

An overview of technologies deployed in GCC Countries to combat COVID-19

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ABSTRACT

Since December 2019, COVID-19 and all of its variants continue to ravage the planet with consequent negative impact that has completely changed our lives within a short period of time after the outbreak of the Virus. On March 11, 2020, COVID-19 was declared a global pandemic by the World Health Organization. Since then, a group of new COVID-19 variants has emerged posing a greater danger to humanity. By the start of August 2021, the reported COVID-19 related death toll across the globe has rocketed to 4,233,139. To deal with the COVID-19 pandemic, countries across the world have rushed to develop various techniques in order to embrace an array of solutions to the problem. Covid-19 negatively affected countries in several sectors including industry, business, health, and education to name a few. The Gulf Cooperation Council (GCC) countries are among the top countries which use cutting-edge technologies in several sectors. This significantly helped these countries to overcome the spread of this virus. In this paper, we present an overview of the technologies, techniques, solutions, and strategies deployed by the Gulf Cooperation Council (GCC) countries to combat the COVID-19 pandemic in order to safeguard their citizens and speedy return of life to normalcy.

Keywords: COVID-19, Technology, GCC, Machine learning, Artificial intelligence, Deep learning, Blockchain, Drones, IoT, Mobile applications

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1. Introduction

The Coronavirus, technically known as COVID-19, is a disease caused by SARS-CoV-2 and appeared, for the first time, in Wuhan in China, in December 2019 [1]. Since its appearance, this virus has spread quickly across the globe, affecting severely almost all countries in the world. On March 11, 2020, the disease was declared a global pandemic by the World Health Organization (WHO). The most common symptoms of COVID-19 identified, in the infected cases, were fever, dry cough and tiredness. In serious cases, patients were found to face difficulty in breathing, increased chest pressure, and loss of smell and taste. In some cases, even the loss of speech and the ability to make bodily movements were also observed.

COVID-19 has adversely affected all countries and sectors of society. At the time of writing this paper, the confirmed worldwide cases of COVID-19 are reported to be 198,562,267 while the reported COVID-19 related death stand at 4,233,139 [2]. Governments, across the globe, are facing challenges in the health sector to ensure the provision of adequate support to their citizens and residents. The main challenges are safeguarding their healthy citizen against the pandemic and providing sufficient health facilities to those who are suffering from COVID-19 symptoms. This requires the availability of effective tools and facilities to manage identification

and then treatment of affected citizens and residents, and range from admission to hospitals for treatment and provision of long-term intensive care.

Governments also need to ensure the provision of screening centers, in sufficient numbers, to provide Polymerase Chain Reaction (PCR) and Diffractive Phase Interferometry (DPI) tests. The tests must be economically affordable and ensure that the test results are made available within the shortest possible time. In addition, Governments need to ensure the availability of Quarantine facilities for positively identified cases. The quarantine facilities need to be either free or economically viable for them to be utilized successfully across each and every level of society. On top of all of this, a huge amount of money needs to be spent by individual government on COVID-19 disinfection programs covering disinfecting of public places such as streets, public places, educational institutions, etc.

Several countries selected to impose country lockdowns in order to contain the virus and stop its spread. These restrictions were then gradually relaxed in an effort to bring life back to normalcy. This has forced governments to find appropriate ways and means to achieve their goal towards return back to full economic activities. For instance, in the education sector, the countries affected by COVID-19 switched to online and distance learning. The developed countries with good Internet infrastructure found it easier to implement E-commerce. For example, online shopping is not a new technique but under the circumstances it became more common especially for procurement of personal groceries. Several new mobile applications and businesses were also developed to take full advantage of the pandemic either to make profit or start of new businesses. In terms of economy, almost all countries and economic sectors across the world have been adversely affected by COVID-19 pandemic. In particular, the Travel and Tourism industry has been severely affected by COVID -19 resulting in high unemployment.

The World also experienced an economic downturn with massive shifts in stock markets. For example, FTSE, Dow Jones, and the Nikkei all had huge falls early at the beginning of the crisis. The FTSE recorded a performance drop of around 14% in 2020 which was the worst since 2008 [3]. Moreover, the year 2020 was recorded to be a difficult year for job seekers [3]. A report by the International Labor Organization (ILO) estimated that 114 million of jobs were lost, across the World, in 2020 [4]. As a consequence, many people were left without jobs, others experienced income cuts resulting in high level of unemployment and sharp decrease in standard of life.

The tourism sector took the brunt of economic downturn with many airline companies cancelling their scheduled flights as people started cancelling their holiday bookings [3] resulting in large number of redundancies or unpaid leave among the associated air and land-based workers.

Similarly, the hospitality sector experienced a severe economic downturn with some businesses going bankrupt. Billions of dollars were lost in 2020 and this appears to continue in 2021. A large number of economists believe that the Hospitality, Tourism, and Aviation sectors would not be able to return back to their normal operation levels until 2025 [3]. The trading and retail sectors have also witnessed lower profitability because of the lockdown restrictions imposed by many governments around the world. According to a recent statistic, 67% of shoppers are not motivated to travel more than 5 km for shopping [3]. Most of the people have resorted to online shopping which is considered safer during the pandemic. It was estimated that COVID-19 had reduced the global economic growth rate by about -3.4% to -7.6% in the year 2020 with a recorded global economic drop of \$90 trillion is reported to be the worst in a century [4][5]. Moreover, it was reported that the advanced economies have shrunk by about 7% during the same period [5].

Middle East and North Africa (MENA) region were affected by COVID-19 as other countries in the world with consequential disruption of their economies. The first COVID-19 case was claimed to be detected in the United Arab Emirates (UAE) in January 2020 for a family who had just arrived from China [6][7].

As per the Institute of International Finance (IIF), the (GCC) countries had experienced the worst economic challenges in their history [8]. As a response and in spite of the experienced recession, the GCC governments had taken major steps to help the financial sector towards recovery [8]. Moreover, the IIF forecasts that the financial deficit aggregation for the GCC countries to increase from 2.5% in 2019 to 10.3% of the GDP in 2020 [8][9].

The main purpose of this paper is to show how various technologies, techniques and strategies are being deployed by GCC countries to fight COVID-19 in order to safeguard and protect their citizens, residents, and economies. The paper is organized in 4 sections. The introduction to subject matter is discussed in Section 1

whereas Section 2 provides an overview of the related published material. In Section 3, an overall view of the technologies, techniques and strategies used by the GCC countries to combat COVID-19 pandemic, is provided. Section 4 concludes with the findings of the paper.

2. Related work

Several papers have discussed various technologies that were deployed to combat COVID-19 in different parts of the world. Qureshi and Al Rajhi [10] provide a detailed description of the strategies and precautionary measures taken by the KSA to contain the virus. The details provided, by the authors, start with the description of responsibility for controlled monitoring and screening of people entering public spaces. This includes the responsibility of sterilization of all public places and provision of spaces equipped with oxygen supply and PCR testing equipment. This was carried out under a strategy that required minimizing the number of people needing hospital visits. In addition, Virtual Clinics and Medical Hotlines were also established to achieve the same goal.

Chamola et al [11] describe one of the IoT applications based on the use of smart thermometers. They claim that the smart thermometers have been successfully used in the US, even before the COVID-19 outbreak, to remotely measure people's body temperature in public places. These thermometers are connected to a mobile application, which facilitates storing and sending body temperature data to the manufacturing company. The smart thermometers have been used by different cities in the US allowing to highlight the regions that exhibited an increase in incidence of body temperatures. This data helps the US authorities to analyze and track regions that might have a rise in COVID-19 infections. Another application of IoT described by the same authors is the utilization of smart buttons in some hospitals in Vancouver, Canada. The authors explained that these IoT buttons, which are battery-operated, were installed to send maintenance and cleaning alerts to the hospital management whenever there are issues that might affect the public safety.

Waheed et al [12] state that several countries such as China, India, Indonesia, Colombia, Chile, and the UAE have used drones for sanitization and disinfection purposes thereby decreasing the risks of human workers being exposed to COVID-19 infection. In addition, Kumar et al [13] describe the use of drones to maintain social distancing between citizens and to ensure the proper usage of masks. Whenever individuals are in close proximity to each other or not wearing masks, drones warn these individuals to keep a safe distance and wear a mask like in China, Spain, UAE, and Kuwait to safeguard their citizens against COVID -19.

Artificial Intelligence (AI) has played a vital role in fighting COVID-19. Li et al and Mbunge et al, respectively [14] [15], describe a deep learning model called COVNet that has been developed in China to identify COVID-19 infections using Computed tomography (CT) scans of the chest area. The authors have indicated that the application has been proven to have an accuracy level of 96% in identifying the COVID-19 virus enabling doctors and other healthcare workers to make faster and more accurate assessments of infections. In addition, Alazab et al [16] have showcased another deep learning model to identify COVID-19 infections through X-ray images. The technique is considered to be inexpensive because of the general availability of X-ray facilities. The authors used this model to forecast COVID-19 confirmed cases, recoveries and death rates over the next seven days. The use of the deep learning model in Australia and Jordan has shown an accuracy level of 98.40% and 88.43, respectively. Another investigation carried out by Ribeiro et al [17], using some machine learning models to forecast COVID-19 infections. The authors claim that models can identify potential COVID-19 infections well ahead of the typical assessment methods by a margin of one, three and six days. The authors state that quicker forecasting helps the Brazilian Government to apply health and safety strategies to contain the pandemic, more effectively.

Blockchain technology has proven to be an important contributor to the fight against combating COVID-19. For instance, the authors in [11] and [15] have claimed that a Canadian company has developed a Blockchain-based application called Civitas which enables linking blockchain records with people's official IDs to validate if the individual is allowed to leave his/her house or not. In addition, Civitas allows doctors to track the health status and symptoms of their patients and send them medical advice if needed. The Developer of the technique claims that the application keeps the patients' records in a secured and safe way. Firouzi et al [18] describe a Blockchain platform named VeChain that has been developed and used to track China's COVID-19 vaccine production process. The production information includes codes, material, and packaging details is stored and documented using the distributed ledger technology. This helps researchers create high-quality vaccines during the pandemic.

Several mobile applications have been developed and used to track and control COVID-19 cases around the world. According to Whitelaw et al [19], a mobile application has been developed in Singapore that enables identification and tracking of individuals diagnosed with COVID -19. They claim that this mobile application uses Bluetooth signals to maintain records on the mobile phone and identify when infected people are in close proximity to each other. This helps the Singapore Government to identify and collect contact details of individuals infected with COVID-19 in order take to mitigating action(s).

The papers reviewed above, provide interesting information on technologies and their applications to combat COVID-19. However, none of these focuses on applications in GCC countries. Our paper extends the current published material by all investigating, identifying, and analyzing various technologies that the GCC countries have used to safeguard their citizens against COVID-19 and its variants. As part of the analysis, the paper also looks into the efficacy of technologies used in combating and mitigating COVID-19 risks to GCC citizens.

3. The GCC Countries and how they are handling the COVID-19 Pandemic

3.1. A brief history of the GCC Countries

The GCC comprises of six Middle Eastern countries and was established by an agreement made in May 1981 in the city of Riyadh [22][23]. These countries are Saudi Arabia, Kuwait, the United Arab Emirates, Qatar, Bahrain, and Oman, as shown in Figure 1.

The agreed constitution of these countries is based on the unity of culture, language, religion, and the nation identity. The collaboration agreement between these six countries was to endorse unity across citizens, promote peace, and to collaborate in other common matters beneficial to all member states [22]. The GCC countries and populations have many common similarities between them such geographical location, social and economic conditions [24]. These GGC countries cover an area of 2.55 million km² with a population of more than 56 million and a gross domestic product (GDP) of around \$3.454tn [22] [24] [25].

The GCC countries are classified as developed countries because of their Gross National Income. The main revenue of these six countries depends on oil production and export since 1970. The GGC countries produce around 45% of the world's oil and provide around 25% of crude oil exports [24]. Most recently, almost all these countries have embarked on initiatives to diversify their income streams away from oil production and export.



Figure 1. GCC Countries Map Taken from [<https://fanack.com/role-of-the-gcc/>]

3.2. COVID-19 in the GCC Countries

Figure 2, as below, highlights the confirmed current cases of corona virus in the GCC countries at the time of writing of this paper. UAE has recorded the highest confirmed cases among other GCC countries at 639,476.

This is followed by KSA 492,785, then Kuwait 362,018, Oman 275,166, Bahrain 266,286, and then Qatar with 222,574 reported cases [25].

Table 1, below, summarizes all the COVID-19 statistics showing numbers of confirmed cases, recovery, deaths, and people vaccinated covering the period from the beginning of the pandemic to the time this paper was written. It is noticed that UAE tops the GCC countries in the number of confirmed cases and total recovery cases of 617,767 followed by KSA. The KSA had recorded the top GCC country in the number of deaths with 7,876 cases followed by Oman 3,283. Furthermore, KSA and UAE are at the top of the GCC countries in the total number of vaccinated people with 18,185,434 and 15,504,238, respectively. Qatar had recorded the lowest number of death cases in the list of the GCC countries with 592 cases only.

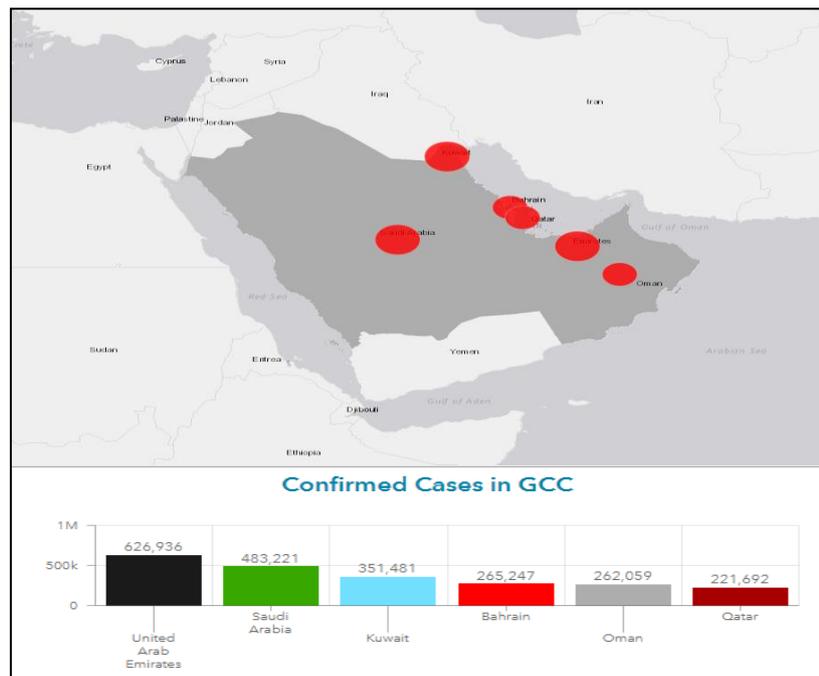


Figure 2. Confirmed COVID-19 cases in GCC countries – June 28, 2021 (Data Source: WHO [26])

Table 1. Statistics showing confirmed reported COVID-19 cases in the GCC countries as of July 04, 2021 [25]

Countries	Population	Cases	
		Confirmed	Total
KSA	34.2 million/ Person	Confirmed	492,785
		Recovered	472,939
		Deaths	7,876
		Vaccinated	18,185,434
UAE	9.8 million/ Person	Confirmed	639,476
		Recovered	617,767
		Deaths	1,834
		Vaccinated	15,504,238
OMAN	4.6 million/ Person	Confirmed	275,166
		Recovered	242,874
		Deaths	3,283
		Vaccinated	1,064,804
BAHRAIN	1.5 million/ Person	Confirmed	266,286
		Recovered	262,552
		Deaths	3,283

Countries	Population	Cases	Total
KUWAIT	4.5 million/ Person	Vaccinated	2,139,789
		Confirmed	362,018
		Recovered	341,477
		Deaths	2,005
		Vaccinated	1,000,000
QATAR	2.8 million/ Person	Confirmed	222,574
		Recovered	220,449
		Deaths	592
		Vaccinated	3,226,308

3.3. ICT use in The GCC Countries

The extent of the usage of ICT is generally taken as an indication of how fast a country is developing. Furthermore, the Internet is an essential technology in our day-to-life. In fact, it is the backbone of any digital infrastructure, especially now that we are witnessing the digitalization of almost all economic activities. The data gathered in 2016 shows that almost all the GCC countries have a high number of Internet users. In UAE, Bahrain, and Qatar, Internet users are exceeding 90% of the total population, as depicted in Figure 3 [27]. The Internet usage, in Bahrain, Qatar, Kuwait, and UAE, has reached almost 100% of the total population by 2019 [28]. With the arrival of COVID-19 lockdowns in March 2019, countries were forced to switch to online activities in almost sectors of economy including but not limited to education, government, health, personal shopping, and other businesses.

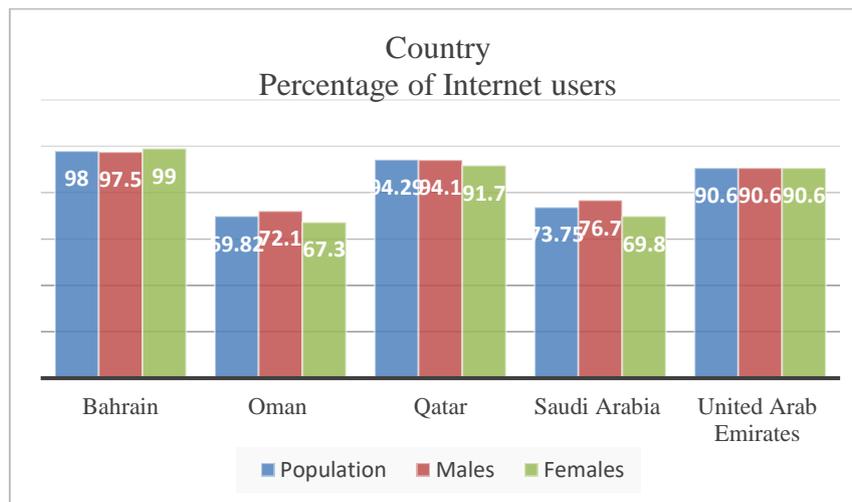


Figure 3. Percentage of Internet users in the GCC (Note: Kuwait not shown in the Figure because of the non-availability of required data)

In terms of the economic affordability to its citizens, all the GCC countries provide Internet subscription in all its forms, such as fixed and mobile broadband, at low prices. For instance, in terms of affordability of mobile cellular technology, UAE leads the GCC countries, followed by Qatar, Kuwait, Oman, Bahrain, then KSA (almost 3 times the price in UAE) [27]. In terms of mobile broadband with prepaid plan with 500 MB of data per month rank Qatar to offer lowest prices, followed by UAE, Bahrain, and Kuwait while Oman seems to be most expensive country for mobile broadband services [27]. The statistics also suggest that by 2025, the usage of smartphone will increase from 79% to 91% of the population of GCC countries [29].

3.4. Adoption of blockchain technology

Blockchain technology has emerged as an efficient solution to frauds involving data records in distributed systems. The technology is mainly based on the concept of immutable shared ledger used in distributed systems

where all transactions are recorded in the shared ledger as a chain of Blocks. Blockchain technology is considered to offer enhanced security, reliability, and management of distributed trust [30]. With the move to digital transformation, Blockchain technology has attracted increased interest in various fields such as combatting fake news [31], the implementation of e-government services, IoT like monitoring patient health [32] and E-health [33].

The Blockchain technology is of particular interest as when deployed where several parties are involved. For instance, this is so in the case of healthcare services where not only health/medical centers but government, insurance companies, and pharmacies may be involved. Researchers in [34] have presented a readiness assessment tool for adopting blockchain technology using a healthcare system. The authors suggest that the deployment of Blockchain technology facilitates the identification of stakeholders with their multitude of inter-relationship and inter-dependencies. They also identify the level of know how required to accept the adoption of this technology along with and the facilitating conditions such as privacy, trust legal and regularity requirements needed for successful implementation of the technology. The authors took UAE as the case study for their research.

Another issue that arose during the COVID-19 pandemic was the spread of fake news directly related to COVID-19 itself and the statistics associated with infected cases and the consequent deaths. Authors in [20] have investigated this issue and have proposed a Blockchain solution tracking system to validate the authenticity of data related to the number of new cases, rate of recovery and number of deaths. H. Hassan et al [35] have developed a blockchain-based solution to stop the spread of COVID-19 called Immunity Passports by tracking patients for their medical tests, medical and travel and quarantine history.

In so far as UAE is concerned, the adoption of Blockchain technology has already started [36]. For instance, the Ministry of Community Development (MoCD) is using Blockchain techniques for digital authentication of certificates and other official documents. Abu Dhabi Digital Authority and Telecommunications Regulatory Authority has developed a mobile application called “UAE Pass” for verification of users through smartphones and allowing them to e-sign documents. The Ministry of Health and Prevention is using a Blockchain platform for recording healthcare data and checking the credentials of healthcare workers.

MiPasa [37] is also a Blockchain based solution developed by HACERA which uses both IBM Blockchain platform for data aggregation and analytics for COVID-19. MiPasa enables public health officials to upload data and even allows individuals to self-report about infected cases along with the time and locations of the infection. Ensuring data privacy, the application enables an individual to verify if he/she has been in proximity to someone infected with COVID-19, in complete data security environment.

UAE has adopted the Blockchain technology to track COVID-19 vaccine sourcing, storage, and the end-to-end administration of the dose. In this vein, UAE is leading the GCC and Arab world countries in the use of cutting-edge technologies in response to the pandemic. In Abu Dhabi, “mUnity” [38], developed by Maqta Gateway, is a system used for safety, security, and tamper-proof distribution of the COVID-19 vaccines. The application is designed to provide transparency of the data gathering process.

Bahrain first adopted Blockchain technology in 2018 for registration of automobiles [39]. In April 2020 and during the COVID-19 breakout, Bahrain announced to use Blockchain technology provided by Bahrain-based pharmaceutical firm MVC Global; a joint project with Cox Logistics called SmartHub logistics warehouse for food and pharmaceutical products.

Airlines industry has also started using Blockchain-based systems. The International Air Transport Association (IATA) Travel Pass platform [40] is also a Blockchain-based application developed by the IATA, to deal with the verification of passengers’ COVID-19 credentials. Emirates, Etihad, and Qatar airways from the GCC countries have tried this platform. The platform provides useful COVID-19 related information to passengers. The information provided includes individual country’s testing requirements and list of testing centers close to the departure location. It also includes a mobile application used by laboratories to send test results, and a contactless travel mobile application used by passengers. It also provides information on test results and serves as the repository base for Digital Vaccine Passport System.

3.5. Adoption of artificial intelligence and machine learning

The GCC countries are developed countries therefore they possess the required resources to implement the use of advanced technologies, such as Artificial Intelligence (AI), based solutions to fight COVID-19 and halt the

spread of the virus. The AI solutions used are based on the application of Machine Learning (ML) and Deep Learning (DL). ML can be considered as the best technique in this matter because it can be applied to predict number of cases and can be applied in patient diagnosis [41]. AI is the branch of computer science which mimics human intelligence thus allowing the computer to think smart and perform massive number of operations in real time. ML is the base process used training of computing machines to think, analyze, and make decision like human beings. DL is part of ML which can improve overall productivity and enables more accurate decisions [42].

The GCC countries are utilizing sophisticated AI based technologies to monitor and maintain the social distance and to ensure COVID-19 safe movement of people and products. They have applied the location-based contact tracing for monitoring positive cases of COVID-19 and restricting their exposure to the population, at large [43].

The KSA has also been a proactive country in applying AI to fight COVID-19. An example is the Danube Online Hypermarket in KSA where “aisle-mapping” is applied using AI technology to minimize delivery time where packers can trace items ordered online which, in turn, are tracked around the stores using an application [43]. In addition, KSA government has speeded up the introduction of tele-health, virtual hospitals, and the use of robotics. The KSA government has realized that the application of AI can efficiently be used to track COVID-19. In compliance thereof, they have developed an AI powered system to prioritizing of vaccination against COVID-19 [44]. This AI system used is empowered with an algorithm to accelerate the identification of targeted individuals who must be vaccinated first and are put on top of the vaccination list [44]. They are now working on using AI to track the effectiveness of the vaccines [44]. In addition, the Saudi Data and Artificial Intelligence Authority released an exposure application named “Tabaud” which alerts individuals if they have come into contact with infected people using Bluetooth technology. The King Abdullah Medical Center Complex, in Jeddah, has launched the use of a robot named “medic” which helps in the treatment process for patients infected with COVID-19 [45]. The KSA government had utilized AI even inside the mosques to serve religious activities. They had launched a social distance robot which provides a personal service of handling sacred spring Zamzam bottles in Mecca Grand Mosque and also functions as a sanitization machine as a step towards of applying social distance in preparation for the pilgrimage [46].

The UAE Government has also incorporated advanced technologies such as AI and big data in its fight against the pandemic. The Dubai police has used AI technology to monitor and regulate the movement of people living in the city of Dubai during the curfew hours [43][47]. They use an AI application known as “Oyoon” which operates a network of cameras to identify residents’ faces and voices along with the recognition of vehicle number plates [43][47]. The recognition system is connected to a large, centralized database and the data is analyzed to determine if the person is part of the group classified as provider of essential services or possess a valid permit that allows him/her to out and about during the curfew periods [43][47]. Abu Dhabi Health Services Company (SEHA), in collaboration with a British Organization, is using an AI technique to forecast how the virus is spreading. In addition, the application is used as study, analyze in estimation of available medical and clinical capacity in order to develop appropriate response plans [47][48]. The adopted technique uses data from hospitals and is analyzed to identify usual surges of demands for beds and other emergency care items. The analyzed data is then compared with the data showing spread of the virus in other countries in order to provide information on possible trends [47][48]. Another application of AI has been developed by Nabta Health, a newly established healthcare company in UAE. Nabta is using the AI based application for COVID-19 symptoms identification and risk assessment [43][47]. The company is also utilizing sophisticated machine learning and blockchain technologies to mitigate the adverse effect of any future pandemic.

In addition, UAE Police Department is using smart helmets embedded advanced AI thermal technologies to measure people temperatures [47]. The helmets are designed to sound a warning alarm if a person with a high temperature is located. The smart helmets can measure the body temperature within five (5) meters away and can scan the body temperature of 200 persons per minute [46]. Late in March 2020, a newly established Abu Dhabi AI and Cloud Computing Company named “Group42” worked in collaboration with world’s largest genome sequencing Company (BGI Group) to open one of the biggest laboratories in the region which is capable of processing tens of thousands of Polymerase Chain Reaction (PCR) tests. The Company uses an AI technique known as the Reverse Transcription Polymerase Chain Reaction (RT-PCR) [47]. The use of RT-PCR puts UAE amongst the top countries carrying out COVID-19 tests relative to its population, as per WHO [47].

Abu Dhabi government has recently announced the application of AI EDE COVID-19 scanners developed by the EDE Research Institute Abu Dhabi, which are to be used at shopping malls, some residential areas, and at entry points across the Emirates [49][50]. These EDE scanners are embedded with EDE detectors which collect electromagnetic waves within an area of a 5-meter radius. The system uses a smartphone with a specific application and is linked to the EDE sensor detectors within one (1) meter of the phone [50]. When a person enters the zone of this radius, the electromagnetic waves are disturbed thereby triggering a machine learning algorithm which compares the collected information with the unique RNA particles of the COVID-19 which are present in effected person's body. If the comparison identifies a positive projection (application's screen turns to red), then the person is potentially infected with the virus and is asked to take a PCR test within 24 hours, otherwise (application's screen turns to green) the person is allowed to enter the desired location [49][50]. This technique will provide a very fast detection of the COVID-19 infections. During trials, it seemed to have operated at an accuracy level with 83% [50]. Etihad Airways in Abu Dhabi has taken extra steps to introduce the use of AI technology to screen and identify passengers infected with COVID-19 [51]. The robots are now in service at Abu Dhabi International Airport to disinfect public areas, cleaning the cabins and screen passengers using infrared thermal technology [52].

In addition, the UAE government through the Ministry of Health and Prevention (MoHaP) has implemented a chatbot service known as "Virtual Doctor for COVID-19". The chatbot is a virtual doctor which is capable of asking specific questions to identify if the person is at risk and connecting him or her to a doctor through the same service [51]. The government has also launched the telemedicine services in hospitals across UAE [51]. Furthermore, the Dubai Road and Transport Authority (RTA) has installed an AI based technology of utilizing computer vision and machine learning algorithms to effectively detect and report violations of the preventive measures implemented by the Government. Another interesting application of AI was implementation, in Abu Dhabi, whereby programmed robots are used to sanitize sanitary areas as part of the national sanitization program [53]. The technique has also been used, both in Abu Dhabi and Dubai, for sanitization of personnel clothing through the addition of sanitization corridor in front of many public places. The sanitization corridors are equipped with AI based tools to sanitize personal clothing [53].

The Qatari government, on the other hand, in collaboration with the Qatar Computing Research Institute, is developing a diagnostic and monitoring application, which is to be directly linked with the ministry of health database. This application will use location-based algorithms to diagnose and track COVID-19 cases [43]. In addition, the Qatar Computing Research Institute (QCRI) has launched an online self-assessment platform that assist individual to learn more about the COVID-19 and provides medical advice [54]. The QCRI also has launched a fake news detection system named "Tanbih" which is used in the fight against COVID-19 [54] related fake news. The QCRI has also developed a data processing platform known as "Rayyan" which enables access to a massive amount of COVID-19 Virus related information to support experts and researchers working on COVID-19 related eradication research projects [54]. The Hamad International Airport is using robots for disinfection purposes [55]. In addition, the Qatar Ministry of Interior is using smart devices with surveillance cameras to monitor infection rates in high density zones such as Doha's Industrial Area [55].

In Bahrain, the private sector is mitigating the impact of pandemic related economic downturn by using AI solutions. For example, some private companies such as the Medical Value Chain (MVC) Global and the Cox logistics are using Blockchain technique along with AI to facilitate delivery of food and medicines across the country [56]. The Kingdom Ministry of Health is using three robots the "Robot Net 20", "Robot Net 21", and the "RobotInfirmiere Nurse Robot" at the Ebrahim Khalil Kanoo Health Centre isolation facility in Manama [57]. The goal of these robots is to assist in the provision of additional protection and safety to all healthcare staff, reduce the transmission of the virus, and also to provide nursing care to boost health services in fighting COVID-19 [57]. The "Robot Net 20" will be used to distribute meals and medication to patient through face recognition. The patient will be able to communicate with the doctors through the robot, while the "Robot Net 21" is to be used for disinfection and sanitizing of isolation rooms and surrounding facilities without any human contact. Finally, the third robot "Robot Infirmiere Nurse Robot" is be equipped with thermal cameras, ventilators, electrocardiogram, and blood pressure monitors [57]. This robot will be used at reception areas to measure individual's temperature and prevents patient with those with high temperature coming in contact with others [57].

3.6. Adoption of mobile applications, online portals, and virtual schools

GCC has promptly responded to curb COVID-19 through implementation of modern technologies and their applications. They had also contributed into a variety of technological developments and initiatives in various sectors of the overall economy such as in the development of Mobile Applications, Web Portals, distance learning, online working, use of robotics, and advanced scientific research. The following sections of this paper summarize most of these technologies and tools developed and implemented as a swift response to fight COVID-19 and assist the GCC countries to return back to the normal life.

3.6.1. Mobile applications initiatives

Table 2 summarizes the most common Mobile Applications that have been implemented by GCC Governments to combat COVID-19. The information relating to the applications are categorized and show main features along with the salient characteristics of each application. KSA has launched Seventeen (17) mobile applications to curb COVID-19 and seems to be leading the development and implementation of mobile technologies. UAE has also developed Six (6) mobile applications which have been successfully implemented and are being used. In a similar vein, Kuwait and Qatar have launched Two (2) mobile applications. Bahrain and Oman had implemented One (1) mobile application.

Table 2. GCC Mobile App initiatives to curb COVID-19 [58, 59, 60]

Country	App	Features	Category
Bahrain	BeAware Bahrain	<ul style="list-style-type: none"> • An App to track active COVID-19 cases. • It provides latest updates about the current situation of COVID-19. • It populates awareness about the active cases locations inside the kingdom. • It helps in maintaining social distances and producing alerts in case an active case is passed nearby. • It helps in providing accurate figures and feedback to the Ministry of Health. 	Tracking COVID-19 cases
Kuwait	Shlonik app	<ul style="list-style-type: none"> • Latest health updates • Health chatbot • Quarantined patients self-check in. • Vitals contact and communication with the Ministry of Health. 	Sharing Information
	Social distancing and COVID-19 tracking	<ul style="list-style-type: none"> • An App to organize and monitor the shopping for foods in shops. • It is used for food shopping appointment reservation. 	E-shopping
Oman	Tarassud Plus app	<ul style="list-style-type: none"> • An App used to track and follow up patients who are infected by COVID-19 and who are in quarantine. • It has two main features, the medical test and the follow up system. • It assists in monitoring and controlling the current status of the COVID-19 and helps to fighting the spread of the virus. 	Monitoring Patients Remotely
Qatar	Droobi app	<ul style="list-style-type: none"> • Ease the information access to COVID-19 infected patients. • Identify high risk patients. • Provide the necessary medical support to infected patients. • Monitoring quarantine patient's movement. 	Monitor patients remotely

Country	App	Features	Category
KSA	Ehteraz	<ul style="list-style-type: none"> • It uses GPS and Bluetooth to track, trace, and monitor COVID-9 infected cases. • Supports the preventive measures to curb COVID-19. • Provides current status and statistics about COVID-19. • Populate awareness and official instructions. • Provides FAQ and hotline consultations. • Users are classified into Red: positive infected, Yellow: people in quarantine, and Grey: suspected people, those with symptoms, or have been in contact with a positive case, and Green: health and negative tested people. 	Tracking COVID-19 and social distancing
	Tawakolna	<ul style="list-style-type: none"> • Provides up to date statistics about the number of infected cases. • It allows people to request exit permits in cases of lockdown and curfews. • The app also warns people if they came across or nearby pandemic hotspots. • The app allows people to register and report any face symptoms and gain the necessary medical support. 	Sharing Information
	SEHA app for doctor consultations	<ul style="list-style-type: none"> • Reduce visits to hospitals and medical centers. • Facilities doctor consultations through virtual visits (telemedicine). • Uses AI-enhanced chatbots. 	Virtual Consultation and doctor communication
	Tamini app	<ul style="list-style-type: none"> • Provides accurate products information to consumers. • Shows nearby pharmacies and assist in searching for the availability of masks, gloves, and sanitizers in nearby pharmacies. 	Medical goods supplementary
	Tatman app	<ul style="list-style-type: none"> • Provides assistance to people who are self-isolated in quarantine and supports them. • Provides COVID-19 test results. • Warn if the person was in contact with an infected COVID-19 case. • 24 Reduce visits to hospitals and medical centers. • Comply with social distances measures. • Facilities doctor consultations through virtual visits, online assistance and support. • Daily follow up about health status. • Monitor people movement who are in quarantine to curb the spread of COVID-19 virus. 	Monitor patients remotely
	Mawid	<ul style="list-style-type: none"> • Provides a tool to check symptoms. • Facilitates appointments to all Ministry of Health services. • Tracking and tracing COVID-19. 	Digital Screening
	Sehaty	<ul style="list-style-type: none"> • Booking for COVID-19 test appointments. 	Digital Screening

Country	App	Features	Category
		<ul style="list-style-type: none"> • Vital symptoms and signs updates. • Retrieving and sharing sick leaves. • Health awareness • Provides e-prescription • COVID-19 self-assessment test • School screening • Other health services 	
	Taqasi (Patient Tracing Unit)	<ul style="list-style-type: none"> • Monitor and manage COVID-19 contact tracing. 	Surveillance
	Tabaud	<ul style="list-style-type: none"> • Tracking COVID-19 spread. • Warns if the person was in contact with an infected COVID-19 case. 	Contact Notification
	Anat	<ul style="list-style-type: none"> • Provides an electronic prescription. • Assists the Saudi Commission for Health Specialties to check the licensure for all health care professionals. 	
	Wasfaty	<ul style="list-style-type: none"> • The official electronic prescription application across the kingdom. 	
	Asefni	<ul style="list-style-type: none"> • Saudi Red Crescent Authority App which provides an instant GPS response to emergency requests. 	
	Cura	<ul style="list-style-type: none"> • Provides telemedicine and virtual doctor consultations (synchronous app). 	Private App
	MayaClinic	<ul style="list-style-type: none"> • Provides telemedicine and virtual doctor consultations (nonsynchronous app). 	Private App
	Nala	<ul style="list-style-type: none"> • Provides telemedicine and virtual doctor consultations. 	Private App
	Labayh	<ul style="list-style-type: none"> • Provides telemedicine and virtual doctor consultations. 	Private App
	80/20 Lifestyle	<ul style="list-style-type: none"> • It provides a virtual patient engagement and lifestyle recommendation. 	Private App
	Virtual Medical Academy	<ul style="list-style-type: none"> • A web portal which provides online medical events to health care experts and professionals. 	Private App
UAE	AlHosn App	<ul style="list-style-type: none"> • Monitor people in quarantine. • Provides results to COVID-19 tests and those who got vaccinated using a classification of colors. • It uses the Bluetooth technology to alert individuals if they are in contact or nearby infected cases. 	Tracking COVID-19 and social distancing
	1MAP Health Facility Locator App	<ul style="list-style-type: none"> • An online interactive map which helps the public to locate all nearby or in any other locations' hospitals, medical centers, clinics and COVID-19 drive through test centers. 	Online health services
	Tamm App	<ul style="list-style-type: none"> • This App was launched during the COVID-19 pandemic in 2021 which facilitates to individuals to finish most of their governmental services using a smart application. 	Government Services
	TraceCOVID App	<ul style="list-style-type: none"> • The app is launched by Department of Health - Abu Dhabi (DoH). The app tries to detect 	Tracking COVID-19 and social distancing

Country	App	Features	Category
		devices installing the same App and share information with it. The App depends on using a ‘Secure Tracing Identifier’ contains a list of individuals that a user has a contact with. If the user got infected with COVID-19, the authorities can access the recorded user’s data and instantly get to know the predicted infected individuals easily.	
	StayHome App	<ul style="list-style-type: none"> It ensures the people under quarantine are commitment to instructions and related requirements. The app also monitors and trace the movement of those people. 	Tracking COVID-19
	DOH RemoteCare App	<ul style="list-style-type: none"> It helps individuals (especially those with chronic diseases and elderly) to receive health care services from home without the need for any physical visit to the hospital, clinic or a medical center. It has many features such as, non-emergency cases diagnoses, symptoms examination, booking appointments, and telemedicine. The app also allows the possibility to receive prescriptions and get the medicine delivered to their homes. 	Virtual Consultation and doctor communication

3.6.2. Websites and online portals

The GCC countries have also taken steps to fight COVID-19 through the development and implementation of mandatory Websites and Web Portals. KSA has introduced Eight (8) main Web-based initiatives in different areas such as Donation, Volunteering, Awareness, Waqf and Webinars. UAE, on the other hand, has developed and implemented Websites in areas such as Job Portals to assist those whose job were affected by the pandemic. In addition, Websites have been developed and established to provide support for mental health and volunteering process. Qatar has also taken on Two (2) different initiatives, one dealing with telemedicine and virtual doctor while other relates to an e-commerce directory that provides information on online shopping. Kuwait has also launched an awareness website to combat COVID-19. Table 3, below, lists the main website initiatives that GCC countries have implemented to curb COVID-19.

Table 3. GCC Website and Web portal initiatives to curb COVID-19 [58, 59, 60]

Country	Website/ portal	Features
Kuwait	Kuwait combatting COVID-19	<ul style="list-style-type: none"> It is a website to post updates on COVID-19 status in Kuwait (total number of cases, recovered cases, number of deaths, active cases). It also includes latest news as well as FAQs.
Qatar	Telemedicine and Virtual doctor “Better Connections”	<ul style="list-style-type: none"> Reduce migrant visits to hospitals and medical centers. Comply with social distances measures. Facilities doctor consultations through virtual visits.
	E-commerce Directory	<ul style="list-style-type: none"> This directory was implemented to provide an easy way for the people to know about and reach their favorite retail shops online during the pandemic period.
KSA	COVID-19 Online Awareness	<ul style="list-style-type: none"> The Saudi Red Crescent Authority (SRCA) has launched a website awareness initiative on how to monitor and prevent COVID-19. The website has a training system, and upon passing the program, the trainee will receive a certificate.

Country	Website/ portal	Features
	“Giving for All”	<ul style="list-style-type: none"> This initiative supports learners with low income to receive an electronic device necessary for the online/ distance learning.
	COVID-19 Volunteers online platform “Yesser”	<ul style="list-style-type: none"> Yesser is a national web portal which allow a real time access to COVID-19 information, current status, measures, travel restriction, and links all government ministries and entities to different dataset on a Data portal.
	“Move to Donate”	<ul style="list-style-type: none"> This initiative was launched by the Saudi Sports for All Federation (SFA) in collaboration with Saudi Food Bank (SFB) during the holy month of Ramadan to reward people and guide them on how to deliver food baskets to most needful people.
	Nafaz service using Absher account for online volunteering	<ul style="list-style-type: none"> An online platform to guide people who would like to volunteer and provide their services to the community. This platform will allow participants to register and gain the necessary related training.
	Blood donation from home	<ul style="list-style-type: none"> It is an initiative where the doners can request the service from the blood bank through WhatsApp or online. The blood bank will then come to the house of the doner and take the blood.
	Waqfy portal	<ul style="list-style-type: none"> It is a website portal launched by the General Authority of Awqaf to provide doners the service to participate in supporting the community with many endowments and secure the online payments.
	SCFHS Webinars	<ul style="list-style-type: none"> It provides support services to health care experts and professional related to their specializations.
UAE	COVID-19 Volunteers online platform	<ul style="list-style-type: none"> A web portal to coordinate and organize the volunteering process during COVID-19 in collaboration between the Ministry of Community Development and Emirates Red Crescent.
	Don’t worry	<ul style="list-style-type: none"> A web portal initiative as a response to a national wide campaign to provide mental health support dealing with the psychological effects of COVID-19.
	Job Portal	<ul style="list-style-type: none"> Ministry of Human Resources and Emiratization (MOHRE) had launched a job portal imitative as a response to support and help non-UAE workforce who were impacted by the preventive measures taken in the UAE to curb COVID-19.

3.6.3. Hackathons and research programs

GCC countries have also taken the lead to find ways and means to eradicate COVID-19 through the application of Hackathons and research initiatives. UAE has launched a coding initiative to prompt programmers to innovate new tools and digital solutions to assist in curbing COVID-19. Oman, Qatar, and KSA have also launched research initiatives to develop new technologies, techniques, and solutions to combat the pandemic. Table 4 summarizes the main online initiatives implemented in Oman, Qatar, KSA, and UAE.

Table 4. GCC Research and Hackathon Initiatives during COVID-19 [58][59][60]

Country	Research Initiative
Oman	The Omani Research Council has launched a research initiative in clinical and non-clinical ideas to find solutions to fight COVID-19.
Qatar	An initiative to allow inventers, innovators, and entrepreneur to propose ideas to curb the COVID-19.
KSA	A 48 hours online event which promotes innovative ideas and solutions to sectors which were affected by COVID-19.
UAE	An initiative launched by Dubai Future Foundation in April 2020 (One Million Arab Coders COVID-19 Hackathon). This initiative was to motivate programmers from the

Country	Research Initiative
	Arab world to innovate digital solutions in the health and education sectors to curb COVID-19.

3.6.4. Virtual schools and tele-working

The GCC countries have, without losing any time, adopted online (distance) learning through implementation of virtual schools and adjusted easily to teleworking approach. The main reason behind this swift adoption of technique is considered to be availability of excellent existing ICT Infrastructure and affordable Internet. This has enabled the workers from various sector of the economy to work remotely. A variety of tools and technologies such as MS Teams, Zoom, Cisco Webex have now been in wide use in GCC countries for over two (2) years.

3.7. Adoption of drones

Drones, also known as remotely controlled unmanned aerial vehicles, have recently attracted attention of researchers and industries. Drones were originally used in military for missile deployment and spying. But they were quickly adopted in several civilian applications like agriculture, logistics, constructions, traffic surveillance, environment monitoring, taking photographs and videos in crowded places, and more recently they have been used to combat the spread of the COVID-19 virus.

With regard to the GCC countries, the drone market was valued at USD 0.64 billion in 2020 and is forecasted to grow to USD 1.86 billion by 2026 [61]. China is the most prominent source of commercial drones in the Middle East, and accounts for 70% of non-commercial drone sales [62]. It is forecasted that the UAE is expected to dominate the drone market in the GCC with construction activities identified as the main area of deployment. UAE leads the GCC countries utilizing Drone technology followed by KSA and Oman.

UAE has used several cutting-edge technologies to fight the COVID-19 pandemic. For instance, Dubai and Sharjah police have made use of drones equipped with cameras and loudspeakers to broadcast warning messages to the public to respect the rules and take precautionary measures like social distancing in order to keep safe [63][64]. Also, Dubai has used drones for aerial disinfection, sanitization, and body temperature checks on individuals [65].

With the current situation and the emergence of several variants of COVID-19, drones have been also suggested to be used for grocery delivery by Anthony Tzes at NYU Abu Dhabi [66] This is considered to be another way to reduce social contact and avoid crowds. The current versions of the drones can carry up to ten (10) kilograms of weight.

The company Voxel, in Saudi, has developed Drones to spray sterilizers. These can also be used for body temperature assessment. Oman also has applied the same technology and drones have been used to measure body temperature of drivers in their vehicles [62]. Likewise, Kuwait [13][67] and Bahrain [68] deployed drones in monitoring of social distance and relaying of COVID-19 related important announcements.

3.8. Adoption of IoT technology

The emergence of smart devices has made it possible to interconnect these devices to help tracking and monitoring of patients' health, creating Internet of Things (IoT for short) and Wireless Personal Area Networks (WPAN). The IoT technology has attracted much attention in several sectors of the economy. Healthcare is the one among the sectors which has quickly started the adoption of IoT solutions. IoT-based solutions provide powerful tools to help in monitoring patients remotely and gathering of data required to enable health workers to make medical decisions promptly. With the COVID-19 outbreak, researchers from healthcare sector along with those from the IT and Engineering-related fields have put great efforts in investigating efficient ways in using IoT technology to combat COVID-19 pandemic.

An intensive research effort has been focused by UAE and Qatar on to investigation of the use of IoT based solutions in the GCC countries. In 2020, UAE government and Health Authority launched a smart solution to monitor and track the geographic location of self-isolated (who have mild symptoms) and self-quarantined people through a smartwatch [69]. The smartwatch is linked to Alhosn application, as already mentioned in

section 3.6 of this paper, to ensure that self-isolated/quarantined people comply to isolation/quarantine requirements. In case of violation of the procedure, the concerned person is to be fined around US\$ 2700 [70].

Also, in the same country and in 2020, the ministry of Interior adopted the use of smart helmet [71]. The helmets, used by specialist police teams and patrols, are equipped with thermal cameras and sensors to diagnose people from a distance. Additionally, the smart helmets are fitted with face and vehicle plates recognition tools and provide recording of relevant data for further analysis. The recorded data is analyzed by the ministry's central operations room to generate reports which can be used for further decision making. Qatar Airway Cargo signed an agreement with SkyCell, a Swiss-based container provider, for transportation of pharmaceuticals [72]. SkyCell employs IoT-based containers with remote monitoring of the temperature conditions of pharmaceutical products while in transit. Under the COVID-19 pandemic, these containers are well suitable for the transportation and distribution of the temperature-sensitive COVID-19 vaccines.

4. Conclusions

This paper has reviewed the technologies being developed and deployed by GCC countries to combat COVID-19 and its variants. The finding is that the most modern, state of the art technologies and techniques have been deployed by GCC countries to protect their citizens against COVID-19 since its appearance in December 2019. The paper also shows that application of related technology has been quick and successful in that the desired level of efficacy has been achieved. The success of the whole enterprise can largely be attributed to the existence of extensive ICT infrastructure and affordable Internet in GCC countries. The deployment of a range of different technologies such as machine learning, artificial intelligence, Internet of Things, mobile applications and online portals, drones, and blockchain would have been impossible without the existence of high level of ICT Infrastructure and Internet in GCC countries.

Declaration of competing interest

The authors declare that they have no known financial or non-financial competing interests in any material discussed in this paper.

Funding information

No funding was received from any financial organization to conduct this research.

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