This includes the use of pervasive mobile apps, sensors, smart infrared thermometers, smart computing devices, smart face shield, smart health bracelets and pendants, and location-based tracking technologies to obtain real-time medical data and to provide health services (Swayamsiddha & Mohanty, 2020). Such a network of smart medical devices facilitates machine-to-machine communication over the Internet to improve health care delivery remotely especially during the pandemic where physical contact is discouraged. IoMT devices together with other emerging technologies such as 5G technology, big data, artificial intelligence, cloud computing, fog computing, IoT, GIS, Blockchain, virtual reality and smart applications among others tremendously assist in fighting the pandemic. These technologies have been applied to provide healthcare services remotely, enforcing and enhancing COVID-19 guidelines such as social distancing, contact tracing, monitoring of individuals in self-isolation as well as tracking individuals exposed to the pandemic. Thus, IoMT helps patients to receive proper healthcare at home and in quarantine facilities. For instance, telemedicine, mobile health, telehealth, teleconsultation, telenursing, telecare have been facilitating remote monitoring of patients, screening and surveillance of patients and remote diagnosis of diseases (Swayamsiddha & Mohanty, 2020). These healthcare services are offered through IoMT smart applications, IoMT smart wearable devices (especially sensor-based) connected via the Internet and storing data into the IoMT cloud database. IoMT wearable devices provide real-time data for remote health detection and diagnostic services. For instance, China implemented symptom checkers that generate data that is used for epidemiological modeling, monitoring the virus spread and evaluating public health measures (Ranisch et al., 2020). Table 3 shows AI-based IoMT smart devices that have been deployed to fight against the pandemic.

However, these technologies are subject to human behavior, environmental factors, and technical glitches. For instance, the use of non-contact infrared digital thermometers in public closed places for COVID-19 screening is relatively influenced by numerous human, environmental factors and equipment variables which ultimately affect their accuracy, reproducibility, and relationship with core temperature (Wright & Mackowiak, 2021). Human factors such as lack of training to use non-contact infrared digital thermometers, consumption of alcohol, pregnancy and menstruation might be associated with a raised forehead temperature (Bitar et al., 2009). Also, the distance between subject-thermometer distance, humidity, ambient temperature affects non-contact infrared digital thermometer readings (Najmi et al., 2020). Hence, there is a need to calibrate non-contact infrared digital thermometers to cater for human, environmental factors and equipment variables based on geographical location. Also, the reliability of non-contact infrared digital thermometers, smart face mask, smart face shield, smart boots, smart health bands, smart helmet, and smart clothes

TABLE 1 Wireless technologies that connect digital technologies

Wireless technology	Description	Functions	Limitations
Bluetooth technology	Bluetooth technology is widely used for short distance exchange of data using computing devices. Bluetooth technology has been widely adopted in developing COVID-19 contact-tracing apps and collect proximity data.	• This technology can be used for COVID-19 contact tracing activities. • Crowd detection especially in public places. • To maintain a safe distance between two or more people to enhance social distancing.	• From the COVID-19 perspective, this technology requires most of the population to use smartphones and always activate Bluetooth to allow the social distancing apps to collect proximity data and close contacts. • Security and privacy implications. • Disclosure of the social graph. • Can only be used by people with smartphones.
WiFi technology	The Wi-Fi technology uses the following protocols and standards to establish the communication link between computing devices; IEEE 802.11, IEEE802.11ax and IEEE 802.11b.	• Crowd detection in various congested places and locations. • Public place monitoring especially in closed public places. • Detect and monitor quarantined and self-isolated people.	• Loss of signal may degrade connection performance. • The technology requires many transceivers attached to each access point to regenerate signal strength to obtain high accuracy. • Not feasible for outdoor environments especially when computing devices are distanced and located in different geographical locations.
Global navigation satellite system	The global navigation satellite system uses technologies such as Global Positioning System (GPS), GLONASS, Galileo and Beidou.	• Provide real-time position and location of suspected and COVID-19 positive tested persons. • Automation of services reduces physical contact between healthcare professionals and COVID-19 suspected individuals or positive tested persons. • Mapping migration patterns and trends of people and detect perpetrators or violators of social distancing guidelines. • GPS data can be used to map COVID-19 hotspots and traffic movement and monitoring.	• Not suitable for proximity estimation especially in indoor environments. • Consumes a lot of battery energy if used for a prolonged period.
Cellular technology	Cellular technology has been evolving from the first generation to the latest generation, which is, 5G technologies and strongly become a pillar for the fastest digital communications that support real-time communication and high-speed data transfer. This technology performs better than WiFi technology-based availability and popularity.	• The latest technology sports real-time monitoring using smart applications. • Facilitates high-speed data transfer. • Traffic density and people Density Prediction based on migration patterns using satellite data. • Predict network traffic and assist to detect crowdedness. • People can consult online through video conferencing tools, telemedicine, e-health among others thereby maintaining social distancing. • With the high-speed network, IoMT devices can capture, send, process, synchronize and analyze COVID-19 data in real-time (Whitelaw et al., 2020).	• Latest 5G Technology huge capital investment which might delay its implementation in low-income countries. • The use of subscribers' location data is subject to security and privacy issues. • Requires synchronization of communication protocols and scaling of the network which might take time • Integration of 5G technology into healthcare requires technical skills which might not be readily accessible because of stringent measures. • The massive connection of computing devices makes the system vulnerable to passive and active attacks (Siriwardhana et al., 2020).

are largely unknown for COVID-19 screening. In support, a study conducted by (Ng et al., 2005) noted variations in temperature readings in three non-contact infrared digital thermometers that were measured against electronic thermometers, hence the need for testing and checking the reliability of these IoMT smart devices for COVID-19 screening.

TABLE 2   AI-enabled social distancing tools and their respective functions and ethical issues

AI-enabled social distancing monitoring tools	Description of the AI-enabled social distancing tool	Ethical issues
Proxxi contacts—Wrist-worn band	The tool provides people with social distancing alerts. It is a wrist-worn tool that vibrates to notify the wearer about the distance between him/her and the next person wearing a similar device. When there is a positive case, the tool provides detailed contact tracking data to trace close contacts for further testing and quarantine. This tool is used for both maintaining social distancing and contact tracing purposes.	Over-surveillance and privacy
Romware COVID-19	It is a digital bracelet that maintains social distancing and assists in contact tracing. The bracelet identifies high-risk contacts (i.e., those that fail to observe a safe distance) and alert healthcare professionals. Contact tracing data is deleted after the incubation period of 14 days. No data connection is required because the bracelet uses the Ultra-Wideband.	Privacy and transparency
Estimote—wireless wearable safety device	It is a wireless wearable safety device that reminds the wearer to maintain a safe distance and directly register contact exposure. Also, the device transmits encrypted signals between each other to keep a safe distance. The wearer uses a button to report his/her health status, in case of suspicious cases, the device generates contact tracing reports. The device is used for social distancing and contact tracing.	Personal data linked to the device and stored in the health dashboard.
Blackline Safety	It is a G7 safety wearable tool connected to ATEX-certified cloud-connected gas detectors for COVID-19 contact tracing. It detects close contacts and provides real-time proactive warning and alerts. It also uses the Blackline Connect smartphone app to pick users' location data (GPS) and send it directly to the cloud.	Transparency, autonomy, security, and privacy.
Tended—COVID-19 Solution	It is a wearable device that uses an ultra-wideband proximity sensor connected to the user's smartphone that notifies him/her to maintain a safe distance. Users can see their close contact through the mobile app installed on the user's smartphone. This device is used for both social distancing and contact tracing.	In the case of the COVID-19 infected case, users can see an infected person's close contacts.
Landing AI	It is an artificial intelligence-based social distancing detection tool used to determine a safe distance in video streams.	Transparency, consent, security, and privacy issues.
Lopos—Safe Distance	It is a wearable device that allows configuring minimum distance and warns the user with a beep and vibrates if it is closer than 1.5 m. The safe distance device communicates with another similar device using ultra-wideband. The safe distance device is used for social distancing.	Data saved in the app dashboard can be accessed which might lead to over-surveillance.

(Continues)

TABLE 2 (Continued)

AI-enabled social distancing monitoring tools	Description of the AI-enabled social distancing tool	Ethical issues
Comarch	It is a contact tracing wearable wristband that uses a button, GPS satellite to collect location data. The device is used by healthcare professionals to also monitor heart rate.	Privacy, consent, and transparency.
Social Distancer	It is social distancing wearable personal protective equipment that warns users if they do not keep a safe distance between them by vibrating and sound an alarm.	Autonomy, privacy, beneficence.

[Correction added on September 1, after first online publication: In Table 2, changes have been made to the following: (1) the information under 'Ethical issue' column for rows 'Estimote—wireless wearable safety Device', 'Blackline Safety' and 'Tended—COVID-19 Solution' have been corrected; and (2) the row 'Triax Technologies' has been removed.]

2.5 | Ethical issues associated with different digital technologies during the pandemic

Notably, several authors raise tremendous ethical concerns by developing theoretical frameworks guiding the ethical use of COVID-19 social distancing monitoring tools and contact tracing apps. For instance, Ranisch et al. (2020) developed a framework centered on ethical values such as public health benefit, harm minimization, privacy, justice, liberty/autonomy, solidarity, stewardship, transparency, proportionality, general trustworthiness, reasonableness, accountability, consistency, engagement, and reflexivity. However, the developed framework is generalized and not contextualized country-specific, yet each country exercises its jurisdiction on e-health policies and the use of digital technologies in healthcare service delivery. Gasser et al. (2020a) also considered privacy, scientific validity, consent and voluntariness accuracy, and data necessity, discrimination, repurposing, expiration, digital equality, and public benefit. However, their study does not provide ways to incorporate ethical values in the development processes of social distancing tools while regularly engaging potential end-users and regulatory authorities. Parker et al. (2020) considered privacy, equity, transparency, fairness justice, and security as important ethical values when deploying digital technologies. However, their study did not consider other ethical values such as solidarity, the balance of power and human dignity. A study conducted by Georgieva et al. (2021) highlighted the importance of transparency, security, privacy, sociocultural determinants, and reversibility to boost public trust. However, their study focused on factors influencing ethical and social acceptability of technological tracking implementation, not necessarily a framework for ethical and acceptable use of digital tools amid COVID-19. Hence the need for incorporating other ethical values.

3 | FRAMEWORK FOR INTEGRATING DIGITAL TECHNOLOGIES TO CONTAIN COVID-19 PANDEMIC

The viability of digital technologies is paramount as a pandemic-response measure that relies on the likelihood of public health benefit effectiveness, and acceptance. To ensure acceptance of digital technologies, risks should be minimized, ethical values and standards should be prioritized and guide the design and development of these apps as well as their implementation. After a thorough analysis of raised ethical concerns by several authors, we propose a generic ethical framework with respect to Zimbabwe's e-health policy. The proposed framework is guided by ethical values such as security, privacy, justice, human dignity, autonomy, solidarity, beneficence, non-maleficence and balance of power, as shown in Table 4.

3.1 | Security

Enforcing data and infrastructural security is imperative to ethics because digitization poses security threats to both data and computing resources. Once a computing device connected to the Internet it becomes susceptible to passive and active security threats that threaten confidentiality and integrity of data, and the availability of the whole system. Padlocks and barriers should be installed to avoid unauthorized entry and restrict access to computing devices. Data should be encrypted as it transverse from one computing device or app to the data storage device by using modern data and communication link encryption standards and blockchain technology (Dai et al., 2020). Also, all authorized users and synchronized apps/tools should be validated and authenticated to avoid unauthorized access to sensitive information or data by malicious and unauthorized users. To ensure that there is no data leakage, authorization, authentication, and auditing methods should be frequently done in social distancing tools/apps, and databases. Authorization, authentication, and auditing methods include identity and access management, implementation of the homomorphism encryption scheme, which allows data to be processed without being decrypted audit trail and compliance (Yaacoub et al., 2020).

3.2 | Privacy

Consent of participants should be guaranteed from the development to the deployment of digital technologies. Consent is the ability of the

TABLE 3 Internet of medical things smart devices deployed during the pandemic

AI-enabled internet of medical things	Functions and ethical issues
Non-contact Infrared digital thermometer (Abuzairi et al., 2021)	This is a non-contact infrared digital thermometer used to measure body temperature. Non-contact infrared digital thermometers have been used to collect real-time data in strategic entry and exit points for COVID-19 screening purposes. The body temperature can be taken from a safe distance and to avoid physical contact thereby reducing the risk of exposure. However, regular checking of temperature in open public places by untrained healthcare professionals violates the privacy of people. If one becomes suspicious, he/she is taken for further screening. Also, the device is susceptible to wrong body temperature reading because of fluctuating environmental factors such as humidity and atmospheric temperature (Crossley, 2020).
Smart face mask (Atif et al., 2020)	A smart face mask is personal protective equipment (PPE) equipped with sensors that can monitor the body's temperature, heart rate, blood oxygen levels and respiratory rate by placing sensors near the wearer's earlobes, nose, and mouth. This smart device can send COVID-19 symptoms in real-time to healthcare professionals and regulatory authorities. The smart face mask is reusable and washable hence reduce the cost of buying disposal convectional face masks.
Smart face shield	It is also personal protective equipment that reduces the spread of COVID-19. A smart face shield is equipped with a body temperature sensor, humidity or moisture sensor, blood oxygen sensor, respiratory rate and heart rate sensor that frequently check the health status of the wearer (Atif et al., 2020).
Smart Boots	Smart boots are an AI-based digital protective IoMT device that is used for both maintaining social distancing and contact tracing during COVID-19. The data of close contacts are recorded in the dashboard app, and the wearer should have a smartphone for data synchronization. The smart boots alert wearers by vibrating when they are in close contact with each other (minimum 2 m distance). This smart device equipped with a temperature sensor and GPS or RFID; and can also send location data and environmental data to the dashboard.
Smartwatches	It is an IoMT sensor-based wearable device that collects physiological data such as pulse, blood oxygen, temperature and sleeping patterns data for early screening of COVID-19 (Singh et al., 2020). Such data can be used for real-time health monitoring, surveillance and assess the likelihood of COVID-19 incidences.
Smart Disinfection Tunnels (Pandya et al., 2020)	Smart disinfection tunnel, also known as the smart epidemic tunnel, is an IoMT sensor-based sanitization tunnel that detects an individual in real-time and disinfects that person using sanitizers within 10 s. The tunnel is solar-powered equipped with a sensor and solar power bank for future use at night. The device counts the total number of people who walk-in and generate daily, weekly, and monthly reports. However, the cost of a smart disinfection tunnel might not be affordable by many organizations and individuals in resource-constrained areas (Biswal et al., 2020) hence affect beneficence as one of the integral ethical values.
Smart health bands	These devices generally consist of two sensors for checking temperature and pulse rate. They collect body temperature and pulse rate in real-time for COVID-19 early screening purposes. During COVID-19, smart health bands have been deployed to monitor the health condition of people with the underlying condition in real-time. Also, Singh et al. (2020) noted that smart health bands have been used to predict the possibility of someone having COVID-19 after analyzing symptoms and also to facilitate contact tracing and social distancing. However, smart health bands do not provide conclusive results that the person is infected with COVID-19 or not. Also, they collect unencrypted health-related data which might compromise the security and privacy of end-users (Singh et al., 2020)
Smart Helmet	The smart helmet with a mounted thermal imaging system can detect the COVID-19 symptoms automatically from the thermal image with fewer human interactions. It uses GPS to find the location of the person after detecting the high temperature, and a camera to capture the image of the person (Atif et al., 2020). However, the device is susceptible to provide false temperature information.
Smart Clothes	Smart garments with built-in sensors empower the far off observing of patients' indispensable COVID-19 signs and further screen for the virus. Smart clothes have built-in sensors for monitoring and tracking body temperature, ECG levels, stress levels, and sleep quality (Waheed & Shafi, 2020). A combination of these variables could be used for COVID-19 screening purposes.

person who is the custodian of his/her data (health and proximity data) or computing device to willingly use digital tools, and also participate in data sharing (Parker et al., 2020). Consent should guarantee apps users that their data is secured and used specifically for tracing purposes without violating their security and privacy. Hence consent

withdrawal and user engagement are paramount in the development process of COVID-19 social distancing tools and contact tracing apps. Also, transparency should be practiced and the engagement of users should be voluntary, meaning free to participate and withdraw from participation without exploitation though it is difficult and debatable.

Also, data protection from malicious and unauthorized users should be guaranteed, keep data confidential, and share anonymized data with intended and authorized people or organization after attaining ethical approval from regulatory authorities. Also, data leakage should be prevented and regularly perform data audit trails.

3.3 | Justice

To ensure equity in access and inclusive use of COVID-19, social distancing tools and contact tracing apps, people should be well-informed about the nature and purpose of data or information collected from their computing devices including smartphones, tablets and smartwatches. Transparency can be achieved in different ways; make the source code of social distancing and contact tracing apps open, engage potential end-users, regulatory authorities, and reputable high-tech companies to develop apps, and this can potentially boost public trust. However, exposing the source code of apps might cause security risks, hence the need for periodic review of source code and security patches. COVID-19-related information such as demographic data, physical address, contact details and profession might be wrongly used for stigmatization, discrimination, over-surveillance and repurposing. Therefore, participants should not be discriminated against, stigmatized and infringement of personal autonomy that should be associated with consent withdrawal and refusal to participate. Also, individuals and organizations should be held accountable for malpractice and malicious use of data.

3.4 | Human dignity

Artificial intelligence devices, IoMT and social distancing monitoring tools, as well as contact tracing apps, should be utilized to fight the pandemic while preserving human dignity. For instance, monitoring an individual's movements should be in accordance with the privacy and dignity of that person. Also, IoMT devices that remotely monitor patients' health status should uphold patients' dignity and refrain from dehumanization, experimentalization and instrumentalization of human beings (Royakkers et al., 2018). Also, the values of people that do not use smartphones because of religion and culture should be preserved and find the best alternative methods for contact tracing.

3.5 | Autonomy

Digital health technologies have the potential to undermine not only privacy but also personal autonomy. End-users or participants should practice free of choice, informed about the purpose of the apps/tools, informed consent, type of data collected, right to know the results. During the pandemic, regulatory authorities implemented mandatory checking of body temperature and hand sanitization to reduce transmission of the virus. However, some people are allergic to sanitizer; they should be informed about the type of sanitizer before sanitized.

Also, the right to opt-out may not be an option due to public benefit outweighing autonomy rights due to public emergency caused by the pandemic. In addition, once the emergency has gone away, a more balanced autonomy would take over.

3.6 | Solidarity

Digital technologies especially mobile technologies are increasingly used to improve health service delivery globally. However, due to the digital divide, poor network coverage, lack of access to computing devices and digital illiteracy, digital technologies are uneven distributed especially in resource-constrained areas which lead to digital inequality. Hence the need for non-digital strategies to be included in COVID-19 containment strategies to avoid discrimination and health inequalities while promoting inclusiveness and public benefit (Gasser et al., 2020b). However, during the COVID-19 pandemic, conflicts are already arising between protecting personal autonomy, beneficence, public benefit, individual rights, and civil liberties due to imposed recursive mandatory national lockdown and vaccination. Hence, the need for trade-offs between freedom of movement and containment of the virus.

3.7 | Beneficence

Beneficence is an integral part of ethics that requires compassion and understanding. Professionals must execute actions that benefit end-users or patients (Kinsinger, 2009). It thrives to provide the best services to the public extrapolated into charity, mercy, kindness, generosity, and supererogatory.

3.8 | Balance of power

During the outbreak of COVID-19, several apps have been developed hurriedly without proper engagement with end-users which affects transparency and public trust (Ahmed et al., 2020). Transparency is important in the public adhesion process to ensure that decisions are made based on scientific validity having done a risk assessment. For instance, to boost public trust in the uptake of COVID-19 contact tracing apps, the population should be well-informed about the importance of such apps in preventing the continuous spread of COVID-19 and guaranteed legal measures for malicious use of such apps to avoid exploitation. From the regulatory perspective, there should be a balance of power and trade-offs between surveillance and privacy of users and also accountability in public–private partnerships.

Figure 1 shows a generic ethical framework for integrating digital technologies in health systems to contain the pandemic. The framework includes major stakeholders in COVID-19 apps development which include regulatory authorities, developers and consultancy companies as well as potential end-users or participants. The ethical roles and activities of each stakeholder are explained below.

TABLE 4 Ethical values for digital technologies in healthcare

Ethical theme	Ethical values
Security	Data encryption, data safety, app and or device security, device or app authentication and verification, data storage, secure both data and device from malicious and unauthorized users, frequently check security attacks
Privacy	Consent of participants, engagement of users should be voluntarily (free to participate and withdraw) and transparency should be observed. Data protection from malicious and unauthorized users, keep data confidential, share anonymized data with intended and authorized people or organization, protect data leakage and perform data audit trails.
Justice	Participants should not be discriminated against and stigmatized, equity in access, data ownership, re-purposing, accountability, inclusiveness, and empowerment
Human dignity	Participants should not be dehumanized, no to experimentalized of human beings, no to instrumentalization, observe religion, culture and values of participants
Autonomy	Potential end-users should practice free of choice, informed about the purpose of the apps/tool, informed consent, type of data collected, right to know the results
Solidarity	Digital inequality and promote public benefit and inclusiveness (Brall et al., 2019)
Beneficence	Inclusiveness, public benefit, scientific validity, conduct risk assessment, show mercy, and kindness.
Non-maleficence	Re-purposing, expiration, accountability, scientific validity,
Balance of power	Transparency, risk assessment, trust, exploitation, accountability, control, public-private partnerships, procedural values

3.9 | Regulatory authorities

Regulatory authorities include governments, health ministries, WHO and non-governmental organizations (NGO) involved in the provision of healthcare. The regulatory authorities are responsible for crafting ethical policies and guidelines, electronic health strategies guiding the development, implementation, and integration of emerging digital technologies into health systems. Also, they are involved in planning and perform a risk assessment before the integration of digital technologies in the health system. They should make sure that societal needs are met and demonstrated proportionality, health data is secured, ethical procedures and standards are sufficiently followed, ethical risks are mitigated, promote justice, autonomy, solidarity, exercise balance of power, beneficence as well as preserve human dignity, hence the need for frequent monitoring and analyzing activities of digital technologies by frequently engaging potential-users, developers and risk assessment team.

3.10 | COVID-19 apps/tools developers and consultancy companies

High technological companies involved in developing COVID-19 solutions should follow policies and guidelines set by the regulatory authorities. These developers act in between end-users and regulatory authorities hence the need for establishing public–private partnerships, proactive communication and practice systematic accountability especially when developing and deploying apps. At this level, high-tech companies should observe ethical values such as but not limited to security, privacy, autonomy, solidarity and non-maleficence when design (design-by-ethics) and deploy digital solutions.

3.11 | Potential end-users and participants

After the successful development of digital solutions to combat COVID-19, end-users will use the digital tools regularly. Hence the need for engaging potential end-users on each development stage to boost public trust. This helps to understand user needs and develop solutions that address their problems.

Therefore, the ethical framework in Figure 1 is supported by ethical, stakeholder and justice theory (Jones et al., 2007). The ethical theory comprises deontology, utilitarianism, rights and virtue. Hence, ethical values considered in this study are based on the ethical theme as presented in Table 4, commonly used for digitalization in health technologies.

4 | RECOMMENDATIONS AND FUTURE RESEARCH

Despite the importance of ethical values in the context of COVID-19 digital tools, relative privacy infringements are potentially justifiable to save lives and possibly reduce the spread of the virus. For instance, many countries imposed blanket lockdown to reduce the spread of the pandemic which constraints liberty and privacy on the affected population though it is, however, partially acceptable especially during global health emergencies (Mbunge, Fashoto, & Batani, 2021; Parker et al., 2020). Therefore, in such situations, trade-offs should be made to save many lives. This is in line with utilitarianism ethical philosophy which states that aggregate welfare or "good" should be maximized and that suffering or "bad" should be minimized (Laakasuo & Sundvall, 2016). This is also known as the consequentialist approach since the outcomes determine the morality of the intervention. This approach could lead to harm to some individuals while the net outcome is the maximum benefit which leads to better consequences. However, there is a need for honesty and transparency in terms of the nature of privacy infringements, the degree of surveillance and future use of the data analysis post-pandemic. For instance, proximity information could be utilized for over-surveillance, abuse of data and political exploitation which is ethically wrong. This is in line with deontological ethics which states that the morality of an action depends on
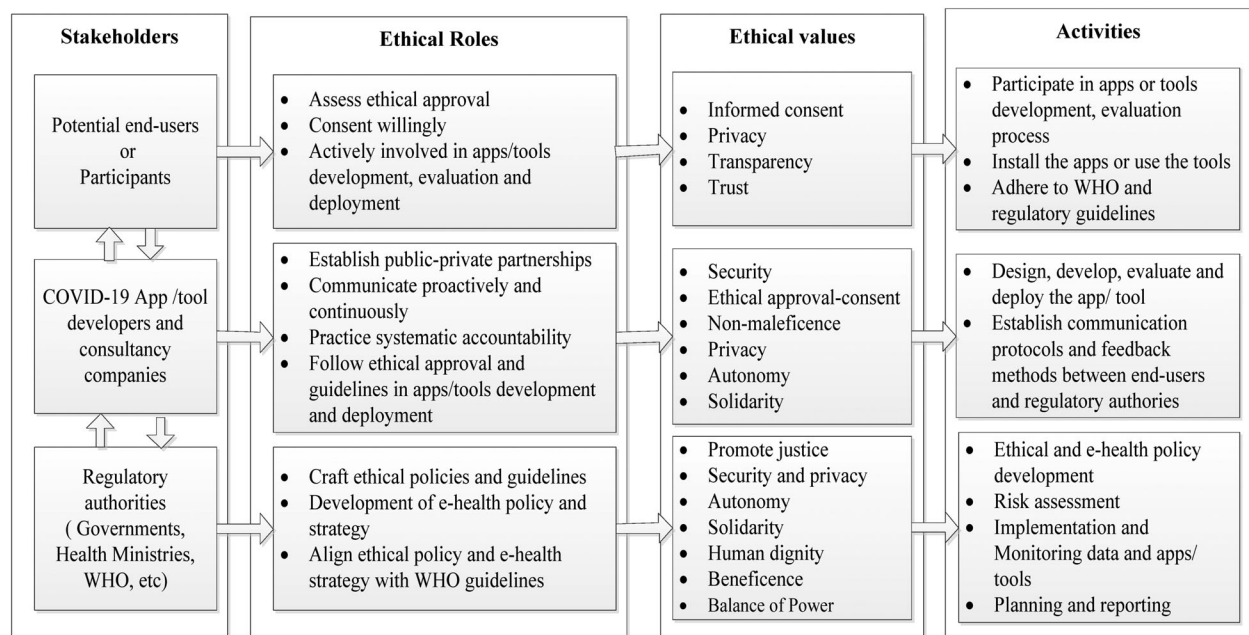
FIGURE 1 Generic ethical framework for integrating digital technologies in health systems

the nature of the action, that is, outcomes may not justify the means (Mandal et al., 2016). Deviation of action from the ethical values because of the outcomes contributes to the ethical violation which subsequently leads to utilitarianism ethical philosophy. Therefore, both utilitarian and deontological perspectives have their importance in tackling COVID-19. In the current scenario, the utilitarian perspective countermanding the deontological perspective and hence most ethical and moral dilemmas. A balance between these two perspectives would bring better harmony and justice when integrating emerging technologies to contain COVID-19. However, Parker et al. (2020) and He et al. (2021) raised the following ethical concerns in the context of COVID-19:

- Will full privacy protections be reinstated after the epidemic?
- Will data gathered now be used in unacceptable ways later?
- Will data gathered during the pandemic be deleted post-COVID-19?
- What data management policies and frameworks are in place to counter abuse of data, over-surveillance and political exploitation of user data?
- As countries re-open, what are international health standards and guidelines are needed for monitoring migrants and verification of their COVID-19 testing certificates?
- How COVID-19 health data is accessed and shared by various regulatory authorities regionally and internationally for effective monitoring and tracking?

Future pandemics are likely to come. These ethical concerns will assist regulatory authorities to prepare for future pandemics, design and developing international contact tracing and tracking tools guided by international health standards and WHO guidelines. However, the future work will focus on COVID-19 social distancing monitoring tools' data security vulnerabilities, breaches, and data leakages, and propose solutions based on evidence gathered.

5 | CONCLUSION

Digital technologies play a paramount role in alleviating the catastrophic impact of the COVID-19 pandemic; however, they are not a panacea but valuable tools that should be involved in the pandemic containment strategy. Despite the valuable impact of digital technologies, their integration in healthcare should be carefully observed to avoid the potential violation of ethical practices and regulatory policies. We identified ethical values and developed a generic framework centered on security, privacy, justice, human dignity, autonomy, solidarity, beneficence, non-maleficence and balance of power. The list provides a sketch of relevant ethical values important to the development of digital solutions and the integration of emerging technologies in the health system. We neither claim that the ethical values considered in this study are complete nor ethical policies be crafted along with these ethical values. Also, ethical values should be context-specific because countries have different health policies, jurisdictions, and technological infrastructure. Hence our framework focuses on principal aid to address several ethical challenges emanating from the integration of digital technologies in healthcare, especially during the COVID-19 pandemic.

CONFLICT OF INTEREST
The authors declare no conflict of interest.

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