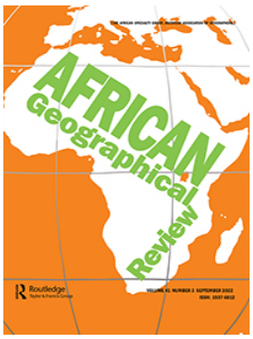

African Geographical Review

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/rafg20

Africa's innovation and creative response to COVID-19

Joseph R. Oppong, Yvonne A. Dadson & Hilary Ansah

To cite this article: Joseph R. Oppong, Yvonne A. Dadson & Hilary Ansah (2022) Africa's innovation and creative response to COVID-19, African Geographical Review, 41:3, 318-335, DOI: 10.1080/19376812.2021.1897635

To link to this article: https://doi.org/10.1080/19376812.2021.1897635

AFRICAN GEOGRAPHICAL REVIEW
2022, VOL. 41, NO. 3, 318–335
https://doi.org/10.1080/19376812.2021.1897635

Routledge
Taylor & Francis Group

Africa's innovation and creative response to COVID-19

Joseph R. Oppong[a], Yvonne A. Dadson[b] and Hilary Ansah[a]

[a]Department of Geography, University of North Texas, Denton, TX, USA; [b]Department of Public Administration, University of North Texas, Denton, TX, USA

ABSTRACT

Rather than decimation and devastation, COVID-19 appears to reveal Africa's innovation and resourcefulness in fighting disease, but this has largely escaped scholarship. Using various search engines, keywords and phrases, we conducted a scoping review of common key innovations and strategies Africa's 54 countries deployed to fight COVID-19. Our results show that African countries have used old tools and approaches in new ways, developed and adapted new technologies, and creatively used limited resources. Thus, COVID provides an opportunity for unparalleled transformation in health care and economy. We offer some policy options for scaling up and sustaining this positive transformation.

ARTICLE HISTORY
Received 25 August 2020
Accepted 19 February 2021

KEYWORDS
COVID-19 pandemic; healthcare systems; innovations; e-commerce policy response

Introduction

Due to systemic vulnerabilities, COVID-19 was expected to devastate Africa. According to the United Nations Economic Commission for Africa (UNECA), with 1.3 billion people, Africa could have nearly 123 million cases of COVID-19 this year, and 300,000 people could die of the disease (United Nations Economic Commission for Africa [UNECA], 2020). As of 20 October 2020, Africa had about 28,409 deaths (WHO Africa Region Situation Report, 2020), a minuscule number compared to the United States with more than 220,338 deaths and 332 million total population, or the United Kingdom with 43,816 deaths and 67.9 million population. The predicted apocalypse has not happened yet. Despite persistent, underlying problems of famine and food insecurity, political instability and wars, droughts, recent flooding, and locust invasion, African countries are yet to experience 'dead bodies in the streets' forecast by philanthropist, Melinda Gates, during her Apr 13 CNN interview (CNN Business, 2020).

While attributing these low numbers to inadequate testing, demographics, or earlier stage of the pandemic, African agility, creativity, and innovative response to COVID-19 appear to be ignored. This paper attempts to fill the gap. Using a brief scoping review of the most common strategies and innovations employed in Africa's 54 countries, we argue that while facing impossible odds in COVID-19, African countries have used old tools and approaches in new ways, developed and adapted new technologies, and creatively used limited resources. In the process, African countries have an opportunity for unparalleled and lasting transformation in health care and economy.

The paper is laid out as follows. Following a brief description of our methodology, we provide a brief assessment of the global devastation of COVID-19 and carefully examine the case for the expected devastation of the disease in Africa. We then show how African countries have responded to the disease with hitherto unknown creativity and innovation. We conclude by reflecting on how COVID-19 may be transforming Africa in unforeseen ways.

Methodology

CONTACT Joseph R. Oppong Oppong@unt.edu

In order to identify common key innovations and strategies Africa's 54 countries deployed to fight COVID-19, we conducted a basic search on various search engines, using keywords and phrases such as 'Covid in Africa,' 'Covid and Africa.' Executing the initial search with and without the Boolean operator 'and'/'in' produced little to no change in the overall results. We conducted a further search, adding new terms and phrases such as 'Africa's innovation to Covid,' 'Africa and Covid innovation,' 'Covid in Africa strategies.' The strategy found innovations mostly from Sub-Saharan Africa with few from North African countries. We used three main types of documents – refereed articles, reports from international organizations such as the World Health Organization (WHO), and magazines, newspaper articles, and media reports. This last category included articles from Reuters Magazine, The Guardian News, The Economist, and reports from British Broadcasting Corporations (BBC). While we tried to be comprehensive, we could not be exhaustive, and thus, focused on the most common innovations reported by multiple countries. The most common innovations we found include rapid test kits, deployment of drones and robots, and pooled testing.

Reasons for an expected COVID-19 apocalypse in Africa

Before the current global pandemic, health systems in Africa were already overstretched by a dual burden of communicable and noncommunicable diseases. Along with endemic communicable diseases such as malaria, HIV/AIDS, and tuberculosis, and excessively high rates of malnutrition, maternal and child mortality, African countries were also grappling with high and escalating rates of non-communicable diseases, including diabetes, cardiovascular diseases, cancer, and injury (Ayandipo et al., 2020; Kushitor & Boatemaa, 2018; Stephens et al., 2020).

Thus, the health care infrastructure of most African countries is inadequate to support routine care for their citizens. With more than 22% of the global burden of disease, Africa has less than 1% of global health expenditure and only 3% of the world's healthcare workers (Table 1). Indeed, most countries have a crippling deficit of health workers. Although the WHO has declared 1:1,000 as the desirable doctor-population ratio and a minimum threshold of 4.45 physicians, nurses, and midwives per 1,000 population as necessary to achieve universal health coverage, most African countries fall way short of the standard. For example, the physician-population ratio in the better served countries ranges from 1:494 in Mauritius, and 1:546 in Algeria, to 1:1,099 in South Africa. However, it is 1:15,873 in Central African Republic, 1:20,833 in Chad, 1:27,027 in Liberia, and 1:62,500 in Malawi (Table 1).

By any measure, African healthcare systems are under-equipped and under-staffed to face COVID-19 and the capacity to provide critical care is the lowest in the world (Albutt et al., 2018; Prin et al., 2016). The entire continent has just 20,000 beds in intensive-care units (ICUs), equivalent to 1.7 ICU beds per 100,000 people (Jayaram et al., 2020). By comparison, China has an estimated 3.6 ICU beds per 100,000 people, while the United States has 29.4 (Society of Critical Care Medicine, 2020). While France has 5.98 beds per 1,000 people and Italy has 5.6, the entire continent has only 1.8 hospital beds per 1,000 people (UNECA, 2020).

Similarly, the shortage of ventilators is particularly acute in Africa. While the United States has about 160,000 ventilators, Africa has only 20,000. The Central African Republic (C.A.R.) has only three for a population of five million people, and South Africa has 3,300 ventilators, although most are in private hospitals and inaccessible to the general public (Houreld et al., 2020). Additionally, ongoing conflict renders the limited resources inaccessible in some countries. In northern Mali, for example, 93% of healthcare facilities have been destroyed by Jihadists (Bhalla, 2020), and the remaining community health centers, struggling to treat endemic malaria and other diseases, could not treat COVID-19 patients.

Moreover, over-dependence on imported medical technology and pharmaceuticals is the norm (UNECA, 2020). Since Africa imports 94% of its pharmaceuticals, global price wars for personal protective equipment (P.P.E.) – the masks and gloves that help keep health care workers from being

Table 1. Medical doctors and health expenditures per capita.

Country	Doctor per 10,000 people 2014–2017	People per Physician 2014–2017	Per-capita health expenditures in PPP	Per-capita health expenditures in US $
Algeria	18.3	546	998.15	260.41
Angola	2.2	4651	185.82	95.22
Benin	1.6	6369	83.48	30.40
Botswana	3.7	2710	931.30	379.92
Burkina Faso	0.6	16667	115.60	40.94
Burundi	0.5	20000	62.41	22.93
Cape Verde	7.7	1300	349.40	159.88
Central African Republic	0.6	15873	263.29	70.38
Chad	0.5	20833	162.64	67.57
Comoros	2.715	3683	29.91	16.36
Congo	No Data	No Data	94.95	31.69
Côte d'Ivoire	2.3	4292	169.29	64.47
Democratic Republic of the Congo	0.74	13514	115.85	59.00
Djibouti	2.2	4545	34.49	20.52
Egypt	7.9	1266	122.08	70.19
Equatorial Guinea	4.0	2500	516.34	130.99
Eritrea	0.628	15923	838.74	281.37
Eswatini	3.285	3044	663.25	220.59
Ethiopia	1.0	10000	55.33	29.89
Gabon	3.6	2770	69.52	27.52
Gambia	1.1	9259	555.63	220.35
Ghana	1.8	5556	74.31	20.93
Guinea	0.8	12658	189.37	67.51
Guinea-Bissau	2.0	5000	107.72	37.46
Kenya	2.0	5025	97.97	39.05
Lesotho	No Data	No Data	242.73	85.52
Liberia	0.4	27027	143.54	66.21
Libya	21.6	463	133.15	68.31
Madagascar	1.8	5525	90.43	24.12
Malawi	0.2	62500	115.16	29.59
Mali	1.4	7194	81.18	29.79
Mauritania	1.8	5587	163.92	46.77
Mauritius	20.3	494	1206.74	553.10
Morocco	7.3	1376	61.65	19.21
Mozambique	0.7	13514	969.26	402.76
Namibia	5.914	1691	61.43	22.68
Niger	0.5	20000	213.74	79.34
Nigeria	No Data	2225	130.38	48.08
Rwanda	1.4	7407	196.90	105.13
Sao Tome and Principe	3.2	3125	143.96	53.45
Senegal	0.7	14493	1122.56	596.92
Seychelles	9.5	1057	148.30	7.51
Sierra Leone	No Data	No Data	244.04	86.31
Somalia	0.2	43478	1071.35	428.18
South Africa	9.1	1099	297.86	152.02
Sudan*	4.1	2439	663.25	220.59
Tanzania	0.4	25000	117.11	37.61
Togo	0.5	20408	99.90	38.77
Tunisia	12.7	786	806.34	256.50
Uganda	0.9	10989	111.98	35.50
Zambia	0.9	10989	175.18	56.54
Zimbabwe	0.8	13158	185.05	93.94

Source: WHO Global Health Observatory Data Repository. http://apps.who.int/gho/data/node.main.HWFGRP_0020?lang=en. Accessed 8/19/19.

Column 1 shows Medical Doctor Density, defined as number of doctors per 10,000 population, for 2014–2017 as reported by the WHO (Global Health Depository). To facilitate meaningful comparison, computed the total number of people per physician rounding to one decimal place (Column 2). For example, for Zimbabwe in 2014–2017, the medical doctor density of 0.8 per 10,000 people translates into each physician serving 13,158 people.

infected and spreading the virus to others – and other COVID-fighting resources have made them unaffordable for African countries. For example, the US recently purchased the entire global supply of remdisivir, a drug that has been approved for treating COVID-19, leaving none for the rest of the world (Boseley, 2020). Furthermore, more than 71 countries have banned, or limited exports of certain supplies deemed essential to fight the disease. Consequently, a severe shortage of P.P.E. is inevitable across the continent.

Poverty, crowdedness, and COVID-19

While the prevailing health systems reduce the ability of African countries to fight COVID-19, even more troubling is the pervasive social vulnerability to the disease. In Africa's urban slums such as Kibera in Kenya, high population density precludes social distancing and facilitates virus spread. Those who live in crowded homes, travel on crowded mass transport, and work in crowded workplaces such as the informal markets, are more likely to catch and spread the virus because they are more exposed, fragile, and likely to have underlying illnesses that compromise their ability to fight infections.

This is the situation in many African countries. According to UNECA, 56% of the African urban population lives in overcrowded and poorly serviced slum dwellings, many people are vulnerable due to HIV/AIDS, tuberculosis, and malnutrition, and only 34% of the households have access to basic handwashing facilities (UNECA, 2020). About 71% of Africa's workforce is engaged in the informal economy, which precludes working from home. Close to 40% of children under five years of age in Africa are undernourished. Such widespread high levels of poverty and poor sanitation make regular handwashing with soap and social distancing impossible or an unaffordable luxury (Oppong, 2020a). Additionally, conflict, climate change, and natural disasters have driven some 18 million people across the continent into poorly serviced and crowded camps, for refugees and the internally displaced, where social distancing, or even hand washing, is impossible (Baker, 2020).

Given all these obstacles and complications, Africans have no choice but to respond innovatively and in non-traditional ways to the COVID-19 pandemic. Compelled by necessity, they have responded in ways previously unheard of. We devote the rest of this paper to reviewing some of these creative and innovative responses that have emerged. We discuss Africa's innovative responses in four main categories – testing and COVID suppression, local manufacturing of COVID gear, e-commerce and cashless transactions, and communication and information dissemination. It is important to note that several agencies, including NGOs, civil society groups (Hamann, 2020), local/national government, private industry, and business, as well as supranational organizations, including the Africa Union and the Africa CDC, have played key roles in Africa's response. However, evaluating the contributions of these agencies and their effectiveness is beyond the scope of the current study.

Lessons from previous disease outbreaks

While lacking the conventional tools for fighting COVID, Africa's wealth of experience in fighting previous outbreaks and making do with very little position the continent and its people uniquely to fight COVID (Oppong, 2020a). Indeed, the dearth of health care infrastructure, personnel, and resources is only superseded by Africa's unparalleled experience in dealing with pandemics and endemic disease. Additional to endemic malaria, schistosomiasis, and tuberculosis, Africans have faced recent outbreaks of Lassa fever, Ebola, HIV, and MERS. In fact, Ebola killed 11,000 people and led to the creation of Africa Centers for Disease Control and Prevention (Africa CDC). Since its inception in 2017, the Africa CDC has facilitated a coordinated response to health and emergencies on the continent. Thus, although devastating, each of these disease outbreaks left Africa a bit better prepared to face the next outbreak because of the infrastructure constructed – particularly health research and treatment facilities, training in contact tracing, and public health.

Along these lines, the residue of infrastructure built for fighting the last major outbreak – Ebola in West Africa and the Democratic Republic of Congo – has come in handy in the current fight against COVID-19.

African innovations to fight COVID

From genome sequencing of the virus to production of hand sanitizers, African countries have made incredible strides in the fight against COVID-19. Table 2 presents a brief list, and we highlight selected items in the following pages. Researchers from the Noguchi Memorial Institute for Medical Research (NMIMR) and West African Center for Cell Biology and Infectious Pathogens (WACCBIP) successfully sequenced genomes of the SARS-CoV-2, from the first 15 cases reported in Ghana – six imported cases and nine locally acquired infections – literally in days (Hayibor, 2020). This allowed them to track virus mutations and trace the sources of new community infections in people with no known contact with confirmed cases.

Rapid test kits

Another area of African innovation is the local development and manufacture of rapid COVID-19 test kits. In Senegal, the Pasteur Institute developed two types of diagnostic test kits for COVID-19. Costing only 1 USD (US), the kits provide results within ten minutes using specimens taken either through saliva (saliva swaps) or blood (thumb prick/paper-strip) (Hirsch, 2020; Yeung, 2020). In Uganda, a rapid test kit for COVID-19 that costs about 1.00, USD has been developed from an existing 'pan-filovirus' quick diagnostic test kit created for identifying animal-borne diseases, including the coronavirus, Ebola, and Marburg viruses (Wetaya, 2020). In Ghana, the Kwame Nkrumah University of Science and Technology (KNUST) developed a COVID antibody test that can produce results in 15–20 minutes (Mastercard Foundation, 2020).

In Kenya, Ultra Red Technologies manufactures plastic face shields for local healthcare workers has also invented a 3D printed prototype for a ventilator adaptor. This invention enables doctors to treat two or four patients at one time if the need arises (CBC Radio, 2020). Similarly, Tunisian engineering students are producing 3D facemasks. The design produces a mask in 2 minutes (Jawad & Smith- Walters, 2020).

Drones as rapid sample transporting and police agent

Before the occurrence of COVID, several African countries including Ghana and Rwanda were transporting medical supplies to remote and densely populated areas using drones provided by Zipline (De Leon, 2020; Meisenzahl, 2020). With COVID-19, both countries use drones for transporting test samples from rural areas across the country to the main testing facilities (Knott, 2020a). Instead of driving, which would take hours, drones transport the samples to the lab site and the test results are returned via text message two days later. In Ghana, the fleet of drones can transport up to 15,000 tests a day, in 300 flights, from two collection points. An additional two drone ports can serve about 2,000 rural health clinics and about 10–15 million residents. Also, Rwanda deploys drones for policing, disseminating COVID-19 advice, and disinfecting public spaces (Mutesi, 2020).

Pooled testing

Responding to the global shortage and cost of COVID-19 testing materials and PPE, African countries have been compelled to adopt truly creative and innovative approaches. Standard detection methods are expensive, ranging from US$30 to US$100, and time consuming due to the

Table 2. Selected African COVID-19 innovation responses by countries.

Subject	Country	Innovation	Reference
Testing and Suppression	Ghana	Using drones for transporting COVID-19 test samples. A telemed app to initiate contact-tracing and communicate with patients COVID antigen test kit by Kwame Nkrumah University of Science and Technology (KNUST).	Knott, 2020a Knott, 2020a Mastercard Foundation, 2020
	Nigeria	Launch of 'COVID Mobile,' a vehicle for taking test samples.	Uroko, 2020
	Rwanda	Robots for taking samples and vitals of suspected COVID cases in the nation's isolation centers, Kanyyinya Health	Uwiringiyimana, 2020
	Senegal	$1 rapid diagnostic test kits by the Pasteur Institute in Dakar. Students of Dakar Polytechnic develop 'multifunctional robot' to take temperatures and deliver medicine and food to patients.	Yeung, 2020 BBC News, 2020
	Uganda	$1 rapid test kits by group of research scientists of Makerere University	Wetaya, 2020
Local Production of COVID Gear:	Ghana	Production of African- print face masks for people in need by Global Mamas	Knott,
	Kenya	Oxygen ventilators by engineering students at Kenyatta University Ultra-Red Technologies manufactures plastic face shields for local healthcare workers	Shiundu, 2020; Barana, 2020 CBC Radio, 2020
	Liberia	Locally Made Face Masks for combatting COVID-19	Harmon, 2020
	Rwanda	Production of facemasks for the public by Apparel Manufacturing Group	Bizimungu, 2020
	Tunisia	AI Lung X-ray scanning device by engineers of the National Institute of Applied Sciences and Technology (INSAT).	Medical Press News, 2020
E-commerce, cashless transactions	Côte D'Ivoire	Jumia online market Côte d'Ivoire experiences three times upsurge in orders for food and products from supermarkets	Jumia Group, 2020
	Ethiopia	Ethiopian airlines remotely provide services ranging from Ethiopian mobile app, E-mail, Social Media and Contact Center, Website, Chatbot.	Ethiopian Airlines, 2020
	Kenya	M-Pesa expanded mobile money service to 24.5 million out of Kenya's 53 million people by April 2020. Airtel has suspended charges on all transactions through its Airtel Money platform. Public Transports adopts mSafari app for payments of fares. Jumia collaborated with Twiga foods to provide cashless transaction and delivery of fresh produce	Bright, 2020a Bright, 2020a Bright, 2020b The Oxford Business Group, 2020
	Namibia	Tambula online market sells various fruits and vegetables from different suppliers.	UNDP, 2020

(*Continued*)

Table 2. (Continued).

Subject	Country	Innovation	Reference
	Nigeria	Konga e-commerce company offered free deliveries and discounts amounting to N10m ($25,700) for shopping made between March 24 and April 6.	The Oxford Business Group, 2020
	Rwanda	Additionally, Kxpress and KongaPay, give users a 'no contact' delivery options	Bright, 2020b
	Senegal	OPay launches new digital platforms	The Economist, 2020
		Mobile-money transactions had grown six-fold to 40bn Rwandan francs ($42m) after a week of the imposition of lockdown in Rwanda in March.	Jumia Group, 2020
		Rapidos adds an online sales platform	
	Somalia	F.A.O. mobile money platform has registered over 2.1 million people since mid- March.	F.A.O., 2020
	South Africa	UberEats, Net Florist, and Mr. D Food have created delivery apps to deliver medications and groceries	Malinga, 2020b
		Pick n Pay Online partners BOTTLES app to deliver groceries and liquor	Malinga, 2020b
	Tanzania	Tigo Pesa, a mobile money service, allows customers to handle their finances remotely and make cashless payments.	Raphael, 2020
	Uganda	Market Garden app which enables vendors to sell and deliver fruits and vegetables contactless	Harrisberg, 2020
Communication Information dissemination	Burkina Faso	Correction of misinformation on COVID-19 by creating awareness and enforcing preventive practices, especially in rural areas and outskirt towns via radio ('Allô Docteur').	MacDougall, 2020
	Guinea	Bulk messaging systems to disseminate COVID related messages in different languages.	African Renewal, 2020
	Rwanda	Drones deployed for policing and disseminating COVID messages and disinfection during the lockdown.	Mutesi, 2020
	South Africa	A WhatsApp bot communicates COVID information as well as provide answers to queries in different languages.	Chaturvedi, 2020; Solomon, 2020
Re-opening strategies. Local and national innovations	Ethiopia	A 'contactless electrical soap dispenser with a built-in sensor' and a mechanical pedal.	Chanie, 2020
		Hair barbers invent a 'barbering booth' that reduces personal contact with clients.	BBC News, 2020
	Ghana	Mechanic invented a barrel based solar automated handwashing device.	Adamu, 2020
	Kenya	Mwea Mpesa agent innovates a Money Sanitizer Machine.	Otieno, 2020
	Lesotho	Production and supply of home-made handwashing soap for hand-washing stations within the Elgeyo community.	Defender Coalition, 2020
	Liberia	Double hand-washing stations have been made available in public spaces across Motimposo, and other locations in the country.	Berting, 2020
	Rwanda	Portable washbasins at bus stops to ensure passengers wash their hands.	The Economic Times, 2020; Edwards, 2020
	Uganda	Motor-taxi drivers in Kampala, are using plastic shields, designed on motorcycles to avoid contact with passengers.	Athumani, 2020
	Zimbabwe	Tippy-tap hands-free and water efficient hand-washing device provided in rural areas.	Berting, 2020

(*Continued*)

Table 2. (Continued).

Subject	Country	Innovation	Reference
COVID-19 surveillance and monitoring	Ethiopia	The Ministry of Health utilizes an application analysis tool created by an Ethiopian IT engineer. The software tool is used mainly for contact tracing.	African Renewal, 2020
	Ghana	Runmila, designed real-time interactive maps for tracking COVID-19 cases across the African continent.	Akogo, 2020
	South Africa	Vulnerable Communities map by University of Pretoria's SDG hub	Chaturvedi, 2020
National learning platforms and tools	Angola	Transmission of tele-classes by public television of Angola.	UNESCO, 2020
	Botswana	Broadcasting of educational television classes	UNESCO, 2020
	Mauritius	Mauritius Broadcasting Corporation broadcasts educational lessons on four different channels for students from grades 1 to 9.	UNESCO, 2020
	South Sudan	Educational programs on Radio Miraya and SSBC.	UNESCO, 2020
Medicinal Remedies	Cameroon	Herbal cure known as "Essential oils' for the treatment of COVID-19	Kindzeka, 2020
	Madagascar	COVID- Organics	Al Jazeera News, 2020
Miscellaneous	Tunisia	Police robots ensures adherence to lockdown rules in the capital, Tunis.	Jawad, 2020
		COVID Free site by Taxibrousse studio and Associazione Le Reseau highlights innovative practices and actions developed by local communities during the epidemic in Africa.	COVID-free, 2020

complex molecular biology. Ghana and Rwanda both use pooled testing – grouping samples and testing individuals only if the pooled sample is positive. This approach offers two main advantages – substantial reduction of cost and major decrease of turnaround time for results (Global Health Now, 2020). Following this success, the US Food and Drug Administration (FDA) approved the use of pooled testing in the US beginning 18 July 2020, in order to address the recent surge in COVID cases. Interestingly, methods developed and tested in Africa are now being adopted in the developed world, an apparent reversal of roles.

Robots as front-liners

To reduce the risk of exposure to COVID infection among health workers and stretch the reach of the limited health workforce, several African countries are deploying robots in treatment centers to perform frontline duties. In Rwanda, robots provide mass temperature screening and monitor patient status in treatment centers (Uwiringiyimana, 2020). They can screen up to 150 people per minute for symptoms such as high temperature and dry cough, capture sound and visual data of patients, and notify health workers of any abnormalities. They also assist with self-diagnosis and educate health workers and patients about observing COVID-19 protocols (Uwiringiyimana, 2020). Similarly, in Tunisia, robots serve as supplementary patrol officers to ensure that people observe lockdown rules and wear face covering. These 'police robots' approach potential violators, check their identification papers, to facilitate appropriate sanctions of offenders (Jawad, 2020).

Artificial intelligence (A.I.) and X-ray devices

In Kenya, the health ministry adopted an X-ray device developed in 2018 that converts the sounds from the heart and lungs into images for diagnosis of respiratory diseases with the help of 'deep learning' (Paul, 2020). Similarly, the Tunisian health ministry uses an X-ray scanning device developed by a group of Tunisian engineers of the National Institute of Applied Sciences and Technology (INSAT). It operates as a web-based scanning device that can identify likely COVID-19 patients (Medical Press News, 2020). Finally, in Kenya, students at Kenyatta University are building 50 oxygen ventilators each week to help fight COVID-19 (Barana, 2020; Shiundu, 2020). These efforts are noteworthy not just because of the immediate benefit of meeting pressing needs for COVID but, more important, for their potential of reducing dependence on imported medical equipment and supplies in the future.

Interactive maps and telemedicine platforms

Many African countries are now using Geographic Information Systems (GIS) to monitor the spatial extent, patterns, and hotspots of COVID-19 spread to inform health care decisions (Africa Geoportal, 2020; Akogo, 2020). In South Africa, for example, the University of Pretoria's Vulnerable Communities Map uses publicly available data to identify and support communities that are most vulnerable based on the state of healthcare, mobility, and prevalence of poverty (Chaturvedi, 2020). Other African countries have also extended the use of telemedicine platforms to enhance contact tracing through data collection, diagnosis, and enable doctors to monitor and communicate with patients (Exarheas, 2020; Knott, 2020a). Such successful application could accelerate widespread deployment of GIS across Africa, especially for public health. For example, Boyda et al. (2019) report nascent but rapidly growing application of GIS and spatial analysis to HIV-related research in Africa. Similarly, the Polio Eradication Program in the World Health Organization (WHO) Regional Office for Africa put out a request for proposals for research grants to fund projects on the innovative use of GIS and other technologies for polio eradication and other public health uses. The announcement came at the end of a GIS summit hosted by WHO in Brazzaville, Congo with more than 150 participants, many of them from health ministries in the 47 WHO Member States.

Local manufacturing of PPEs and COVID fighting gear

Perhaps the most common COVID response is the local manufacturing of facemasks by clothing and textile workers and industries. To get around the prohibitive costs of facemasks recommended by WHO (N95, KN 9 surgical masks), the local fabric and dressmaking industry began the commercial production of simple and inexpensive facemasks for public use, using local FDA approved guidelines. In South Africa, the government initiated a project to create FFP2 and N-95 standard masks for all South Africans (Mazibuko, 2020). Thus, South Africa's U-Mask manufacturing company has provided N-95 facemasks for healthcare workers in South Africa and donated 30,000 facemasks to China (Maeko, 2020). In Ghana, Global Mamas, a local NGO which manufactures clothing and household goods, has shifted to the production of African-print face masks for people in need (Knott, 2020b). Across the continent, facemasks are now incorporated into local fashion and African print clothes are completed with a matching facemask. Companies like GTP in Ghana have mounted billboards with models wearing facemasks with the same fabric as their clothes, contributing to the appeal of facemasks. Indigenous companies have also begun the production of affordable FDA-approved face shields (Hayibor, 2020). Similarly, Rwanda's Apparel Manufacturing Group has channelled existing resources toward the production of facemasks for the public (Bizimungu, 2020).

By the end of March 2020, more than fifty locally manufactured hand sanitizers had been registered with the Ghana Food and Drugs Authority replacing the overpriced, imported brands making the precious commodity easily accessible to all. Similarly, local metalworkers have made hand washstands to help the handwashing campaign. In Ghana, one of the largest liquor manufacturing companies switched production to making hand sanitizer, while in Kenya, a factory retooled to make 30,000 surgical masks a day, in a country that scarcely produced any before the pandemic.

Contact-free handwashing stations

To address the problem of inadequate handwashing, the Rwandan government deployed portable washbasins at bus stops to ensure passengers wash their hands. Other African governments have flooded cities with portable sinks and hand sanitizers in public spaces such as churches, restaurants, banks, and shops (Edwards, 2020; The Economic Times, 2020). In Kenya, the Nairobi City Water and Sewerage Corporation has provided about 500 free handwashing stations to alleviate the spread of COVID-19 (The Standard, 2020).

In rural areas with limited access to electricity, very simple, yet useful, handwashing apparatuses such as gallons tied with a strip of rope, what is generally described as the 'footless handwashing station,' are being used (CitiTube, 2020<italic></italic>). Other innovations include conventional aluminum barrels, automated hand basins, and contactless electrical soap dispenser with a built-in sensor and a mechanical pedal that can be used during power cuts (Adamu, 2020; Chanie, 2020).

Medicinal remedies discovered

Amidst critical global shortages, disrupted supply chains, and export bans, African pharmaceutical and manufacturing companies are stepping up to fill the gap. For example, the Malagasy Institute of Applied Research (IMRA) and the National Pharmacology Research Center have developed an alternative herbal medicine known as COVID-Organics. This medicine was generated from artemisia and other local medicinal plants, such as ravintsara. With the enthusiastic support of President Andry Nirina Rajoelina, COVID-Organics is currently being proffered as a cure for COVID-19 in Madagascar and other African countries. Though not approved by WHO (Al Jazeera News, 2020), several African countries, including Tanzania, Liberia, Equatorial Guinea, and Guinea-Bissau, have either placed orders, or have received consignments of the remedy.

Nevertheless, while derivatives from artemisia have been used as treatment for malaria and respiratory tract infections, promoting unproven remedies could be deadly. An urgent need exists for further research on such herbal compounds to evaluate their efficacy.

Consequently, the recent action of the WHO is timely. In a joint effort to enhance research and development of traditional medicines for COVID-19 in Africa, the World Health Organization (WHO) and Africa CDC launched an expert advisory committee/panel to provide independent scientific advice and support to countries on the safety, efficacy, and quality of traditional medicine therapies. WHO recognizes that traditional, complementary, and alternative medicine has many benefits and Africa has a long history of traditional medicine and practitioners that play an important role in providing care. As the world races to find treatment and vaccines against the virus, this provides essential research into traditional and orthodox medicines as potential COVID-19 therapy.

We now turn our attention to innovations and transformations in response to COVID that promise to have lasting transformative impact on the continent. Specifically, the lockdowns are producing drastic changes in information technology, e-commerce, and even virtual tourism.

Information and communication transformations

Given the ubiquity of mobile phones in Africa, several governments are working with telecom and technology companies to deploy these technologies in the fight against COVID. For example, the South African government is using an interactive WhatsApp chatbot to answer common queries on COVID-19 and has reached over 3.5 million users in five different languages (Chaturvedi, 2020; Solomon, 2020). The Ministry of Health in Guinea is similarly utilizing bulk-messaging systems to disseminate COVID-related messages in different languages (African Renewal, 2020).

National E-learning platforms and tools

To deal with the closure of educational facilities, UNESCO is working with over 36 African countries to provide remote learning. Several mediums of communication – print, radio, and television – have been adopted to assist the education system of these African countries. For example, in Angola, the Public Television of Angola has been transmitting teleclasses. Likewise, Botswana launched educational television broadcasting classes through television channels to assist distance learning. Mauritius Broadcasting Corporation also broadcasts educational lessons on four different channels for students from grades 1 to 9. Even amidst local clashes in the Jonglei state of South Sudan in May, which claimed at least 300 lives, educational programs that cover English language, mathematics, and science subjects continue on Radio Miraya and SSBC Monday (UNESCO, 2020).

COVID forced African media organizations to change hurriedly to digital platforms – much more than at any other time in history – and they are producing more content online than ever before. As advertising and sales revenues plummet, news organizations are closing operations, laying off staff, and suspending their print operations. To thrive in the post-COVID world, they must find ways to generate revenue online (Bertam, 2020).

E-commerce and cashless transactions

The COVID-19 crisis is transforming fundamental aspects of African ways of doing business, service-delivery systems, and accelerating trends such as digitization, and e-commerce. In fact, COVID is producing a massive acceleration in digital payments and mobile banking (Baig et al., 2020). It is also accelerating an expansion of e-commerce toward new firms, customers, and types of products. Transactions have expanded to include everyday necessities relevant to many individuals such as medical supplies, groceries, and food. For example, in Kenya, Jumia collaborated with

Twiga foods to provide cashless transaction and delivery of fresh produce (The Oxford Business Group, 2020). South African companies such as UberEats, NetFlorist, and Mr. D Food have created delivery apps to deliver medications and groceries across South Africa (Malinga, 2020a). In Namibia, Tambula online market sells various fruits and vegetables from different suppliers.

Cashless transactions are also booming across Africa during the COVID pandemic. In Somalia, the F.A.O. mobile money platform has registered over 2.1 million people, making up more than 350,000 households (F.A.O., 2020), and securely conveyed 4 USD million to 200,000 people since the outbreak of COVID-19 in mid-March. In East Africa, M-Pesa was serving 24.5 million out of Kenya's 53 million people by April 2020 (Bright, 2020a). Similarly, in Tanzania, Tigo Pesa a mobile money service, allows customers to handle their finances remotely and make cashless payments (Raphael, 2020).

Some public transport operators in Kenya are using cashless payments for fares. Passengers can make cashless payments for their fares by entering their contact details on a free mobile app called mSafari (Bright, 2020a). Similarly, bus operators in the Ruvuma region in Tanzania use electronic ticket processing in order to minimize the spread of COVID-19. This has resulted in a significant reduction in congestion at bus stations (Raphael, 2020).

Lockdowns imposed by COVID have accelerated consumer behavior change with many exploring online shopping and e-commerce out of necessity. For example, Jumia, the e-commerce giant of Africa, has reported a spike in both customer and seller interest with booming demand for groceries and other essentials across Africa (Kazeem, 2020). COVID-induced lockdown restrictions left brick and mortar retail outlets closed and reduced vehicular traffic. This meant fast deliveries in cities known for notorious traffic jams – a positive experience for new customers and boon for customer retention. Consequently, the expectation is that the surge in e-commerce will outlast COVID, and lead to reduced foot traffic at normally crowded shopping malls and stores. More important, COVID has produced a massive acceleration in digital payments because for many businesses, accepting digital payments was the only option. Thus, the COVID-19 crisis could be a catalyst for accelerating digital transformation in sectors as diverse as financial services, retail, education, and government (Jayaram et al., 2020).

Virtual tourism

Prior to COVID, Africa was the fastest-growing tourism region. In 2018, some 67 million tourists visited the continent, bringing 38 USD billion in revenue. In 2019, the number of tourists increased by 4.2%, with an expected increase of 3–4% in 2020 (Frolich, 2020). Now, the tourism industry has collapsed across all the countries in Africa. National parks and hotels are empty, with no tourists. The World Travel and Tourism Council (WTTC) puts the number of jobs lost in Africa's tourism sector alone at almost 8 million. In response, several African tourism associations are pushing virtual tourism – supplying avid travelers with digital impressions of the continent's favorite tourist destinations. For example, from the comfort of their own homes, virtual tourists can now enjoy Safaris in Kenya, strolls through the Namib Desert in Namibia, paragliding in South Africa or standing on the edge of the Victoria Falls at the border between Zambia and Zimbabwe. Virtual tourism provides a new dimension that could generate new business.

COVID as a centripetal force

In response to COVID, the African Union Commission and the Africa CDC launched a new initiative, the Partnership to Accelerate COVID-19 Testing (PACT). PACT provides pooled procurement of diagnostics and other medical commodities for distribution across the continent. Bulk purchasing ensures secure supplies and competitive pricing and transparency in procurement, reduces logistical delays, and simplifies payment processes. The platform sells everything from test

kits to ventilators, oxygen, and PPE at fair prices. For instance, at the start of the pandemic, global demand drove up the price of an N95 mask to 30 USD but it only costs 2 USD on the platform (Wadvalla, 2020).

While COVID-19 has undermined international cooperation, with global competition for COVID-gear at precisely a time when global solidarity is most necessary, it has strengthened African unity and cooperation, and some of Africa's institutions – like the Africa CDC – are achieving a new degree of maturity and recognition (Jayaram et al., 2020). The centralized procurement of critical medical supplies has made a huge impact already. Despite their internal differences, African countries are pooling their efforts in a bid to fight COVID.

Discussion – COVID-19 as a catalyst for african innovation and transformation?

COVID-19 was expected to devastate Africa. Instead, it appears to have become the critical catalyst facilitating important transformative changes. From local manufacturing of COVID-fighting materials to accelerated e-commerce and cashless transactions, African countries appear to be undergoing significant transformative change that could not have happened otherwise. Changes that would have taken a long time are happening literally overnight or within weeks. Our examples show that African countries have united in the fight against disease by creating the common purchase front. In this sense, COVID has become a centripetal force and enhanced the leadership role of Africa CDC.

In commerce, cashless transactions are quickly replacing cash transactions facilitating inter-state commerce. As Africans, trapped in their homes, have resorted to mobile money and new payment forms, Uber delivery of groceries, food, and medicines is transforming the retail trade sector. Jumia and other e-commerce companies are positioned to take advantage of these important changes.

Perhaps most important is the potential for change in health care delivery. Since COVID meant the rich could not fly to seek care elsewhere, African leaders are realizing the importance of developing local health resources to manage health care challenges. This could translate into increased investments in health care. Additionally, successful local manufacturing of pharmaceuticals, PPEs, and other essentials for COVID should be a morale booster for fledgling industries. Health care research, including the development of testing kits or even genome sequencing, is off to a great beginning and, with support and the right policies, could make a huge impact under the leadership of Africa CDC. Similarly, the use of drones and robots in health care opens new doors for overcoming historical barriers of transportation in healthcare systems. In addition, new tools for communicating health information can pave the way for expanding health education on future pandemics and pressing health challenges such as obesity and noncommunicable diseases. It is time for health care apps that promote healthy living and communicate essential basic health information in multiple local languages. Given these changes, what should be the appropriate policy response?

Policy responses

Build enduring systems for outbreak prevention and response. Just as Ebola forced African countries to develop surveillance and contact tracing systems, COVID-19 calls for expanding and strengthening structures for local outbreak response. Led by Africa CDC, accelerated investment in robust primary healthcare and disease surveillance systems is essential. It will facilitate early detection of future outbreaks. COVID-19 has opened the door for strong regional cooperation to fight disease.

Expand local manufacturing of critical medical supplies. Amid global shortages, disrupted supply chains, and export bans, *A*frican pharmaceutical and manufacturing companies displayed their ability to produce critical supplies and drugs. Expanded support and regulation of these industries are necessary to prepare for future pandemics and avoid fake drugs.

Support and expand digital innovations in health service delivery. COVID has demonstrated clearly the huge potential for e-health and digital communication services. For example, several countries are using interactive WhatsApp chatbots to answer common queries on COVID-19 in local languages. New technologies, such as telemedicine, offer the ability to deliver healthcare without the confines of physical space, and circumvent the obstacles of cost, distance, and availability of experienced health personnel (Oppong, 2020b). It can help patients to manage chronic diseases through effective self-monitoring and provision of information to influence behavior. As Oppong (2020b) argued, remote consultations and regular self-health monitoring can replace routine medical consultations and improve the overall quality of care. However, this requires significant investment in infrastructure, including basic national address systems for electronic health data collection and routine use of such data, improved data security, and expanded internet access.

While acclaiming Africa's innovative response to COVID, caution is necessary. We cannot ignore prevailing endemic diseases; that will be disastrous. COVID has disrupted global health campaigns against diseases such as malaria, HIV, and TB. Diverting resources toward COVID runs the risk of a major resurgence of diseases that were previously being effectively managed. As happened with Ebola in West Africa and the DRC, where the death toll from other diseases exceeded Ebola itself, ignoring endemic diseases such as malaria could be more devastating (Hirschel-Burns, 2020; Mnyanda, 2020). We need to avoid repeating that mistake with COVID-19.

Conclusion

While exposing the known fragility of Africa's health care systems, COVID-19 has illuminated Africa's resilience, resourcefulness, and innovativeness. As we document in this paper, Africa largely appears to have avoided the worst and COVID is accelerating the much-needed transformation to better public health care systems and improved health research capacity. Carefully nurturing these nascent changes with appropriate policies is crucial to ensure that Africa is ready to face the next global pandemic.

Disclosure statement

No potential conflict of interest was reported by the authors.

Notes on contributors

Joseph R. Oppong is a Professor of Geography and Academic Associate Dean of The Robert Toulouse Graduate School at the University of North Texas, where he has been teaching and doing research since 1992. Dr. Oppong's research centers on the geography of disease and health services and seeks to answer the question: who is getting what disease where and why? Previous research topics include HIV/AIDS in Africa and Texas, Buruli Ulcer in Ghana, and Tuberculosis in Tarrant County. A native of Ghana, Dr. Oppong has a BA in Geography from the University of Ghana and Masters and PhD degrees from the University of Alberta, Edmonton, Canada. He has served as Chair of the Medical and Health Geography Specialty Group and also the Africa Specialty Group of the Association of American Geographers. His current research focuses on disease mapping and simulating geographic patterns of communicable disease spread. Dr. Oppong currently serves on the governing council of the American Association of Geographers.

Yvonne A. Dadson is a graduate student in Public Administration at the University of North Texas. She holds Master of Philosophy (MPhil) and Bachelor of Arts degrees in Economics from the University of Ghana and Kwame Nkrumah University of Science and Technology, respectively. Her research interest is governance and public policy. E-mail: YvonneDadson@my.unt.edu

Hilary Ansah is a graduate student in Geography at the University of North Texas. She has a BA in Economics and Geography from the University of Ghana. Her research interests include globalization, urban geography, political economy and social theory. Hilary's current research focuses on understanding how contemporary processes of globalization are transforming urban processes and the informal economy particularly, street hawking in Ghana. Email: Hilaryansah@my.unt.edu.

References

Adamu, Z. (2020, May 11). A solar-powered hand-washing basin encourages personal hygiene in Ghana amidst coronavirus. *CNN Africa*. Retrieved May 23, 2020, from https://www.cnn.com/2020/05/09/africa/ghana-coronavirus-handwash/index.html

Africa Geoportal. (2020). *COVID-19 response: Monitoring coronavirus in Africa*. ESRI. Retrieved May 26, 2020, from https://www.africageoportal.com/pages/COVID-19-response

African Renewal. (2020, April 29). Innovative tech and connectivity key to fighting COVID-19 in Africa. *United Nations African Renewal*. Retrieved May 22, 2020, from https://www.un.org/africarenewal/news/coronavirus/innovative-tech-and-connectivity-key-fighting-COVID-19-africa

Akogo, D. A. (2020, March 14). *AI4 COVID-19: Live data on COVID-19 In Africa*. Medium. Retrieved May 25, 2020, from https://medium.com/@darlingtonahialeakogo/ai4covid-19-african-statistics-minohealth-ai-labs-and-runmila-ai-institute-607f969b7a59

Al Jazeera News. (2020). *Coronavirus: What is Madagascar's 'herbal remedy' COVID-organics?* Al jazeera. Retrieved May 30, 2020, from https://www.aljazeera.com/news/2020/05/coronavirus-madagascar-herbal-remedy-COVID-organics-200505131055598.html

Albutt, K., Yorlets, R. R., Punchak, M., Kayima, P., Namanya, D. B., Anderson, G. A., & Shrime, M. G. (2018). You pray to your God: A qualitative analysis of challenges in the provision of safe, timely, and affordable surgical care in Uganda. *PloS One*, *13*(4), e0195986. https://doi.org/10.1371/journal.pone.%200195986

Athumani, H. (2020, June 29). Ugandan creates COVID shield for motorcycles. *Voice of Africa (VoA) News*. Retrieved August 4, 2020, from https://www.voanews.com/africa/ugandan-creates-COVID-shield-motorcycles

Ayandipo, O., Wone, I., Kenu, E., Fasehun, L.-K., Ayandipo, O., Gaye, F., Ojo, A., Ayoola, Y., Omogi, J., Lakew, D., & Thiam, S. (2020, March 25). Cancer ecosystem assessment in West Africa: Health systems gaps to prevent and control cancers in three countries: Ghana, Nigeria and Senegal. *Pan African Medical Journal*, *35*, 90. https://doi.org/10.11604/pamj.2020.35.90.18516

Baig, A., Hall, B., Jenkins, P., Lamarre, E., & McCarthy, B. (2020, May 14). *The COVID-19 recovery will be digital: A plan for the first 90 days*. Mckinsey Digital. https://www.mckinsey.com/business-functions/mckinsey-digital/our-insights/the-COVID-19-recovery-will-be-digital-a-plan-for-the-first-90-days#

Baker, A. (2020, April 7). Few doctors, fewer ventilators: African countries fear they defenseless against inevitable spread of coronavirus. *Time*. https://time.com/5816299/coronavirus-africa-ventilators-doctors/

Barana, S. (2020). KU students develop ventilator prototype in fight against Coronavirus. *Ugandatv*. Retrieved May 26, 2020, from https://www.youtube.com/watch?v=88a5vCgD25U

BBC News. (2020, August 16). Coronavirus: Ten African innovations to help tackle COVID-19. *BBC News-Africa*. Retrieved August 16, 2020, from https://www.bbc.com/news/world-africa-53776027

Bertam, M. (2020). *Digitization without monetization: African news media stuck between a rock and a hard place*. DW. Retrieved August 06, 2020, https://www.dw.com/en/digitization-without-monetization-african-news-media-stuck-between-a-rock-and-a-hard-place/a-54470345

Berting, N. (2020). *Innovative handwashing stations pop-up across Africa*. Whatdesigncando.com. Retrieved August 4, 2020, from https://www.whatdesigncando.com/stories/hand-washing-stations-africa/

Bhalla, N. (2020). *Coronavirus: Africa braces for impact 'like nothing we have seen*. Thomson Reuters Foundation. https://news.trust.org/item/20200406160051-t6vri/

Bizimungu, J. (2020). *Local companies turn to production of COVID-19 protective gear*. The New Times. Retrieved June 08, 2020, from https://www.newtimes.co.rw/COVID-19/local-companies-turn-production-COVID-19-protective-gear

Boseley, S. (2020, June 30). US secures world stock of key COVID-19 drug remdesivir. *The Guardian*. https://www.theguardian.com/us-news/2020/jun/30/us-buys-up-world-stock-of-key-COVID-19-drug

Boyda, D. C., Holzman, S. B., Berman, A., Kathyrn Grabowski, M., & Chang, L. W. (2019). Geographic information systems, spatial analysis, and HIV in Africa: A scoping review. *PloS one,14*(5), [e0216388]. https://doi.org/10.1371/JOURNAL.PONE.0216388

Bright, J. (2020a). *Africa turns to mobile payments as a tool to curb COVID-19*. TechCrunch. Retrieved May 20, 2020, from https://techcrunch.com/2020/03/25/african-turns-to-mobile-payments-as-a-tool-to-curb-COVID-19/

Bright, J. (2020b). Jumia adapts Pan-African e-commerce network in response to COVID-19. *MSN News*. Retrieved May 23, 2020, from https://www.msn.com/en-za/money/technology/jumia-adapts-pan-african-e-commerce%20network-in-response-to-COVID-19/ar-BB11yStP

CBC Radio(2020). This 3D printing company is solving Kenya's PPE shortage by producing face shields. *CBC Radio* (May 1, 2020). Retrieved May 23, 2020, from https://www.cbc.ca/radio/spark/montreal-ai-lab-develops-privacy-first-contact-tracing-app-to-track-covid-19-cases-1.5552857/this-3d-printing-company-is-solving-kenya-s-ppe-shortage-by-producing-face-shields-1.5552859

Chanie, T. (2020, May 5). Young inventor helps Ethiopia's COVID-19 crisis. *DW News*. Retrieved May 25, 2020, from https://www.dw.com/en/young-inventor-helps-ethiopias-COVID-19-crisis/a-53334966

Chaturvedi, A. (2020, April 21). How South Africa uses tech to fight COVID-19. *Geospatial World*. Retrieved May 23, 2020, from https://www.geospatialworld.net/blogs/how-south-africa-uses-tech-to-fight-COVID-19/

CitiTube. (2020). 9-year-old boy makes a handwashing device for Achiama residents. *Citi Newsroom*. Retrieved May 26, 2020, from https://www.youtube.com/watch?v=Jrj7upMigeE

CNN Business. (2020). *Melinda Gates: COVID-19 will be horrible in the developing world*. CNN. https://www.cnn.com/videos/business/2020/04/10/melinda-gates-coronavirus.cnn-business

COVID-free. (2020). *Actions collection*. COVID-free-toolkit.org. Retrieved August 3, 2020, from https://www.covidfree-toolkit.org/actions-collection/

De Leon, R. (2020, April 4). Zipline begins drone delivery of COVID-19 test samples in Ghana. *CNBC*. Retrieved May 20, 2020, from https://www.cnbc.com/2020/04/20/zipline-begins-drone-delivery-of-COVID-19-test-samples-in-ghana.html

Defender Coalition. (2020, April 9). *Women human rights defenders' efforts against COVID-19 bolstered*. Retrieved August 4, 2020, from https://defenderscoalition.org/women-human-rights-defenders-efforts-against-COVID-19-bolstered/

Edwards, N. (2020, March 24). Rwanda's successes and challenges in response to COVID-19. *Atlantic Council*. Retrieved May 25, 2020, from https://www.atlanticcouncil.org/blogs/africasource/rwandas-successes-and-challenges-in-response-to-COVID-19/

Ethiopian Airlines. (2020). *Ethiopian Airlines intensifies COVID-19 containment efforts, urges customers to use digital options*. Ethiopian Airlines Travel Updates. Retrieved May 20, 2020, from https://www.ethiopianairlines.com/et/travel-updates/use-digital-options

Exarheas, A. (2020, June 5). NNPC develops COVID-19 contact tracing app. *Rigzone News*. Retrieved June 8, 2020, from https://www.rigzone.com/news/nnpc_develops_COVID19_contact_tracing_app-05-jun-2020-162308-article/

F.A.O. (2020). Using innovation to deliver in Somalia despite COVID-19. *Food and Agriculture Organization of the United Nations News*. Retrieved June 12, 2020, from http://www.fao.org/news/story/en/item/1277798/icode/

Frolich, S. (2020). *Virtual Tourism in Africa takes off amid the coronavirus pandemic*. DW. Retrieved August 12, 2020, from https://www.dw.com/en/virtual-tourism-in-africa-takes-off-amid-the-coronavirus-pandemic/a-54229320

Global Health Now. (2020, May 13). *Did ghana get it right?* Global Health Now.Org. Retrieved May 14, 2020, from https://www.globalhealthnow.org/2020-05/did-ghana-get-it-right

Hamann, R. (2020, July 3). *Civil society groups that mobilised around COVID-19 face important choices*. The Conversation. Retrieved January 27, 2021, from https://theconversation.com/civil-society-groups-that-mobilised-around-covid-19-face-important-choices-140989

Harmon, Q. W. (2020). Liberians combatting COVID-19 locally made face masks. *Daily Observer*. Retrieved May 30, 2020, from https://www.liberianobserver.com/news/liberians-combating-COVID-19-with-locally-made-face-masks/

Harrisberg, K. (2020). *From chatbots to online markets, Africans craft weapons against coronavirus*. Thomson Reuters Foundation. Retrieved May 20, 2020, from https://www.reuters.com/article/health-coronavirus-africa-tech-idUSL8N2BN2GA

Hayibor, M. (2020, August 10). Maybe we need more pandemics. My *Joy Online*. https://www.myjoyonline.com/opinion/maybe-we-need-more-pandemics/

Hirsch, A. (2020, May 21). Why are Africa's coronavirus successes being overlooked? *The Guardian*. Retrieved May 23, 2020, from https://www.theguardian.com/commentisfree/2020/may/21/africa-coronavirus-successes-innovation-europe-us

Hirschel-Burns, T. 2020. Malaria May still be 2020's biggest killer. *Foreign Policy*. Retrieved June 12, 2020, from https://foreignpolicy.com/2020/06/12/coronavirus-malaria-pandemic-deaths-treatment-prevention/

Houreld, K., Lewis, D., McNeill, R., & Granados, S. (May 7, 2020). *Virus exposes gaping holes in Africa's health systems*. Reuters. https://graphics.reuters.com/HEALTH-CORONAVIRUS/AFRICA/yzdpxoqbdvx/

Jawad, R. (2020, April 3). Coronavirus: Tunisia deploys police robot on lockdown patrol. *BBC News Africa*. Retrieved May 20, 2020, from https://www.bbc.com/news/world-africa-52148639

Jawad, R., & Smith- Walters, M. (2020). Coronavirus: The students that are printing PPE masks in Tunisia. *BBC News Africa*. Retrieved June 2, 2020, from https://www.bbc.com/news/av/world-africa-52236678/coronavirus-the-students-that-are-printing-ppe-masks-in-tunisia

Jayaram, A. L., Ooko-Ombaka, A., & Ying, S. S. (2020). *Finding Africa's path: Shaping bold solutions to save lives and livelihoods in the COVID-19 crisis*. Mckinsey & Company. Retrieved August 20, 2020, from https://www.mckinsey.com/featured-insights/middle-east-and-africa/finding-africas-path-shaping-bold-solutions-to-save-lives-and-livelihoods-in-the-COVID-19-crisis

Jumia Group. (2020, May 26). *Le Monde: In Africa, the coronavirus does the business of home delivery platforms*. JUMIA. Retrieved May 26, 2020, from https://group.jumia.com/le-monde-in-africa-the-coronavirus-does-the-business-of-home-delivery-platforms/

Kazeem, Y. (2020). *Jumia is selling more groceries and digital services—but revenue fell in the first quarter*. Quartz Africa. Retrieved May 13, 2020, from https://qz.com/africa/1856896/africas-jumia-e-commerce-up-in-tunisia-morocco-with-COVID-19/

Kindzeka, E. M. (2020). Hundreds rush for popular cleric's herbal COVID 'Cure' in Cameroon. *VOA*. Retrieved June 12, 2020, from https://www.voanews.com/COVID-19-pandemic/hundreds-rush-popular-clerics-herbal-COVID-cure-cameroon

Knott, S. (2020a), COVID-19 drives health care tech innovation in Ghana. *Voice of Africa News*. Retrieved May 25, 2020, from https://www.voanews.com/COVID-19-pandemic/COVID-19-drives-health-care-tech-innovation-ghana

Knott, S. (2020b). *Global Effort under way to create African-print face masks for Ghana*. Retrieved June 16, 2020, from https://www.voanews.com/science-health/coronavirus-outbreak/global-effort-under-way-create-african-print-face-masks-ghana

Kushitor, M. K., & Boatemaa, S. (2018). The double burden of disease and the challenge of health access: Evidence from access, bottlenecks, cost and equity facility survey in Ghana. *PloS One*, *13*(3), e0194677. https://doi.org/10.1371/journal.pone.0194677

MacDougall, C. (2020, July 20). To help his country fights misinformation, a doctor fights misinformation. *The Christian Science Monitor*. Retrieved August 4, 2020, from https://www.csmonitor.com/World/Africa/2020/0720/To-help-his-country-fight-COVID-19-a-doctor-fights-misinformation

Maeko, T. (2020). Face masks from SA to the world. *Mail & Guardian*. Retrieved June16, 2020, from https://mg.co.za/article/2020-03-12-face-masks-from-sa-to-the-world/

Malinga, S. (2020a). *Digital wallet use soars in SA amid COVID-19*. ITWeb. Retrieved June 02, 2020, from https://www.itweb.co.za/content/lwrKx73KwZx7mg1o

Malinga, S. (2020b). *Mr. D Food, UberEats, NetFlorist shift focus for COVID-19*. ITWeb. Retrieved May 30, 2020, from https://www.itweb.co.za/content/dgp45va6ZKd7X9l8

Mastercard Foundation. 2020. *Diagnostic startup, KNUST develop rapid COVID-19 test*. Mastercard Foundation. Retrieved May 29, 2020, from https://mastercardfdn.org/diagnostic-start-up-knust-develop-rapid-COVID-19-test/

Mazibuko, T. (2020). SA designer Inga Gubeka develops reusable fashion masks. *MSN News*. Retrieved May 20, 2020, from https://www.msn.com/en-za/lifestyle/lifestylebeautyandstyle/sa-designer-inga-gubeka-develops-reusable-fashion-masks/ar-BB12g7O3

Medical Press News. (2020, April 17).COVID-19: Tunisia researchers use AI, X-rays to create online virus scan tool. Retrieved May 22, 2020, from https://medicalxpress.com/news/2020-04-tunisia-ai-x-rays-online-virus.html

Meisenzahl, M. (2020, June 27). These drones drop PPE and COVID-19 test samples to medical facilities using tiny parachutes — Here's how it works. *Business Insider*. Retrieved July 3, 2020, from https://www.businessinsider.com/zipline-drones-deliver-masks-for-coronavirus-doctors-2020-6

Mnyanda, L. (2020, April 23). Coronavirus fight risks setting malaria progress back two decades, WHO says. *Business Day* Retrieved August 15, 2020, from https://www.businesslive.co.za/bd/national/health/2020-04-23-coronavirus-fight-risks-setting-malaria-progress-back-two-decades-who-says/

Mutesi, G. 2020. Rwanda police uses drones to enforce lockdown and raise awareness about COVID□19. *Rwanda tv*. Retrieved May 26, 2020, from https://www.youtube.com/watch?v=qPCkKUTwSqE

Oppong, J. R. (2020a). The African COVID-19 anomaly. *African Geographical Review*, *39*(3), 282–288. https://doi.org/10.1080/19376812.2020.1794918

Oppong, J. R. (2020b). Disruptive technologies and the African health-care crisis: A path to sustainability. In P. Arthur, K. Hanson, & K. Puplampu (Eds.), *Disruptive technologies, innovation and development in Africa*. International Political Economy Series (pp. 117-145), Palgrave Macmillan.

Otieno, M. (2020). *M-Pesa agent innovates automatic money sanitizer*. Retrieved August 16, 2020, from https://www.kenyans.co.ke/news/53220-m-pesa-agent-innovates-automatic-money-sanitiser-video

Paul, E. (2020). 6 amazing African innovations against Covid-19: A cure from physics? *Techpoint Africa*. Retrieved May 20, 2020, from https://techpoint.africa/2020/04/23/african-innovations-covid-19/

Prin, M., Itaye, T., Clark, S., Fernando, R. J., Namboya, F., Pollach, G., Mkandawire, N., & Sobol, J. (2016). Critical care in a tertiary hospital in Malawi. *World Journal of Surgery*, *40*(11), 2635–2642. https://link.springer.com/article/10.1007/s00268-016-3578-y

Raphael, P. (2020). COVID-19: Why Tanzanians must adapt to the new circumstances. *The Citizen*. Retrieved June 12, 2020, from https://www.thecitizen.co.tz/oped/COVID-19–Why-Tanzanians

Shiundu, L. (2020, April 11). *Kenyatta University students develop ventilators in fight against COVID-19*. Tuko. Retrieved May 20, 2020, from https://www.msn.com/en-xl/news/other/kenyatta-university-students-develop-ventilators-in-fight-against-COVID-19/ar-BB12u5B7

Society of Critical Care Medicine. (2020, March 20). *United States resource availability for COVID-19*. Sccm.org. https://sccm.org/Blog/March-2020/United-States-Resource-Availability-for-COVID-19. This figure includes both full-feature and older models

Solomon, S. (2020, April 4). *South African-created mobile alert puts COVID info into hands of millions*. VOA News. Retrieved June 4, 2020, from https://www.voanews.com/africa/south-african-created-mobile-alert-puts-COVID-info-hands-millions

Stephens, J. H., Alizadeh, F., Bamwime, J. B., Baganizi, M., Chaw, G. F., Yao Cohen, M., Patel, A., Schaefle, K. J., Mangat, J. S., Mukiza, J., & Paccione, G. A. (2020, June 5). Managing hypertension in rural Uganda: Realities and strategies 10 years of experience at a district hospital chronic disease clinic. *PLos One*, *15*(6), e0234049. https://doi.org/10.1371/journal.pone.0234049

The Economic Times. (2020, March 18). *Rwanda installs portable washbasins at bus stops to contain COVID-19*. The Economic Times. Retrieved May 28, 2020, from https://economictimes.indiatimes.com/news/international/world-news/rwanda-installs-portable-washbasins-at-bus-stops-to-contain-COVID-19/portable-washbasins-at-bus-stops/slideshow/74689146.cms

The Economist. (2020, May 28). The COVID-19 crisis is boosting mobile money. *The Economist; Middle & East Africa*. Retrieved June 12, 2020, from https://www.economist.com/middle-east-and-africa/2020/05/28/the-COVID-19-crisis-is-boosting-mobile-money

The Oxford Business Group. (2020). *How can digital solutions aid Nigeria's COVID-19 fight?* Oxford Business Group. Retrieved May 30, 2020, from https://oxfordbusinessgroup.com/news/how-can-digital-solutions-aid-nigeria-s-COVID-19-fight

The Standard. (2020, March 31). *500 hand washing points in Nairobi to curb coronavirus spread*. The Standard. Retrieved May 22, 2020, from https://www.standardmedia.co.ke/article/2001365100/500-hand-washing-points-in-nairobi-to-curb-coronavirus-spread

UNDP. (2020). *Connecting informal vendors to a digital platform*. UNDP. Retrieved May 26, 2020, from https://www.na.undp.org/content/namibia/en/home/presscenter/articles/2020/connecting-informal-vendors-to-a-digital-platform.html

UNESCO. (2020). *National learning platforms and tools*. UNESCO. Retrieved June 2, 2020, from https://en.unesco.org/COVID19/educationresponse/nationalresponses

United Nations Economic Commission for Africa (UNECA). (2020). *COVID-19 in Africa: Protecting lives and economies*. UNECA. https://www.uneca.org/sites/default/files/PublicationFiles/eca_covid_report_en_24apr_web1.pdf

Uroko, C. (2020, May 8). Flying Doctors launches COVID Mobile to ramp up testing, protect health workers. *BusinessDay, Nigeria* Retrieved May 22, 2020, from https://businessday.ng/health/article/flying-doctors-launches-COVID-mobile-to-ramp-up-testing-protect-health-workers/

Uwiringiyimana, C. (2020, May 30). *Rwandan medical workers deploy robots to minimize coronavirus risk*. Thomson Reuters Foundation. Retrieved June 4, 2020, from https://www.reuters.com/article/us-health-coronavirus-rwanda-robots/rwandan-medical-workers-deploy-robots-to-minimize-coronavirus-risk-idUSKBN2360EW

Wadvalla, B. (2020). How Africa has tackled COVID-19. *The BMJ*, *370*, m2830. https://www.bmj.com/content/370/bmj.m2830

Wetaya, R. (2020, April 13). *Ugandan scientists develop quick, low-cost COVID-19 test kits*. Cornell Alliance for Scientist. Retrieved May 22, 2020, from https://allianceforscience.cornell.edu/blog/2020/04/ugandan-scientists-develop-quick-low-cost-COVID-19-test-kits/

WHO Africa Region. (2020). *COVID-19 spurs health innovation in Africa*. WHO. Retrieved October 31, 2020, from https://www.afro.who.int/news/covid-19-spurs-health-innovation-africa

WHO Africa Region Situation Report. (2020). *Coronavirus disease (COVID-19) weekly epidemiological update and weekly operational update*. https://www.who.int/emergencies/diseases/novel-coronavirus-2019/situation-reports

Yeung, P. (2020, May 13). Cheap and easy $1 coronavirus test to undergo trials in Senegal. *New Scientist*. Retrieved May 20, 2020, from https://www.newscientist.com/article/mg24632823-700-cheap-and-easy-1-coronavirus-test-to-undergo-trials-in-senegal/#ixzz6QFcSsZ9R