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COVID-19 crisis and engineering in sub-Saharan Africa

Rapid Research Response for the Royal Academy of Engineering, UK

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The photographs featured in this report were taken by Kit Oates.

Contents

List of acronyms

Acronym	Definition
4G	Fourth generation of broadband cellular network technology
5G	Fifth generation technology standard for broadband cellular networks
AC	Air conditioning
ACEK	Association of Consulting Engineers of Kenya
ACEZ	Association of Consulting Engineers of Zambia
AI	Artificial intelligence
AIDS	Acquired immune deficiency syndrome
APWEN	Association of Professional Women Engineers of Nigeria
ARI	Afrikan Research Initiative
ATM	Automated teller machine
AUI	University Agency for Innovation
B4SA	Business 4 South Africa
BBC	British Broadcasting Corporation
BIE	Botswana Institution of Engineers
BIUST	Botswana International University of Science and Technology
BWICO	Botswana Women in Construction Organisation
CARE (Project)	Project COVID-19 Rapid Africa Entrepreneurs
CC19RRTT	Construction COVID-19 Rapid Response Task Team
CDC	Centres for Disease Control
CEO	Chief executive officer
CESA	Consulting Engineers South Africa
CGTN	China Global Television Network
CNN	Cable News Network
COREN	Council for the Regulation of Engineering
CPAP	Continuous positive airway pressure
CSIR	Council for Scientific and Industrial Research
DeKUT	Dedan Kimathi University of Technology
DPR	Department of Petroleum Resources
DTIC	Department of Trade and Industry and Competition
ECG	Electrocardiogram
ECOWAS	Economic Community of West African States
ECZ	Engineering Council of Zimbabwe
EIZ	The Engineering Institution of Zambia
EMG	Electromyography
EPS	Expanded Polystyrene system

Acronym	Definition
ERB	Engineers Registration Board
ETIC	Engineering and Technology Innovation Centre
EVS	Electric Vehicle
EWB	Engineers Without Borders
FAEO	Federation of African Engineering Organisations
FDI	Foreign Direct Investment
FET	Faculty of Engineering and Technology
FNSE	Fonds National de Solidarité pour l'Eau
FY	Financial year
GARID	Greater Accra Resilient and Integrated Development project
GB	Gigabyte
GCPS	Ghana COVID-19 Private Sector Fund
GDP	Gross Domestic Product
GhIE	Ghana Institution of Engineers
GHS	Ghana Health Service
GMC	Gray Matters Capital
GPS	Global Positioning System
HIV	Human immunodeficiency virus
ICT	Information and Communications Technology
ICU	Intensive Care Unit
IPRC	Integrated Polytechnic Regional College Kigali
IEEE	Institute of Electrical and Electronics Engineers
IEK	Institution of Engineers of Kenya
IETG	Institute of Engineering and Technology Ghana
IHR	International Health Regulation
IMF	International Monetary Fund
IRADDAC	Initiative de Recherches et d'Analyses pour le Développement Durable en Afrique Centrale
IT	Information Technologies
JKUAT	Jomo Kenyatta University of Agriculture and Technology
KES	Kenyan shilling
KPMG	Klynveld Peat Marwick Goerdeler
LAASE	Lesotho Association for the Advancement of science and Engineering
LAE	Lesotho Association of Engineers
LECSA	Lesotho Evangelical Church in Southern Africa
LesYAS	Lesotho Young Academy of Science

Acronym	Definition
LSL	Lesotho Loti
MNSE	Member of the Nigerian Society of Engineers
NAE	Nigeria Academy of Engineering
NEC	National Engineering Centre
NECC	National Emergency Command Centre
NERC	National Emergency Response Committee
NGN	Nigerian Naira
NGO	Non-Governmental Organisation
NIMechE	Nigerian Institution of Mechanical Engineers
NSE	Nigerian Society of Engineers
NSE-VI	Nigerian Society of Engineers Victoria Island Branch
NVP	National Ventilator Project
OCHA	Office for the Coordination of Humanitarian Affairs
OHA	Opine Health Assistant
PEI	Professional Engineering Institution
PETG	Polyethylene Terephthalate Glycol
PPE	Personal Protective Equipment
RIL	Response Innovation Lab
SAAE	South African Academy of Engineering
SADC	Southern African Development Community
SAEE	South African Energy Efficiency
SAHPRA	South African Health Products Regulatory Authority
SAIAE	South African Institute of Agricultural Engineers
SARAO	South African Radio Astronomy Observatory
SAVE-P	South African Ventilator Emergency Project
SAWIC	South African Women in Construction
SEKU	South Eastern Kenya University
SLIE	Sierra Leone Institute of Engineers
SMaRT	SImulation Machine Learning, Robotics and Technopreneurship
SME	Small and Medium Enterprises
SMS	Short Message Service
SNV	Stichting Nederlandse Vrijwilligers
STEM	Science, Technology, Engineering, and Mathematics
UACE	Uganda Association of Consulting Engineers
UCT	University of Cape Town
UIPE	Uganda Institution of Professional Engineers
UIRI	Uganda Industrial Research Institute

Acronym	Definition
UK	United Kingdom
UN	United Nations
UNABCEC	Uganda National Association of Building and Civil Engineering Contractors
UNAIDS	United Nations Programme on HIV/AIDS
UNDP	United Nations Development Programme
UNDS	United Nations Development System
UNECA	United Nations Economic Commission for Africa
UNICEF	United Nations Children's Fund
US	United States
USA	United States of America
USADF	United States African Development Foundation
USB	University of Stellenbosch Business School
USSD	Unstructured Supplementary Service Data
UV	Ultraviolet
VA	Voluntary Association
WAEC	West African Examination Council
WASH	Water, sanitation, and hygiene
WEB	Women Engineers Botswana
WETT	Women Engineers, Technologists and Technicians
WHO	World Health Organization
WinE	Women in Engineering
WPS	Wi-Fi Protected Setup
XAF	Central African CFA Franc
ZAR	South African Rand
ZBE	Zimbabwe built environment professionals
ZIE	Zimbabwe Institution of Engineers
ZWES	Zambia Women in Engineering Section

Executive summary

The COVID-19 outbreak is widely understood as a health and economic crisis, but it is also fundamentally **an engineering challenge.** This research strived to:

- Identify the main impacts of the COVID-19 crisis on engineering in SSA.
- Evidence the contribution of engineering to tackling the crisis.
- Provide a forward-looking view on how the crisis will impact SSA engineering in the coming years.
- Develop recommendations on how to seize opportunities offered by the crisis.

We have identified **6 main ways** in which engineers have contributed to tackling the COVID-19 crisis in SSA:

1. Local design and manufacture of medical, protective and sanitary equipment.
2. Rapid building of treatment, isolation and testing facilities.
3. Collecting data, analysing and modelling the epidemic response.
4. Funding, fundraising and direct support to vulnerable members.
5. Moving education and training online.
6. Robotics innovations.

Impact of the COVID-19 crisis on engineering in sub-Saharan Africa (Section I)

The COVID-19 crisis has exposed **existing vulnerabilities in health**, connectivity and communications infrastructure in sub-Saharan Africa (SSA). The crisis has highlighted the over-reliance of SSA countries on foreign manufacturing. More critically, the crisis has disrupted foreign direct investment (FDI) to Africa, which will have adverse effects on investment in essential engineering infrastructure in the coming years and has negative impacts on engineering education and research, including reduced opportunities to carry out laboratory work.

The pandemic has had a **variable impact across engineering sectors**. The traditional fields of engineering, including civil, mechanical, chemical, electrical and transport disciplines, have experienced a negative impact, as these disciplines rely on work by on-site teams. Conversely, information and communications technologies (ICT); computer engineering; robotics; artificial intelligence (AI); and geospatial, medical, and biomedical engineering have thrived because they have directly supported efforts tackling the crisis, and will continue to be crucial in the 'new normal'.

The crisis has had a **distinct impact on different demographic groups**. Women engineers have been disproportionately affected, with studies or research activities being interrupted more frequently. They have also taken a bigger share of the additional household caring responsibilities induced by the crisis. Young engineers have also been more negatively affected, as their education and employment prospects have been disrupted. Overall, the pivot to online courses for engineering education is exacerbating existing inequalities between students.

Engineering's contribution to tackling the crisis in sub-Saharan Africa (Section II)

A range of actors have been involved in responding to the COVID-19 crisis. **Donors and development partners** have played an enabling role by providing funding and capacity-building. **Academia**, and in particular engineering university incubators, have played a crucial part in deploying innovative solutions to tackling the challenges presented by the crisis.

The **private sector** has quickly mobilised to manufacture essential equipment at scale. Professional engineering institutions (PEIs) have also contributed to recovery efforts in a variety of ways: these include distributing essential PPE, fundraising, and contributing their expertise to policymaking. Despite the additional burden placed on women by the COVID-19 crisis, **women engineers** have led noteworthy recovery efforts including PPE and food distribution; capacity-building activities; and policy engagement.

Engineers have contributed to tackling the COVID-19 crisis in sub-Saharan Africa in 6 main ways:

1. **Locally designing and manufacturing medical, protective and sanitary equipment:** As they could no longer import medical equipment from abroad, countries such as Kenya, Nigeria, Rwanda, Senegal and Zimbabwe have designed and manufactured their own medical material for the first time. Engineers have also stepped up to produce sanitary products locally, such as sanitiser and soap, innovating in the process.

2. **Rapidly building treatment, isolation and testing facilities:** Engineers have swiftly mobilised to build health facilities and install hand wash stations across SSA countries.

3. **Collecting data, analysing and modelling the epidemic response:** SSA engineers have helped to develop software tools to facilitate live tracking and visualisation of the spread of the virus, and develop applications to support contact tracing.

4. **Funding, fundraising and direct support to vulnerable members:** PEIs in Ghana, Kenya, Nigeria and Zimbabwe have coordinated fundraising efforts to support the response to the crisis. The Nigerian Society of Engineers (NSE) even established a cash transfer scheme targeting its most vulnerable members.

5. **Moving education and training online:** Engineers and PEIs have been supporting efforts to transfer education and training online during the crisis. Efforts have included creating a virtual school in Nigeria and organising a virtual entrepreneurship competition in Ghana to tackle the urgent need for more educational technologies.

6. **Developing robotics innovations:** SSA engineers have successfully utilised the potential offered by robotics to support efforts to tackle the crisis in Rwanda and Senegal. There, prototypes take on certain medical staff responsibilities in treatment facilities to minimise human contact.

While there is evidence that the crisis has prompted some interest for greater supranational exchange, our research found little evidence of cross-country collaboration. Two cross-country initiatives are worth mentioning, however: the **Strengthening Engineering Ecosystems in sub-Saharan Africa project**, funded by the International Development Research Centre in Canada, and the COVID-19 Rapid Africa Entrepreneurs (CARE) project, funded by the Royal Academy of Engineering for the United Kingdom (UK).

One positive impact of the crisis is that it has strengthened or prompted **new collaboration at the national level**: PEIs and the private industry have joined forces to build health facilities or manufacture PPE at scale. In countries such as South Africa, 32 PEIs have joined forces for the first time to advise the government on how to get the industry back to work safely.

Post-crisis outlook for engineering in sub-Saharan Africa (Section III)

Our research found that the COVID-19 crisis is likely to **accelerate the digital transformation** of SSA, and the **investment in emerging technologies** such as telecommunications, AI , robotics, 4D printing, bio-medical engineering and geographical information systems. These engineering disciplines have played a pivotal role in tackling the crisis and will remain critical in meeting the needs of the post-COVID-19 world. Technology and system design will also shift towards greater automation, distance control, and contactless features to meet the demand for more hygienic infrastructure.

For many SSA countries, the pandemic was a wake-up call in terms of the need to **support local production** and to secure capital within the health industry. Countries are operating a shift towards supporting local production and facilitating local manufacturing's access to capital. Engineers will be an integral part of that effort.

While there is a risk that SSA countries lose sight of sustainability considerations in the short term as they focus on immediate needs, interviewed stakeholders think that in the medium term there will likely be a greater focus on **green infrastructure**. In particular, the crisis is likely to prompt countries to strengthen the resilience of their water infrastructure and optimise the use of water resources for environmental purposes. Indeed, as in the rest of the world, the crisis has made SSA stakeholders realise that, where there is an opportunity to strengthen local infrastructures, there is also an opportunity to improve their environmental performance.

Key lessons from the COVID-19 crisis include the need for engineers to be more adaptable and deliver solutions quickly. Engineers also need to maintain tighter links with policymakers so they can contribute to anticipating similar crises and designing responses hand-in-hand with governments. Finally, the crisis has highlighted the urgent importance of investing in research and development in Africa to spur innovation

An important priority will be to develop **new engineering skills**. There will be higher demand for technical skills that help support the digitalisation of SSA countries. The crisis has also highlighted the need for the training of engineers to be more flexible, entrepreneurial, and creative. Future engineers will be expected to work across sectors. The crisis is driving a major shift in the way engineering education is delivered. Remote learning and teaching will become much more common, and this means that the engineering education paradigm will need to evolve accordingly.

Opportunities and recommendations (Section IV)

Our research has identified a number of opportunities that the SSA engineering profession could build on in the years to come:

- Realising the transition towards self-reliance in manufacturing.
- Building local engineering capacity.
- Increasing the visibility and standing of the engineering profession.
- Matching skills to changing future priorities.
- Expanding cross-sectoral collaboration.
- Building more socially responsive and resilient infrastructure.
- Sharing best practices.
- Utilising the greater ease of doing business.

We identified several ways in which PEIs have stepped up and worked with the government and other partners to meet the crisis, through fundraising, distributing PPE, and coordinating efforts to build essential facilities. Our research also found common ways in which PEIs can develop: SSA PEIs have a stake in helping their countries to transition into the 'new normal', whatever that might look like. They can do so by bringing the engineering profession together, facilitating reflection, and advocating for what is needed for the future of their countries. As a result of the crisis there is also an opportunity for PEIs to become more agile, play a more central role in recovery efforts, and exert greater thought leadership.

Introduction

The COVID-19 outbreak is primarily depicted as a health and economic crisis, but it is fundamentally also a **crisis of an engineering nature**. While research has been carried out on the impact of the pandemic on engineering globally or in the West, little to no research has been conducted about its impact on the engineering profession in SSA. This research strives to fill this gap.

How is this research helping?

The aim of this research was twofold:

- to collect evidence on the **contribution of engineering to tackling the COVID-19 crisis** in SSA by mapping the different interventions that have taken place and their outcomes.
- to provide a **forward-looking view** on how the crisis is likely to impact engineering in SSA in the years to come and to develop recommendations for the engineering profession on how to make best use of the opportunities offered by the crisis.

Ultimately, this research seeks to inspire and facilitate learning among engineering actors across SSA, to support the impact of their crisis recovery efforts, and enhance their profile among governments and their constituents.

Research questions

This research addressed the following questions, structured around its two aims:

Engineering response to the crisis in SSA

- What sort of impact has the COVID-19 crisis had on the engineering profession in SSA?
- How has the engineering community contributed to tackling the COVID-19 crisis in SSA?
- What have been the most effective interventions in responding to the crisis?
- Has the crisis highlighted or reinforced any strengths in terms of the capability of the SSA engineering community, and in particular PEIs, to react to a global crisis?
- Conversely, has the crisis highlighted or exacerbated any needs or gaps in the capability of the SSA engineering community to react to a global crisis?
- How well has the engineering community collaborated with other key stakeholders in the management of the crisis?
- What role have women's engineering groups played in the response to the COVID-19 crisis?

Post-crisis role and outlook for the SSA engineering community

- What impact is the crisis likely to have on engineering priorities in SSA?
- What lessons can be learned from the crisis in terms of how to deliver infrastructure in SSA?
- How can PEIs and the engineering community best adapt to, and meet, the post-COVID- 19 needs of society?
- In what ways can the engineering community best contribute to building resilience to future global crises?
- What opportunities might arise after the crisis, and how can the SSA engineering community respond?
- What engineering skills need to be developed further as a result of this crisis?

Methodology

In discussion with the Royal Academy of Engineering, we selected 10 countries to be covered in detail by our research, based on early evidence of effective engineering interventions, namely: **Botswana, Cameroon, Ghana, Kenya, Lesotho, Nigeria, South Africa, Uganda, Zambia and Zimbabwe**. In half of these countries, we were privileged to be able to draw on the networks we have built over time[1], as part of our work with the Academy on the GCRF **Africa Catalyst programme**. In the other countries, the team is indebted to the people who voluntarily (and enthusiastically) agreed to contribute to the research. We also closely collaborated with the **Federation of African Engineering Organisations (FAEO)** through a Memorandum of Understanding.

Our methodological tools included:

- In-depth desk review and 20 interviews with engineering stakeholders in each of the 10 countries covered by this research. The number of interviews and breadth of the desk review carried out per country were adapted to the level of sophistication of the engineering response to the crisis.
- Wider desk review and 6 interviews with high-level stakeholders able to provide a cross-country perspective, namely the Royal Academy of Engineering; FAEO; WomEng; the Science, Technology and Innovation Policy Research Organization; the African Center for Economic Transformation; and the African Centre for Technology Studies.

We structured the findings of the qualitative data collected through interviews and desk review in 10 dedicated **country case studies**, which can be found in the annex to this report. We then carried out a **thematic analysis** of the data we collected, which forms the basis for this report. Drawing on these findings, we have drawn up **recommendations** on how the engineering profession can best adapt and make the most of the opportunities offered by the post COVID-19 world.

Outputs

The outputs of this research are as follows:

- This report provides a snapshot of the contribution of engineering to tackling the COVID- 19 crisis in SSA and how the crisis will shape engineering for the years to come. This includes case studies covering the 10 target countries, and recommendations for the SSA engineering profession going forward.
- The research team also presented the findings of this research during a Learning Webinar jointly organised by FAEO, the Academy and Ecorys UK on 29 October 2020[2]. Attendees from across SSA had an opportunity to feed into the findings and recommendations in this report.

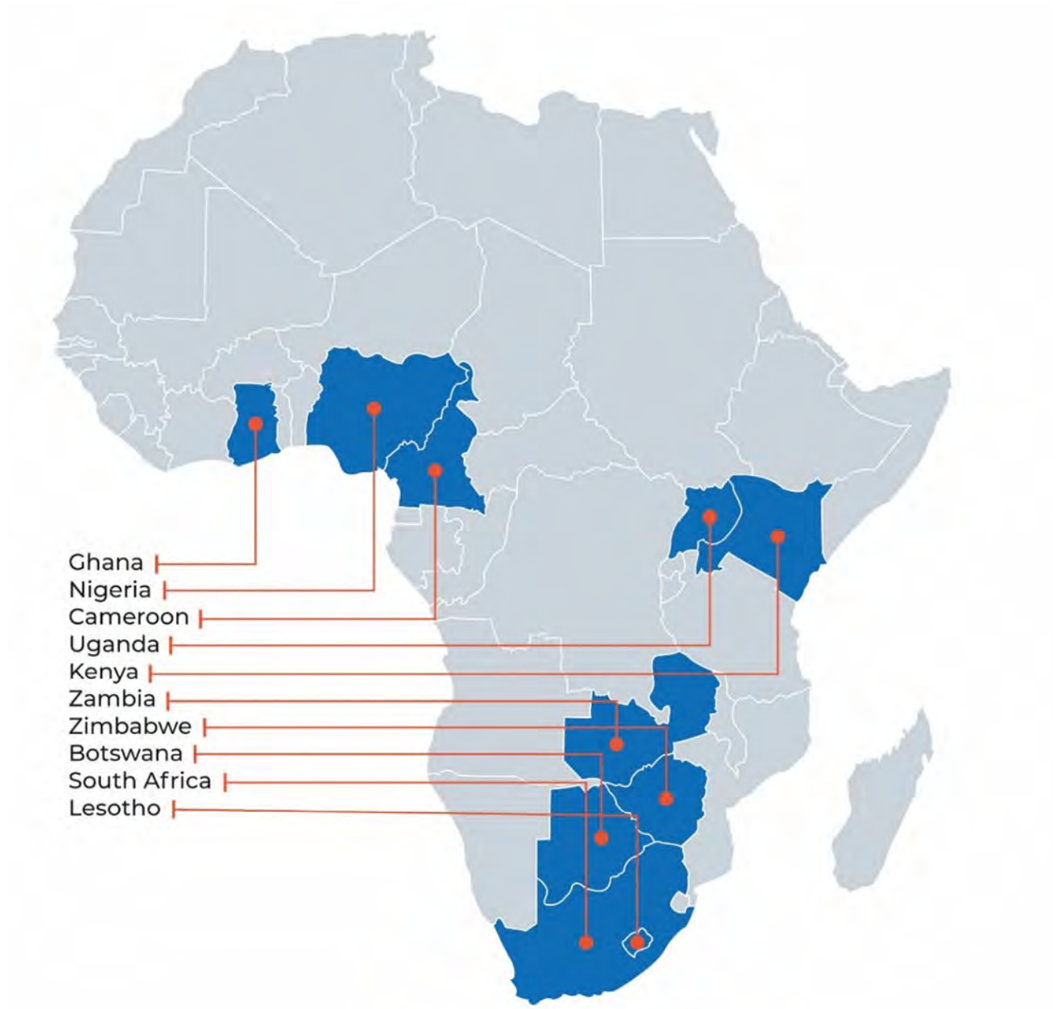
Key terms

Sub-saharan engineering community: We refer to all engineering professionals and stakeholders in SSA, that are exercising the profession, regulating it, orchestrating and/or commissioning engineering services. This includes, but is not limited to, individual professional engineers, PEIs, national government and supranational bodies working on science and technology, engineering universities, and engineering companies.

Youth: The national policies of all 10 SSA countries covered in this research define youth as citizens aged under 35. For the purpose of this report, we are hence defining youth, and the young generation, as people between the ages of 15 and 35 years.

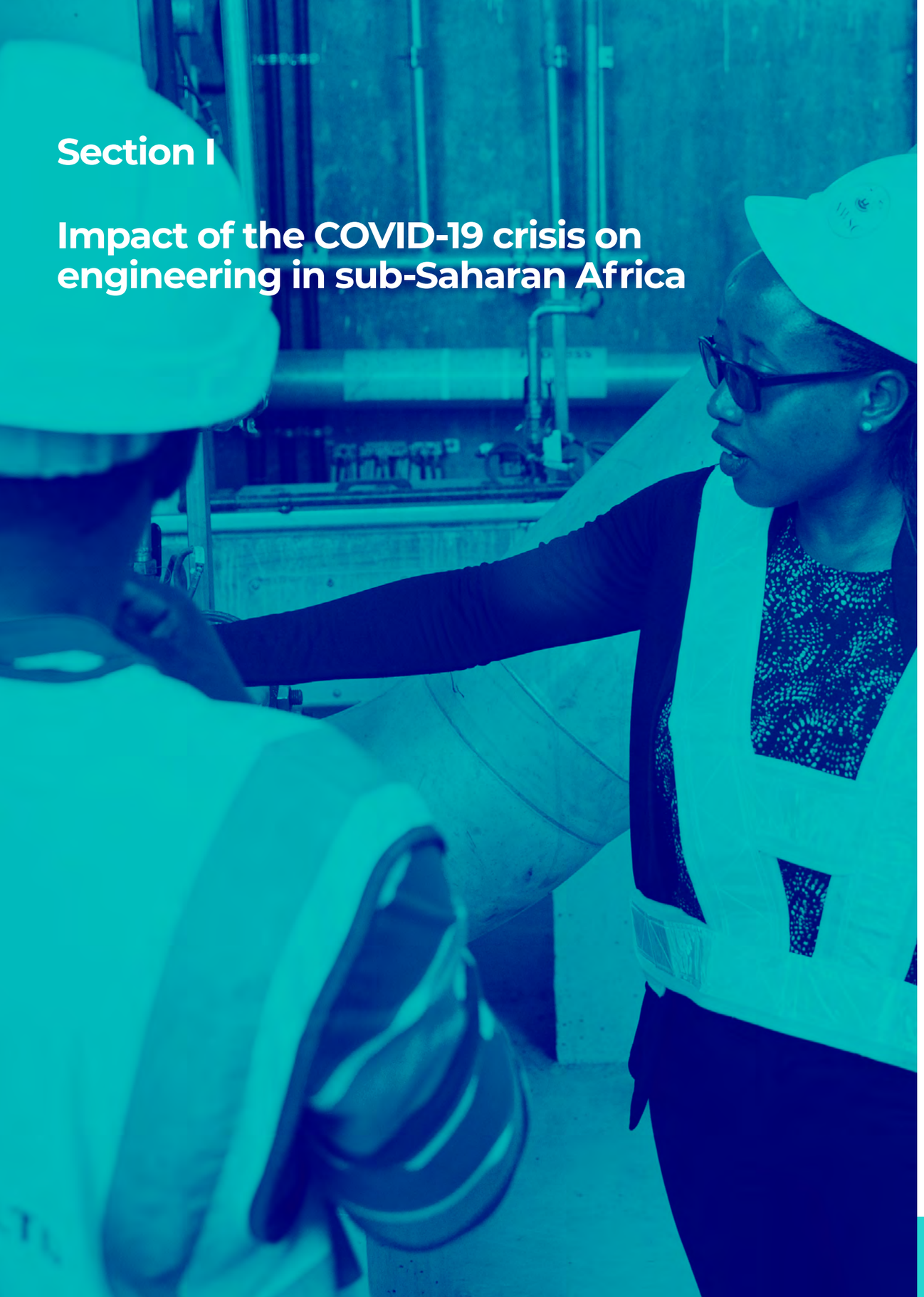
Supranational: For the purpose of this report, supranational initiatives are those that are not attached to a particular country, but rather implemented beyond national realms (for example across several countries).

Figure 1 Overview of the 10 countries targeted by the research



1 Ghana, Kenya, Nigeria, South Africa, Uganda.

2 GCRF Africa Catalyst Research Component - Learning Webinar, Jointly hosted by FAEO, The Royal Academy of Engineering and Ecorys UK.



Section I

Impact of the COVID-19 crisis on engineering in sub-Saharan Africa

Impact of the COVID-19 crisis on engineering

The COVID-19 crisis has exposed the **vulnerabilities of existing engineering infrastructures across SSA**. It has highlighted a number of significant gaps in **connectivity and communications infrastructures**, as many parts of Africa still do not have access to the internet. In South Africa, one of the most advanced economies in SSA, only 11.5% of the population uses the internet[3]. The fact that universities have struggled to move their teaching online during the crisis and are experiencing difficulties in reaching their students in rural areas is emblematic of this issue. This has created a huge demand to accelerate digital transformation in Africa.

The crisis has also highlighted **major shortcomings in SSA health infrastructure**. Challenges include poor coordination, management, and leadership, and inadequate human resources and budget allocations for health[4], which result in limited bed capacity to accommodate COVID-19 patients. In many countries, hospitals are understaffed and face shortages of personal protection equipment (PPE) and other appropriate equipment.

One major impact is the fact that, due to the pandemic, **foreign direct investment (FDI) to Africa has collapsed**. The United Nations Conference on Trade and Development expected FDI flows to contract between 25% and 40% in 2020[5]. However, in April 2020 alone, the number of cross-border merger and acquisition projects targeting Africa had fallen by 72% compared with the previous year's monthly average[6]. In addition, aid flows are now all directed to COVID-19-related initiatives. This will critically hamper investment in essential engineering infrastructure building for the years to come, and in turn hamper the ability of engineering to contribute to the sustainable development of the continent.

The crisis has also exposed the **reliance of SSA countries on foreign manufacturing and prompted the development of local manufacturing**[7]. SSA countries have had to produce locally to cope with the global shortage of PPE. Kenya, for instance, only had about 50 ventilators for a population of 50 million[8].

This has led a number of SSA countries to produce their own sanitiser, masks, and ventilators for the first time. This has been a learning exercise for governments, which have needed to develop quality and safety standards to counteract the proliferation of locally made PPE from non-approved vendors.

Finally, the crisis has had a **negative impact on engineering education and research** as moving teaching online is not equally easy for all engineering specialisms. For example, reduced laboratory work and less exposure to the working environment is likely to take a toll on the quality of education and research in the short and medium term. On a positive note, however, enhanced virtual collaboration has exposed engineers to a greater number of training opportunities, enhancing lifelong learning.

A multi-faceted impact

As is the case in the rest of the world, the pandemic has had a differentiated impact across different engineering sectors in SSA. The traditional fields of engineering, including **civil, mechanical, chemical, electrical, and transport** specialisms, have experienced a negative impact, as these disciplines require a lot of work in person on site and in teams. Restrictions to movement, social distancing rules, and limited supplies of PPE have therefore resulted in higher costs, higher time investment, and reduced productivity for businesses. The implementation of lockdowns has led to workforce disruptions and schedule delays. Disruptions in supply chains have led to shortages in raw materials, making it difficult for engineers to meet production schedules. Finally, spending cuts have halted critical road and infrastructure projects.

3 *"Africa's response to the COVID-19 pandemic: A review of the nature of the virus, impacts and implications for preparedness"*, Badu, K and all, 18 May 2020.

4 Ibid.

5 *World Investment Report 2020: International Production Beyond the Pandemic*, UNCTAD, 16 June 2020.

6 *"Africa must boost internal trade to recover from COVID slump, AU says"*, Financial Times, undated.

7 SSA economies rely on international imports and exports for around 30% of their GDP. See: *"COVID-19 effects in SSA and what local industry and governments can do"*, UNIDO, April 2020.

8 *"La tech africaine pleinement engagée dans la lutte contre le Covid-19"*, France 24, 19 May 2020.

Conversely, the crisis has revealed the importance of investing in **ICT and computer engineering**, which are crucial in terms of addressing the challenges of the crisis, and will continue to be crucial in meeting the needs of the 'new normal' post-crisis. Going forward, the digital content of hybrid engineering fields, such as industrial design and systems engineering, is likely to increase. **Robotic engineering** has also flourished as a result of the crisis because of its contribution to supporting social distancing through radar technologies, and the provision of medical care by robots. In the same vein, **AI and geospatial engineering** have thrived, as geographic information systems and big data play an important role in the tracking, modelling, and monitoring of COVID-19 cases and hotspots. Finally, the development of **medical and biomedical engineering** is accelerating because of the crisis.

COVID-19 and women engineers

As in the rest of the world, COVID-19 has been a huge burden for women engineers. Most of the women working in this profession have suddenly had to work from home, often while carrying out the role of primary caregiver for their families and coping with anxiety triggered by the COVID-19 crisis. WomEng[9] fears many of the advancements made by women in obtaining equitable education and job opportunities are being eroded by the crisis. Conversely, there is also sentiment that COVID-19 **has highlighted entrenched gender inequalities** across the globe, and that this has created more empathy.

African women are also more likely to have their **studies or research activities interrupted** because of the pandemic. Research shows that **85% of women** compared to 81% of men have been experiencing course interruptions[10]. Younger women in their 20s are more likely to report experiencing interruptions to their learning (90%, compared to 81% of men their age)[11]. As women often lag behind their male counterparts in science, technology, engineering and mathematics (STEM) as a result of engrained gender stereotypes, the disproportionate effects of the crisis on an already under-represented group in profession are particularly concerning.

COVID-19 and young engineers

The crisis has **negatively affected the education and job prospects** of young engineers by reducing opportunities for paid or voluntary work. More critically, across all countries covered by this research, engineering **higher education** was disrupted and has moved online because of the pandemic, with varying levels of success between countries. One of the reasons why teaching engineering online is difficult is the practical and hands-on nature of the curricula. Furthermore, training within companies and on construction sites has been paused, and technical checks cannot be carried out remotely.

As seen all over the world, moving education online is **exacerbating existing inequalities between richer and poorer communities**, as those with few financial resources are most likely to lack an adequate infrastructure to pursue their studies online. An additional challenge for less privileged young people is that young women are more likely to face increased childcare and household responsibilities, and young men are more likely to face increased labour responsibilities as a result of this[12].

An additional challenge for most SSA universities has been to maintain the quality of education and carry out examinations online for the first time. Online examinations present many challenges, including greater risks that students falsify their answers. The African Institute of Informatics in Cameroon trialled an application developed by its own engineers to **monitor candidates' workstations during online assessments**, including through a facial recognition system. This has allowed the institute to detect more than 20 cases of cheating.

Despite these challenges, COVID-19 has also given young engineers many opportunities. The younger generation of engineers tend to be more flexible than the older generation, and are therefore likely to be able to adapt more easily to the needs of the new post-COVID-19 world. The fields that will be able to expand post-crisis (healthcare, ICT, computer engineering, industrial and system design) will be dominated by this new generation, who will have had unique opportunities to step in and collaborate in tackling the issues created by this crisis.

9 See: www.womeng.org

10 'Surveying the impact of COVID-19 on Africa's higher education and research sector', Mugo, K., Odera N., Wachira, M., 8 June 2020.

11 Ibid.

12 Interview with Paul Kyoko, Former CEO of Institution of Engineers Kenya and Dean at the School of Engineering and Technology in SEKU.

Section II

Engineering's contribution to tackling the crisis in sub-Saharan Africa

The engineering actors involved in tackling the crisis

Beyond relevant government ministries and agencies, a range of engineering actors have been involved in responding to the COVID-19 crisis at both sub-Saharan and national levels. **Donors and development partners**, such as the World Bank and United Nations (UN) agencies, have played an enabling role by providing funding and/or capacity building to support the development of technical engineering solutions to a range of challenges posed by the pandemic. **Academia**, and in particular engineering university incubators, have played a crucial role in mobilising cutting-edge knowledge to innovate and develop PPE and other medical material. The **private sector**, including engineering companies, startups, social enterprises and individual entrepreneurs, quickly mobilised to manufacture essential products and to innovate to tackle the crisis (from PPE to applications supporting contact tracing and health monitoring).

PEIs have also contributed to crisis recovery efforts, although with wide divergences between countries. Across SSA, the **Federation of African Engineering Organisations** (FAEO) has actively assisted PEIs in sharing ideas and transferring knowledge. For example, in the early stages of the outbreak, FAEO helped its members to identify ways to best maintain the functioning of essential services and critical infrastructure. FAEO has also been steering a pilot programme aimed at strengthening the water treatment value chain in Africa to prevent the spread of COVID-19.

National PEIs have contributed in a wide range of ways, for example by:

- Helping raise awareness about the virus and the measures that can prevent its spread.
- Distributing PPE, sanitiser and, in some cases, food.
- Facilitating discussions with their members and other relevant stakeholders around the implications of the COVID-19 outbreak, and how engineers can best cope with and minimise the spread of the virus.
- Developing health and safety guidance for engineering activities.
- Contributing to policymaking by contributing ideas and expertise.
- Initiating fundraising efforts to support the response to the crisis.

The diverse contributions of engineers to tackling the crisis

The SSA engineering community has actively mobilised and deployed an array of interventions and solutions.

1. Local design and manufacture of medical, protective, and sanitary equipment
2. Rapid building of treatment, isolation, and testing facilities
3. Collecting and analysing data, and modelling the epidemic response
4. Funding, fundraising, and direct support for vulnerable members
5. Moving education and training online
6. Robotics supporting efforts to tackle the crisis

1. Local design and manufacture of medical, protective, and sanitary equipment

As they could no longer import medical equipment from abroad, countries such as Kenya, Nigeria, Rwanda, Senegal and Zimbabwe have designed and manufactured their own **medical material** for the first time, for a fraction of the cost of imported equipment. In Rwanda, biomedical engineers from the Integrated Polytechnic Regional College Kigali (IPRC) have successfully produced the first ventilator from the country[13]. In Kenya, engineers at Kenyatta University in Nairobi have developed a prototype ventilator for a tenth of the cost of an imported machine which is estimated at KES 1,072,000[14]. Further, Jomo Kenyatta University of Agriculture and Technology (JKUAT) has developed a portable solar-powered ventilator for the first time[15]. In Ghana, engineering universities have joined efforts to develop a ventilator for between GHS 2,900 and 5,800, the installation of which only takes an hour.

The importance of stepping in to manufacture ventilators locally is evident when considering the low numbers of ventilators available in SSA in the first place. The table below provides an overview in the 10 target countries of this research.

Table 1: Number of ventilators and needs estimates in the UK and the 10 target research countries

Country	Ventilators as of May 2020	Ventilators needed at pandemic peak (estimates)
UK	11,900[16]	59,000[17]
Bostwana	150	215
Cameroon	40	2,422
Ghana	200	2,680
Kenya	297	4,511
Nigeria	500	20,325
South Africa	3,200	5,362
Uganda	100	No estimates
Zambia	100	2,070
Zimbabwe	35	1,640

Source: Ecorys based on Reuters reporting and MRC Centre for Global Infectious Disease Analysis/Imperial College London[18]

13 Rwandan Engineers Complete First Made in Rwanda Ventilator As Response to Covid19, Taarifa, April 2020.

14 'La tech africaine pleinement engagée dans la lutte contre le Covid-19', France 24, 19 May 2020.

15 See the Kenya country chapter for more information.

16 Coronavirus: Ventilator availability in the UK, House of Commons library, Briefing Paper, 3 June 2020.

17 Covid-19: Supply of ventilators, House of Commons Public Accounts Committee, Twenty-Seventh Report of Session 2019–21, 16 November 2020.

18 Virus exposes gaping holes in Africa's health systems, Reuters, 7 May 2020.

Beyond medical material, engineers have stepped up to produce **sanitary products** locally, such as sanitiser and soap, in more than half of the countries studied for this research. In Zimbabwe, the younger generation was involved in this process; primary and secondary school students were invited to make their own face masks and sanitiser, raising their awareness about chemical engineering in the process. In Nigeria, the private company Macjames built on its experience of the Ebola outbreak to improve the effectiveness of its hand sanitisers.

In addition to the rapid mobilisation of the engineering community to manufacture this type of equipment, several **innovations** are worth noting:

Figure 2 Sanitary equipment innovations

Disinfection portico	In Cameroon, engineers from the University Agency for Innovation created a portico that decontaminates people entering public spaces.
Medical oxygen station	In Cameroon, engineers from the National Advanced School of Engineering of Yaoundé created an oxygen station, allowing hospitals to generate their own oxygen for a fraction of the cost of using a ventilator.
Self-sanitising mask	In Uganda, engineers have developed a mask with a built-in sanitiser.
Automated disinfectant sprinker system	In Uganda, engineers have equipped buses with an automated disinfectant sprinkler.
Solar-powered hand-washing machine	In Kenya, engineers have developed an automatic solar-powered hand-washing machine .

2. Rapid building of treatment, isolation, and testing facilities

Engineers have also swiftly mobilised to build treatment, isolation, and testing facilities. The main PEI in Ghana, the Ghana Institution of Engineers (GhIE), was instrumental in steering efforts towards **building the first infectious disease treatment facility** in the country, with a capacity of 100 beds. In Zimbabwe, engineers, architects, and building professionals came together to design an **isolation centre** with a capacity of around 400 beds, and the Zimbabwe Institution of Engineers (ZIE) was a central actor in this project. Beyond facilities, engineers have been instrumental in installing hand-wash stations across SSA countries, such as Sierra Leone and Nigeria.

3. Collecting and analysing data, and modelling the epidemic response

Engineers have helped to develop **software tools to facilitate live tracking and visualisation** of the spread of the virus. In Botswana, these tools include a web map visualisation and a live tracking dashboard that can track real-time trends, and self-assessment applications to remotely monitor the status of patients in quarantine. In Ghana, engineers have built a COVID-19 monitoring dashboard providing live data and trend analysis.

In many SSA countries, engineers have helped to develop **applications to support contact tracing**. In Kenya, for example, the Msafari application has been developed to track the movements of passengers on public transport. In Ghana, a startup launched an application through which users can check-in daily and report whether they are experiencing symptoms. In Botswana, the COVID-19 e-permit application digitalises the COVID-19 movement permit application process. Finally, in Ghana, citizens can self-report their symptoms and location through an online platform using an unstructured supplementary service data (USSD) protocol. In addition, a Cameroonian entrepreneur founded OuiCare, a simple health platform to allow users to save their medical data and make appointments with health professionals. This is a response to the fact that many deaths in Cameroon are due to a lack of access to patients' medical history.

4. Funding, fundraising, and direct support to vulnerable members

PEIs in Ghana, Kenya, Nigeria, and Zimbabwe have **coordinated fundraising efforts** to support the response to the crisis. The Institution of Engineers of Kenya (IEK) raised over £14,000 (KES 2 million)[19] to support the production and supply of vital protective and medical equipment, as well as distribute food and household essentials to families in need. In Nigeria, the National Society of Engineers (NSE) raised £36,000 (NGN 18 million) to fund the production of hand sanitiser, face masks, and hand-washing stations. Some of the money collected was set aside to purchase food items for distribution to vulnerable NSE members. Beyond this, the NSE also established a **cash transfer scheme** targeting its most vulnerable members, such as young people and employees at small- and medium-sized enterprises (SMEs). In Zimbabwe, ZIE fundraised to support the procurement and branding of PPE for frontline medical and health staff. In Sierra Leone, the Sierra Leone Institute of Engineers (SLIE) distributed sanitisers and masks. Finally, in Ghana, GhIE was involved in funding a mobile application for contact tracing.

5. Moving education and training online

Engineers and PEIs have been supporting efforts to transfer education and training online during the crisis. For example, the Nigerian Institution of Mechanical Engineers (NIMechE) moved all its activities to an online bootcamp (funded by the Royal Academy of Engineering), thereby creating a **virtual school** on engineering and entrepreneurship called ENGentrepreneur. Also in Nigeria, the non-profit organisation TheReformers, made up of mechanical engineering students who have held leadership roles in NIMechE, created **School Online** in June 2020. In Uganda, the Uganda Institution of Professional Engineers (UIPE), the College of Engineering, Design, Art and Technology at Makerere University, and RedR UK are **building the capacity of local engineers to respond to humanitarian needs**. This will involve around 2,000 engineers, around 100 of whom will receive targeted training on humanitarian principles and standards, disaster risk reduction, urban humanitarianism, and the application of engineering skills in response to urgent humanitarian needs. In Ghana, Ashesi University's D:Lab organised an **entrepreneurship competition dedicated to educational technology**[20].

19 Primarily donations from individuals, full list available at this link.

20 Future Learning Hackathon, Ashesi Design Labcom.

6. Robotics supporting efforts to tackle the crisis

SSA engineers have successfully utilised the potential offered by robotics to support efforts to tackle the crisis. In Rwanda, for example, **humanoid robots** take on certain medical staff responsibilities in COVID-19 treatment facilities to minimise human contact, such as taking patients' temperatures. Similarly, in Senegal, students from the Advanced School of Engineering in Dakar developed Dr Car, a robot with mechanical arms and a mounted camera. Through Dr Car, hospital staff can remotely interact with patients, bring them equipment and meals, measure their blood pressure, and take their temperature. Beyond minimising the risk of transmission of the virus to health staff, the use of robots should help reduce the costs associated with the need to provide protective equipment for medical staff.

Drones have also been utilised as part of efforts to recover from the crisis. In Rwanda and Ghana, drones from the company Zipline fly with loudspeakers to **communicate prevention measures** against the pandemic and help with the **surveillance and control of containment and quarantine measures**[21]. Drones also **transport packages of blood, test samples, COVID-19 tests, and drugs** between multiple hospitals or test facilities in a short time period because they do not use roads, which can often be in bad condition. Through an app, doctors and health facilities can order blood, vaccines, and PPE, and track shipments[22]. Drones can be launched 5 to 7 minutes after an order is received, with flight times varying from 15 to 30 minutes. This project is due to be exported to the United States (US). Finally, in Botswana, sprayer drones can **disinfect the air** in public spaces such as hospitals, grocery stores, petrol stations, and quarantine facilities (cleaning around 3,000 cubic metres of air in 30 minutes)[23].

Women-led initiatives

Nevertheless, despite the additional burden placed on women by COVID-19, women engineers have proactively contributed to recovery efforts. Women's branches of key PEIs in Ghana, Nigeria, and Sierra Leone have **led on food and PPE distribution to members in need**. In these instances, women engineers have mobilised outside of their normal jobs and with their own money, rather than based on an institutional mandate. Women engineers have therefore distinguished themselves for being particularly successful at community support and outreach in these countries.

Furthermore, the Botswana Women in Construction Organisation (BWICO) has proactively communicated and shared government updates and other health protocols to remind its members that remote services are still available. BWICO has also run webinars to explore the impact of COVID-19 on the built environment in the country. In Ghana, a group of women engineers presented to the government a proposal to reshape markets in the country. The Uganda Industrial Research Institute (UIRI) trained women from rural areas to produce three-layer masks. Women were mobilised to produce about 100 masks a day in exchange for an allowance, following which women were able to train others in their communities.

Supranational initiatives are also worth noting. **WomEng** is a social enterprise working to develop the next generation of women in engineering leadership through the organisation of capacity-building activities. During the pandemic, it has adapted its activities to train women engineers on how to respond to the crisis. **FAEO's Steering Committee on Women** has also been active during the pandemic by supporting its members' women's chapters to cope with COVID-19: it has, for instance, supported the Namibia Women in Engineering Association to host a COVID-19 webinar on what women engineers have done, and can do, in this space.

Cross-country collaboration

According to FAEO, the COVID-19 crisis has **helped unite SSA countries**. For example, FAEO has been invited to ministerial meetings for the first time to share experience in tackling the virus. In addition, the opportunities offered by remote collaboration have further accelerated cross-country cooperation; FAEO signed a Memorandum of Understanding with its Asian and European counterparts within 3 months[24], whereas such an endeavour would have previously taken around a year. As online meetings are cheaper and easier to organise, there is a real opportunity for engineers to intensify collaboration beyond national borders, and FAEO has dramatically improved its reach in that way.

However, beyond experience sharing, there seems to have been **relatively little cross-country engineering collaboration**. The closest to this has come from donors who have coordinated when funding innovative engineering solutions[25]. Furthermore, 2 cross-country initiatives are worth mentioning in relation to the response to the COVID-19 crisis.

First, the initiative **Strengthening Engineering Ecosystems in sub-Saharan Africa**[26], funded by the International Development Research Centre in Canada, involves a range of African engineering actors, including the Ghanaian Kwame Nkrumah University of Science and Technology, the Nigerian Academy of Engineering, the Tanzania Water Partnership, and the Science, Technology and Innovation Policy Research Organization based in Tanzania. While the project started before the COVID-19 crisis, the implementing partners have been collaborating to address the impact of COVID-19 in engineering education in Africa, and the role that engineering researchers should play. Partners released a collective statement[27], and are planning to adapt their projects to include measures and lessons learned on how to adapt engineering education in Africa in the aftermath of the COVID-19 outbreak.

Second, **the Royal Academy of Engineering, UK** launched Project CARE (COVID-19 African Rapid Entrepreneurs).[28] The initiative is building the capacity of engineers in SSA through the provision of technical expertise, grants, and materials to enable the local manufacture of PPE and the development of local clinical value chains. Through a competitive process, 48 entrepreneurs from 11 countries across the Africa Prize and Leaders in Innovation Fellowships (LIF) alumni networks were selected to rapidly produce PPE and sell these products to local clinics and front line health workers. A further 8 entrepreneurs were selected to pivot or scale their businesses as a response to COVID-19. These include innovations such as incinerators to safely dispose of used PPE on site, manufacture of hand sanitiser, and connecting small holder farmers with local supply chains. To date, over 12,000 items of PPE have been produced by 26 entrepreneurs in 11 countries. Additionally, the 8 alumni who pivoted their businesses have made 16 formal partnerships and agreements with new organisations, generated over £4,000 in revenue, and reached more than 23,000 beneficiaries, including vulnerable groups such as the elderly, rural smallholder farmers, and those in highly populated low-income communities. Their work has received media coverage in the UK and Africa, and on high-profile Twitter accounts including the UK High Commissions in Ghana, Kenya, and Nigeria.

National collaboration

One positive impact of the crisis is that it has **brought engineering actors together** around the same goal of fighting the pandemic. New national collaborations have been formed as the result of the COVID-19 outbreak and collaboration is reported to have improved overall. In some countries, the crisis has fostered a new mindset in the private sector, whereby competitors now seek to pool their resources to help[29]. Many of the engineering successes evidenced by this research are the result of strong collaboration between engineers and key stakeholders. For example, the establishment of treatment and isolation facilities in Ghana and Zimbabwe was the result of **collaboration between many different stakeholders**: PEIs, relevant national and regional government ministries and/or agencies, the private sector, and international donors. It is recognised that for such efforts to be effective and sustainable, countries require policy, regulatory, management, and health-related technical expertise.

Furthermore, in South Africa, **32 engineering associations joined forces for the first time** under the umbrella of the Construction COVID-19 Rapid Response Task Team (CC19RRTT) to develop a liaison forum with the government on how to get the engineering profession back to work safely. Similarly, in Botswana, the Engineering and Technology Innovation Centre (ETIC) demonstrated that **academic institutions and other country's governments are coming together** to share knowledge and address the immediate health needs of the population. There has also been **intensive collaboration regarding funding**: PEIs have fundraised to donate to governments, governments have strived to fund the scale-up of engineering innovations, and the private sector has contributed to emergency funds.

21 'En Afrique, la technologie est aussi au front contre la Covid-19', Cimalamungo, D., July 2020.

22 A tech company engineered drones to deliver vital COVID-19 medical supplies to rural Ghana and Rwanda in minutes', Lewis, N., 12 May 2020.

23 The African Physics Newsletter, undated.

24 LinkedIn post, Federation of African Engineering Organisations, June 2020.

25 Interview with Federica Yawson.

26 'Strengthening engineering ecosystems in sub-Saharan Africa', International Development Research Centre, undated.

27 'How COVID-19 is transforming engineering in Africa', University World News, 28 November 2020.

28 Royal Academy of Engineering, UK website, Link and Link.

29 'La tech africaine pleinement engagée dans la lutte contre le Covid-19', France 24, 19 May 2020.

Section III

Post-crisis role and outlook for engineering in sub-Saharan Africa

Impact of the crisis on engineering priorities in sub-Saharan Africa

From the research conducted in this study, it is clear that the COVID-19 crisis is likely to have a lasting impact on engineering priorities in SSA. Firstly, the crisis is expected to **accelerate the digital transformation** of Africa. The pandemic has made it a necessity to invest in essential digital infrastructure and to democratise access to high-speed broadband, 4G and 5G[30]. Digital infrastructure requires lower levels of funding and investment than traditional infrastructure, and there is widespread sentiment that this might enable African countries to make progress towards maximising their potential.

Linked to this, the crisis has illustrated the **benefits of technology to fill critical gaps in the healthcare sector**. This is the case in Ghana, where there is a growing focus on online pharmacies, electronic payment systems, online healthcare systems and testing, and online medical services. As a result, established industry players and engineers in Ghana have already started investing more in digital infrastructure to deliver more and better e-health solutions.

The crisis has also increased the focus on wider emerging technologies, such as **telecommunications, AI, robotics, 4D printing**[31]**, and bio-medical engineering**, all of which have played an incremental role in tackling the crisis, and will remain critical in terms of meeting the needs of the post-COVID-19 environment. For example, robotics and AI will help to limit human contact: robots can absorb some of the responsibilities of healthcare personnel, and radars can help to enforce social distancing between people in public spaces via alarm systems. AI will be further utilised to help model virus spread scenarios and mutations and help to develop medical solutions. Biomedical engineering will be crucial for COVID-19 testing. Technology will also be more widely used within the medical field through telemedicine, applications to support doctor and patient engagement, and innovations such as digital passports to help people track their medical record from one doctor to another.

In the same vein, **geographic information systems** will be in greater demand to continue to track and combat contagion: applications that are able to track and understand the spread of the disease and display results in interactive and real or near real-time dashboards have a key role to play in informing government decision-making. Furthermore, systems and applications that provide data on urban mobility and road traffic, and how these were impacted by lockdown measures, are and will continue to be important in relation to pandemic management and to mitigate related disruption. Engineering can also help by supporting the development of infrared scanners for the rapid detection of infected individuals and contact tracing, and the collection of further geospatial data in various forms to inform policy formulation and interventions.

Technology and systems design will shift towards **greater automation, distance control, and touch-less features** to meet the demand for more hygienic infrastructures. When building infrastructure, and in particular public buildings, engineers will need to design surfaces that limit disease transmission and that are easy to disinfect. Engineers will have to develop air conditioning (AC) and ventilation systems that prevent the spread of infectious diseases. Engineers are also prompted to remodel the clean water value chain, purify water more rapidly and transport it safely, in order to improve sanitation. Preference will further be given to sensor mechanisms, such as in automated doors, to minimise contact with surfaces.

For many SSA countries, the pandemic was a wake-up call in terms of the need to **support local production and secure capital**. In Ghana, for example, the **One District One Factory initiative**[32] strives to facilitate access to funding for businesses. The **sourcing of components** in sectors such as construction has also proved particularly difficult during the pandemic due to lockdown constraints, which has renewed awareness of the need for local production.

While in the short-term there is a risk of losing sight of sustainability considerations, in the medium term there is likely to be a greater focus on **green infrastructure, renewable energy,** and the construction of energy-saving buildings. Overall, the crisis has shed light on the poor environmental performance of African infrastructure. It is felt that there is a real opportunity to design lowercar-bon infrastructures and preserve the ecosystem.

Most specifically, our research has shown that the pandemic is likely to bring about major changes in the way that water services are managed across the entire continent, and particularly in land-locked countries such as Botswana. Here, PEIs told us that

30 'Une opportunité pour une nouvelle Afrique numérique', Financial Afrik, 18 April 2020.

31 The introduction of the fourth dimension to the 3D printing technology is termed as '4D Printing'. 4D printed objects can change shape by themselves with the influence of external stimuli, such as light, heat, electricity, magnetic field, etc.

32 'One District One Factory' website.

water, sanitation, and hygiene services (WASH) are a key aspect of Botswana's COVID-19 action plan, which aims to foster further partnerships and enable engineers to help address the health needs of the population at a more systemic level. On the one hand, more attention will be paid to **improving the resilience of the water infrastructure** through the implementation of early warning systems to deal with episodes of shortage caused by climate change, migratory movements, and pandemics. PEIs in Ghana told us that, given the importance of providing basic drinking water and sanitation services during the pandemic, engineers have a critical role to play in strengthening water production and distribution systems, as well as quality controls, to ensure adequate service levels in terms of continuity, quantity, and quality. On the other hand, greater financial resources will need to be allocated to the renewal of infrastructure and the optimisation of the services provided, strengthening both the use of water resources and the use of treated water for environmental and other human-related purposes. PEI interviewees in Ghana cited the work of the water security consultancy Idrica on the main future water-related challenges for Africa[33].

Water is a major concern for Botswana, as a landlocked country. Here, the view of interviewees was that PEIs need to work with government and other sectoral experts to exchange best practices, as the pandemic evolved in an unpredictable manner, particularly in the specific area of water management. Botswana has vulnerable populations who are at further risk of lack of provision of sufficient and clean water, particularly in the case of large households, where social distancing is a challenge.

Finally, the COVID-19 crisis has created a positive **new sense of innovation and purpose** within the engineering community across the SSA region, with engineering professionals stepping in with solutions for the common good, as evidenced by the many examples in this report.

Lessons learned

A key lesson from this crisis is that engineers need to be **more adaptable and deliver infrastructure quickly**. This was the case in Ghana, for example, where the engineering community mobilised to build a treatment facility of 100 beds in a record time of 3 months. More widely, engineering needs to deliver **integrated solutions** as part of wider systems of infrastructure. For example, the crisis has increased awareness around the fact that healthcare is not only about solid infrastructure such as hospitals, pharmacies, and ambulances, but rather, it is a whole value chain that includes feedback loops and leverage points. Therefore, an effective engineering response requires close collaboration all along the value chain: inputs into healthcare policies, inputs into the logistics of healthcare equipment, and inputs into risk assessment and emergency plans.

The crisis has further highlighted the need for engineers to maintain **tighter links with policymakers** both at national and regional level. Engineers have a lot of value to add to policy forums. Firstly, when it comes to predicting a crisis of this kind, but also in terms of articulating adequate responses. Many interviewees feel that it is urgent for governments to tap into the expertise and strategic thinking of engineers and work hand in hand towards solving the challenges caused by the crisis. There is also a real opportunity for engineers to voice their opinions in supranational forums such as the African Union institutions.

Although this has been a long-standing issue, the crisis has shed light on the urgency of increasing **investment in research and development** in Africa. Current levels of funding are exceptionally low: although Africa comprises 15% of the world's population, it only accounts for around 1.3% of global investments in research and development[34]. Under-resourcing critically hampers the ability of African engineers to innovate and exert thought leadership. The current climate has also reinforced the sense of urgency for academics and the private sector to work more closely together in developing practical solutions.

Developing engineering skills and education further

The **acceleration of digital transformation** in Africa resulting from the crisis will require the development of new skills. It is clear that there will be higher demand for technical skills in telecommunications, programming, 3D modelling, and coding. Beyond this, new technologies mean that there is a need to incorporate **ethical thinking** into engineering training. Emerging technologies such as AI present risks in terms of the role of the human workforce and therefore need to be designed ethically. Another consequence of the acceleration of digital transformation is the need for **cyber security** skills and **privacy protection considerations**. It is likely that engineers will have a higher level of responsibility than in the past to protect the privacy of companies and citizens from state surveillance and to guarantee transparency in the use of new telecommunications technology.

Another important evolution in engineering education and skills will be the need for **greater flexibility, inter-disciplinarity, and adaptability**. Coping with the consequences of the pandemic requires multi-skilled engineers who can exhibit critical thinking, think creatively, and navigate uncertainty. This also requires engineers to be in tune with the needs of society and have a knowledge of social and behavioural sciences. The crisis has further highlighted the need for the profession to think beyond typical/traditional engineering, and develop more soft skills, creative thinking, and ability to collaborate.

Entrepreneurship skills will also be key. Although engineers can be natural innovators, according to many of our interviewees, they often lack the entrepreneurship skills needed to turn innovations and ideas into businesses. At a time when several firms have had to close, self-employment may seem preferable to trying to find a job in a very flat jobs market. Therefore, an emphasis on entrepreneurial skills will be needed in the future.

Following the crisis, there is a need to revitalise the curriculum in schools and universities to reflect the skills highlighted above, for which there will be greater demand. In Zimbabwe, for example, the ZIE is looking at ways to refresh the curriculum with help from universities that offer specialised engineering programmes. Changing curricula is a longer-term process, however. A first immediate step that can be taken by universities is to incorporate **problem-based learning** in their teaching.

The crisis is also driving a major shift in the way engineering education is delivered. Remote learning and teaching will become much more common, and this means that the entire education paradigm must evolve accordingly. Many teachers have little experience in online pedagogy but will need to embrace these new tools. To support these efforts, the Kenyan government has, for example, put into place the Kenya Education Network, which has provided an online learning platform for use by public universities. Moving education online in this way brings a set of challenges, including the need for procedures to assess students online in a way that prevents cheating. Another challenge is to maintain the practical components of engineering education. Tackling these new challenges will take a long time.

33 'The impact of COVID-19 on water and sanitation services in Africa', Idrica, 10 June 2020.

34 'The need for Robust African Research & Development', Coalition for African Research and Innovation, undated.

Section IV

Opportunities and recommendations

Role of the engineering community as a whole

Our research has identified a number of opportunities that the SSA engineering industry could build on in the years to come.

Accompanying the journey towards self-reliance in manufacturing

Just as in the rest of the world, the COVID-19 outbreak has been a wake-up call for many countries in SSA about the need to reduce reliance on global supply chains, and in particular reliance on European or Chinese manufacturing. The crisis has led to the development of aspirations to build self-reliance and develop national supply chains. Engineers have a critical role to play in accompanying this transformation. There is an unprecedented opportunity for African engineering to become more focused, practically-oriented, and to make the most of existing capacities in the health, manufacturing, and pharmaceutical sectors.

Building local engineering capacity

Directly in line with this, there is a major opportunity to build the local capacity of engineers. As a result of COVID-19-related international travel restrictions over the past year, there has been limited influx of foreign engineers in SSA, meaning local engineers could get involved in delivering complex projects that were previously dominated by their foreign counterparts. In addition to absorbing skills and knowledge through this process, local engineers have been working collaboratively as equals with Western or Asian peers rather than as subordinates, thereby positively reequilibrating the power balance with their counterparts in other parts of the world.

There is an ongoing need for the engineering industry to keep its talent at home rather than losing young engineers to emigration. The pandemic has shown that local engineers can work to provide innovation and solutions, and there is now an opportunity to build on this by focusing on matching local talent to post-COVID-19 engineering needs.

Increasing the visibility and standing of the engineering profession

While the COVID-19 crisis is primarily labelled as a health and economic crisis, it is fundamentally also a crisis of an engineering nature. As documented in our research, the SSA engineering community has played a critical role in recovery efforts. Yet, these efforts have gone unnoticed by the general public for the most part. Engineers should not shy away from branding themselves and showcasing the efforts they have undertaken. This is an occasion to raise awareness about the essential nature of engineering and improve general public trust in the field.

By improving the standing of the profession, engineers will be in a stronger position to voice their agenda and influence policymaking towards building resilience against future global crises with world-class technologies and innovative ideas to solve practical problems. This increase in recognition could also enhance allocation of finances for infrastructure and engineering research.

Matching skills to changing future priorities

Given the changing future priorities for the engineering industry, linked to issues such as digitalisation, the green economy, climate change, and water management, it is key that skills acquisition and development are adapted to them. This will require collaboration between PEIs and skills providers, including universities. The recent increase in the visibility of the engineering industry may help to increase student intake in key engineering disciplines.

Expanding cross-sectoral collaboration

During the COVID-19 outbreak, it became clear that a wide range of successful projects were being carried out based on cross-sectoral partnership. Collaboration between engineering practitioners, researchers, and the government is likely to improve, as the need to relocate production will enhance the need for cooperation throughout the value chain. However, stakeholders fear this renewed impetus in collaboration could fade in the medium term. Deeper issues also remain unaddressed, such as the gap between universities and industry, the lack of communication between PEIs and the government, and low resources and capacity of PEIs.

It is therefore crucial that engineers continue to collaborate with key organisations within their countries, such as governments, universities, and industry, forging partnerships across countries, disciplines, and sectors of the economy (i.e. public and private sectors). This is indispensable to help tackle the longer-term impacts of the pandemic, cope with future crises, and respond effectively society's future priorities.

The post-COVID-19 world is also an opportunity for governments to collaborate more with the engineering community. In South Africa, the government is now focusing on delivering infrastructure, and there is appetite to develop partnerships between the public and private sectors in terms of capacity building. In Zambia, for example, the Engineering Institution of Zambia (EIZ) expressed a view that mechanical, civil, biochemical, electrical, management, and geotechnical engineering will need to change and adapt following the crisis, notably through more regular and meaningful collaboration and cooperation with the health and emergency services, water and sanitation, oil and gas, renewable energy, digital and technology, defence and marine sectors, and the education system as a whole. It is vital to plan ahead so that links can be built and communication channels and processes can be put in place.

Building more socially responsive and resilient infrastructure

The crisis has been an opportunity to decompartmentalise engineering and align innovation and infrastructure more directly with the needs of African society. Human behaviour is not always rational, especially in times of crisis, and this needs to be reflected in infrastructure. By coming together across multiple disciplines and gaining greater exposure to social sciences, African engineers are encouraged to 'think out of the box' and develop more holistic solutions that better address societal needs. Finally, this is a real opportunity for engineers to lead emergency preparedness efforts and build resilience as part of their design processes. Engineers need to adopt human-centred designs with the next generation in mind to ensure sustainability. An example of this is the need to accommodate the greater demand for cross-border mobility and technological solutions from the new generation.

Sharing best practices

Engineering communities will need to increase the sharing of best practices among themselves and keep a forward-looking outlook. Different engineering actors tend to work in silos, even within countries: for example, entrepreneurs tend to be disconnected from PEIs. Cross-country fertilisation of ideas and learning could go a long way to improving engineering capacity in SSA and keeping the profession innovative and forward-looking. There is also scope to establish channels to facilitate such exchange and learning, and to make the most of FAEO.

Utilising the greater ease of doing business

One of the positive aspects of the crisis is of course the increased possibilities of working, collaborating, and networking online. There is an opportunity for engineers to make the most of these new avenues to expand the reach of their businesses, find new business partners, and increase their visibility. Technology also offers engineers an opportunity to work more closely and seamlessly in teams across different countries. Building on this, engineers may soon be able to utilise online tools to brainstorm ideas and strategies, and develop prototypes in real time in a virtual room. Focus group/qualitative research and survey technologies could also allow real-time data capture and facilitate remote collaborative engineering work. Finally, the opportunities offered by moving work online can also lead to new business models.

Role of professional engineering institutions in the 'new normal'

Stakeholders interviewed for this research felt that PEIs have primarily contributed to collaborative efforts, rather than led their own initiatives. It was also felt PEIs have not always been on the front line, and that they could sometimes have played a more prominent role in the effort to mitigate the effects of the crisis. Nevertheless, this research has identified many ways in which PEIs have stepped up and worked with the government and other partners to help out, in particular through fundraising, distributing PPE, or coordinating efforts to build essential facilities. COVID-19 could therefore help advance PEIs' longer-term vision to promote the character and status of the profession and increase public awareness and confidence in this. PEI efforts have also widely diverged from one country to another, although our research identified one number of common ways in which PEIs can develop.

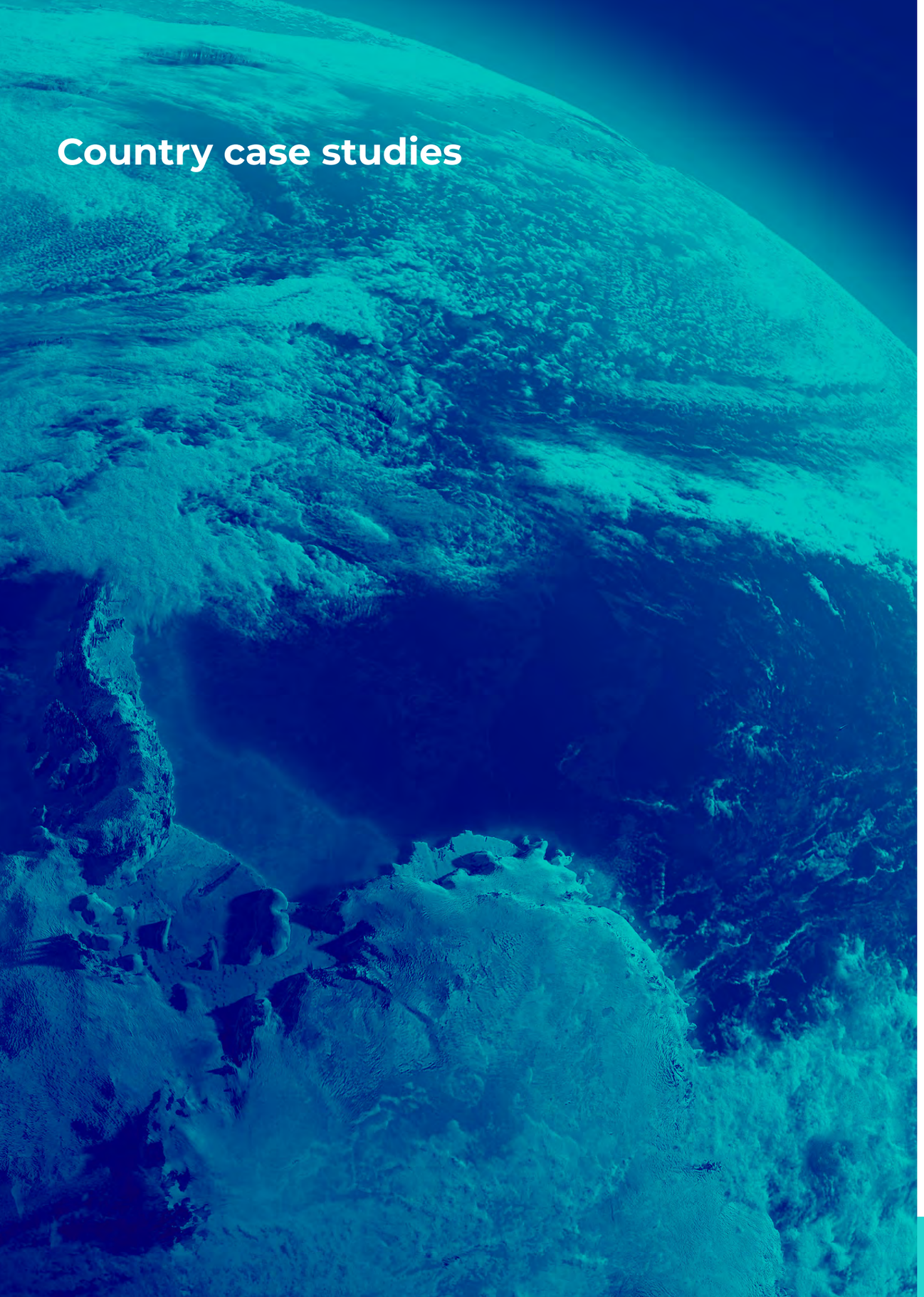
Reflecting, learning, and helping the transition towards the 'new normal'

SSA PEIs have a responsibility to help their countries to transition into the 'new normal', whatever that might look like. They can do so by bringing the profession together to facilitate reflection on what is needed for the future of their countries in the years to come, and initiate an open and sustained dialogue with policymakers. They can also steer efforts to build new infrastructure. Of course, this is not a simple journey for PEIs, as many of them are under- resourced and have limited capacity.

Nevertheless, there are examples of PEIs embracing that role already. In Nigeria, for example, the National Society of Engineers (NSE) is encouraging its members to use funds made available by the Nigerian government to boost entrepreneurship development. The NSE is also encouraging its members to develop innovations that can help the nation to grow and stimulate job creation.

Becoming more agile

Our research found that SSA PEIs are often seen as bureaucratic, highly political, and difficult to navigate for outsiders. For this reason, some engineering actors feel like they are playing catch-up rather than leading the way forward. There is now a real opportunity, as a result of the crisis, for PEIs to embrace the need to become more agile, play a more central role in recovery efforts, and exert more thought leadership. A priority in the eyes of many is for PEIs to migrate online as soon as possible. Another immediate priority would be to organise dedicated conferences with members, and the profession more widely, to agree on resolutions to address future challenges.



Country case studies

Country case studies

This section covers case studies on the following 10 countries:

Botswana	Nigeria
Cameroon	South Africa
Ghana	Uganda
Kenya	Zambia
Lesotho	Zimbabwe

The below table provides an overview of the key COVID-19-related figures for the 10 target countries of this research (as of February 2021). South Africa and Botswana have the largest number of cases compared to the size of their population. Zimbabwe has the largest number of deaths as a proportion of the number of cases.

Country	Cases	Deaths	Population	Cases to deaths ratio	Cases to population ratio
Botswana	23,503	163	2.4 million	144.2	0.010
Cameroon	31,394	474	26.5 million	66.2	0.001
Ghana	70,768	457	31.1 million	154.9	0.002
Kenya	84,361	1,779	53.7 million	47.4	0.002
Lesotho	9,380	183	2.1 million	51.3	0.004
Nigeria	139,242	1,667	209.4 million	85.3	0.001
South Africa	1.5 million	46,290	59.3 million	32.4	0.025
Uganda	39,848	327	45.7 million	121.9	0.001
Zambia	62,633	853	18.4 million	73.4	0.003
Zimbabwe	34,552	1,326	15.0 million	26.1	0.002

Source: Worldometer as of 7 February 2021

Botswana

1. Context/background

Overall impact of the COVID-19 crisis in Botswana

The spread of COVID-19 in Botswana has been relatively slow in comparison to other African nations, with the first 3 reported cases confirmed as late as 30 March 2020. From April 2020, initial measures were put in place by the Ministry of Health and Wellness to tackle the gradual increase in cases, which included contact tracing in Molepolole, Metsimotlhabe, Mahalapye, Bobonong, and Siviya, closing the national borders, and strictly imposing quarantine measures for those in contact with people with COVID-19 and people returning to Botswana, in accordance with World Health Organization (WHO) recommendations. In late September 2020, according to Worldometer, the country had a total of 2,567 coronavirus cases and 13 recorded deaths.

A public state of emergency was declared on 31 March by the president of Botswana, which was later extended until 2 October 2020. The government expanded its precautionary measures to control the virus, which included closing non-essential business and economic activities, banning gatherings of more than 50 people, closing schools (with teaching resuming in June 2020), and enforcing the wearing of face masks outside the home from May 2020. Towards the end of May 2020, lockdown restrictions were lifted and a 'zoning' strategy was introduced, whereby the country was divided into 9 COVID-19 zones with checkpoints to restrict movement between Boteti, Chobe, Ghanzi, Greater Francistown, Greater Gaborone, Greater Palapye, Greater Phikwe, Maun, and Kgalagadi. Certain locales, such as the Greater Gaborone zone, have since been put on lockdown again because of risks of a second wave.

The Ministry of Health and Wellness has coordinated a health response, as per the five-pillar response structure recommended by the WHO/UNDS framework (see Figure 1), providing funding for essential services to meet health and social protection needs, such as provision of personal protective equipment (PPE), tents, beds, accommodation, disinfectant, medical teleconsultations, additional health workforce, and welfare measures for workers.

In a recent impact analysis by UN Botswana, it was estimated that the economy could contract by approximately 13.1% because of COVID-19's effect on mining (-33.6%), trade and hospitality (-32.2%), manufacturing (-10%), social and personal services (-4.8%), and transport and communications (-4.1%). This is likely to increase levels of unemployment, with informal workers and those in vulnerable groups being affected the most. While lockdowns have helped to limit the spread of the virus, the reduced capacity of Botswana's healthcare system means that even slight increases in cases are expected to result in significant loss of life without a stricter containment response. In terms of social impact, attention has been paid to the guiding principle of 'leave no one behind', considering the concern that COVID-19 will disproportionately, and more severely, affect marginalised populations.

These populations include the following:

- People with disabilities, due to the increased likelihood of being out of work, and reliance on the informal economy.
- Women, due to increased risk of gender-based violence, and burden of unpaid family care.
- Children and youth, due to closure of educational institutions and growing unemployment, have a negative impact on learning outcomes and career stability.
- People in prisons, due to proximity in detention, and poor hygiene, food, and nutrition.
- Migrants, due to limited access to essential services and infrastructure, and increased vulnerability to financial shocks.
- People living with HIV/AIDs, due to a lowered immune system, which makes them more vulnerable to infections.
- Older people, due to being most at risk of severe illness/death from COVID-19, or living in crowded family conditions which make social distancing less possible.

Inequality in access to healthcare services among rural populations is also expected to be exacerbated by the COVID-19 pandemic, especially given Botswana's shortage of doctors and nurses, the number of which are well below the WHO recommendation of 10 doctors per 10,000 people and 2.3 nurses/midwives per 1,000 people. The redistribution of healthcare workers to respond to COVID-19 in locales that are already facing a shortage of staff is expected to have a significant impact on the smooth running and sustainability of sexual and reproductive health, HIV, and gender-based violence services. The closure of educational institutions is expected to further impact this shortage because of students' inability to graduate as planned. According to UN Botswana, the COVID-19 pandemic, coupled with relatively weak health management information systems, is reducing the availability of essential health products because of a disruption to the global supply chain for relevant equipment, medicines, PPE supplies, and testing kits.

Brief overview of the key engineering stakeholders in Botswana

The main PEI in Botswana is the Botswana Institution of Engineers (BIE), which consists of practitioners across numerous disciplines, including mechanical, civil, electrical, and mineral engineering, as well as industrial design, management, and technology, and architecture and planning. BIE was formed in 1983 with the aim of promoting the development, practice, and status of engineering in the country, emphasising its crucial role in national development as a whole. BIE registers all engineers, technicians, new graduates, and current students, and grants certificates after approval of membership. The Board of Council Members meets every 2 months to discuss BIE's strategic direction, and Members are nominated each year at the Annual General Meeting.

The Engineers Registration Board (ERB) is a statutory body that directly regulates the activities and conduct of engineers operating in the country, promoting the highest regulatory standards of engineering practice, as well as protecting the welfare and interest of the public in receipt of engineering services and developments. ERB was established by an Act of Parliament with the primary objective of ensuring that engineering work in Botswana is carried out for the public good. The functions of ERB are focused on registering engineers, issuing practising certificates, monitoring standards of engineering practice and ethics, conducting enquiries regarding alleged misconduct in the field, and prescribing eligibility requirements for people who want to practice engineering in Botswana.

Academic stakeholders include the Faculty of Engineering and Technology (FET) at the University of Botswana, and the Botswana International University of Science and Technology (BIUST). With regards to the former, according to the university's website, FET is dedicated to the following objectives:

- Producinghigh-quality engineering graduates who can adapt to the work environment and carry out their duties to the satisfaction of their employers.
- Responding to the needs of industry in all sectors of the Botswana economy.
- Responding to the needs of industry through research, consultancy, advisory and related services.
- Maintaining a continuous dialogue with industry and other relevant bodies to determine and fulfil any needs that may be raised.
- Providing access, with proper theoretical and practical backing, to recent developments in the technology sector, and preparing graduates for professional responsibilities.
- Preparing FET graduates to pursue further studies in their relevant engineering and technology disciplines.

Botswana International University of Science and Technology (BIUST) is a key actor in the engineering industry, as the only research-intensive university that specialises specifically in STEM at both undergraduate and graduate levels. The university is supported directly by the government as a national initiative and key capacity-building platform for transforming Botswana's economy from a resource-based to a knowledge-based one. BIUST regularly works with the private sector through applied research, and its curriculum takes into account the needs of some private businesses that have the potential to drive economic growth and development.

Private stakeholders include a variety of consultancy organisations that work with public institutions and offer services in many engineering fields. Mattra International-Civil Engineering Consultants, for example, offers consultancy services in geographical information system mapping, digital ground modelling, control and Global Positioning System (GPS) surveys, land surveying, structural design and geo-technical investigations of damages to infrastructure, as well as design and regulatory checks on civil structures, such as roads and bridges. Mattra also undertakes preliminary research in the engineering space, including feasibility studies and environmental impact assessments.

At government level, the main departments engaging in the engineering space are:

- The Ministry of Infrastructure and Housing Development
- The Ministry of Transport and Communications
- The Ministry of Agriculture
- The Ministry of Natural Resources and Environment

Impact of the COVID-19 crisis on the engineering industry in Botswana

COVID-19 has had a growing impact on the engineering industry in Botswana. Movement restrictions and social distancing appear to impact businesses in different ways, and most engineering work is dependent on face-to-face interaction and worker collaboration, most notably in construction, manufacturing and crafts, woodwork and metal work, and mining engineering. Mining is central to Botswana's economy, and the country faced an initial risk of mine closures. The Botswana Mine Workers Union and the Botswana Labour Migrants Association have requested donations from the private sector to provide social protection support to miners and to enable the continuation of key logistics, supply, and community support activities. At the end of March 2020, according to the Botswana Mine Workers Union and Botswana Labour Migrants Association, De Beers Group contributed tens of millions of dollars to support the government in mitigating the effects of the pandemic, with a particular focus on the mining industry.

Unemployment among engineers is also expected to increase, resulting in major economic contraction. This is reflected in some PEIs' views that engineering opportunities have decreased, and closures of existing projects that have taken place since the start of pandemic. Employers in the aerospace industry, for example, regularly employ a large number of engineers each year, but have not been able to do so because of cessation of international and domestic air travel. Some engineers are working from home, but are not sure if they have a secure job in the longer term.

Due to the closure of universities, BIUST responded by announcing the cancellation of in-person lectures and closure of dormitories, and by implementing plans to curtail the spread of the virus via virtual committee meetings, as well as driving forward options for online distance education. For international students and those without consistent or widespread access to the internet, Student Representative Council meetings have continued. It is felt by BUIST that a committed attitude to studies still remains, albeit remotely. For example, in the case of one module – Process Control in Chemical Engineering – staff have had to move communications with students to the messaging platform WhatsApp. This allows for real-time problems to be discussed and solved, and for presentations and other work to be shared with classmates and lecturers for regular feedback.

In terms of the impact on PEIs themselves, BIE has observed that some members are already defaulting on payments for membership subscriptions. This is because they are reluctant to part with money for non-essential reasons if they are not sure whether they have a job and a reliable salary to depend on during the pandemic or in the aftermath, in case of a recession.

2. Engineering response in Botswana

The position of key engineering actors

At national level, the government of Botswana has prioritised a public health response across sectors relevant to engineering, and acted quickly to establish a COVID-19 response plan, with a range of prevention and containment measures, prior to registering positive cases in the country. The Ministry of Health and Wellness has proposed an operational planning, preparedness, and response framework that can be applied to the engineering industry.

It is clear that PEIs and other key engineering stakeholders have adopted an approach that prioritises engineers' health and welfare by closing or halting all in-person business. Dr Kereng Masupu, Botswana's COVID-19 Task Force Coordinator, has made it clear that the government will respond in accordance with the disease pattern, noting that a return to lockdown is always an option.

ERB has continued to express the view that COVID-19 is a "major concern", and has encouraged any customers and ERB staff to avoid visiting their offices and to "follow guidelines and protocols put forth by public health officials". ERB has developed clear guidance (including informational videos delivered by the ERB Registrar, released on the ERB website and Facebook) regarding COVID-19 safety measures. It is now introducing webinars to replace workshops and lectures, and It offers dedicated contact by email, phone, and Facebook for reporting of malpractice or other serious issues. ERB also sends certificates to engineers via courier to minimise visits to its premises, and is undertaking 'enhanced monitoring'.

BIE has similarly been proactive in communicating lockdown measures via social media posts, including encouraging members to observe the 'hierarchy of controls', setting out effective means of controlling the virus: elimination (staying home), substitution (remote working), engineering controls (hand washing), administrative controls (social distancing), and use of face masks to protect oneself and others.

The contribution of engineers to tackling the crisis

The higher education sector has been pivotal in tackling the COVID-19 crisis in Botswana. Many PEI members who are also university students or recent graduates have been engaged in innovative developments to help monitor and directly address immediate needs that have resulted from the pandemic. Alongside the development of essential PPE, including face shields, ventilation hoods, face masks, and ventilators, researchers within the Faculty of Engineering and Technology (FET) at the University of Botswana have created sophisticated software tools to facilitate tracking of the virus. Such tools include a **web map visualisation** and **live tracking dashboard**, developed in collaboration with the Botswana Institute of Geomatics, which is able to track and record data and real-time trends on COVID-19 cases in the country, as well as self-assessment applications for remotely monitoring the status of patients in quarantine. According to the university's Vice Chancellor, there are currently 3 software tools in operation, which will help "drive data received from the Ministry of Health and Wellness Department of Monitoring and Evaluation for assessment and analysis to assist in real-time decision-making".

In recognising that faculty members and students of the university have made huge headway with such developments, cross-country partnerships are already being formed. On 25 June 2020, the Vice Chancellor met with Chinese Ambassador Dr Zhao Yanbo to discuss and agree on the establishment of an ETIC at the university. According to the university's website, the ETIC will be used as a platform for "research collaboration, design, prototyping, testing and building innovative solutions", using the latest technology and manufacturing tools. The centre is designed to provide sufficient space, tailored facilities, and business support for students, alumni, staff, and the public to develop viable prototypes and ideas to tackle the pandemic now and post-crisis, with a view that such efforts "should help create jobs, drive innovation, and foster a knowledge-based economy". The Chinese Ambassador noted the importance of the strategic partnership, highlighting that the university "carries the important mission of developing innovative technologies and cultivating innovative talents for Botswana" during this crisis.

Similarly, BIUST has started working collaboratively with the government of Botswana on mitigating the spread of COVID-19 by undertaking the following projects:

1. **Production of sanitiser:** The production and provision of sanitiser for the community of Palapye and surrounding villages is a project that has been undertaken in collaboration with Morupule Coal Mine. The sanitiser is produced according to WHO standards and the Botswana Bureau of Standards specifications on hand sanitiser.

2. **Design of sanitiser dispensers:** Sanitiser dispensers have been designed and manufactured to be used in public areas, such as hospitals and clinics.

3. **Production of soap:** BIUST has partnered with the Local Enterprise Authority for provision of much needed production equipment to ensure sufficient production of BIUST bathing soap and liquid soap for the national market. The bar soap was tested by the Botswana Medical Regulatory Authority and is safe for use for general bathing purposes.

4. **Drone projects:** The aim of these projects is to disinfect the air in open public spaces during the COVID-19 pandemic. The air disinfection by drone is intended to work in collaboration with manual disinfection of ground surfaces. Drone sprayers have been developed by the SImulation Machine Learning, Robotics and Technopreneurship (SMaRT) Laboratory.

5. **Development of a dashboard:** A dashboard for visualising the COVID-19 pandemic in Botswana has been developed through a collaboration with iThemba LABS, and the University of the Witwatersrand. This dashboard gives a detailed analysis of COVID-19 using maps, diagrams, graphs, and pie charts.

6. **Development of Botswana COVID-19 e-permit application:** This project aims to digitise the COVID-19 permit application process. Through this application, law enforcers will be able to verify the permits issued by scanning a barcode, which will have been sent to the applicants upon approval of their application.

How engineers have collaborated during the crisis

The engineering industry in Botswana has been proactive in locally identifying and operationalising partnerships and collaboration opportunities within the public and private sector, as well as appealing to global actors with a vested interest in keeping the Botswanan economy and engineering industry afloat. The ETIC demonstrates that academic institutions and other country governments are coming together to share knowledge and address the immediate health needs of the population.

Due to the impact the pandemic has had, or is likely to have, on global engineering stakeholders, private corporations have already stepped forward to support local operations. De Beers, with key partners and beneficiaries in Botswana, have been proactive in supporting suppliers and manufacturers in the mining sector through monetary and in-kind donations, social protection for workers, and research and development investments in order to ensure the mining economy is protected.

The government is directly supportive of these collaborative, symbiotic efforts, given how the pandemic has highlighted the extent of global interdependency and interconnectivity. In a statement to the UN Global Compact Leaders Virtual Summit, the President of Botswana expressed a clear need to "work together as the international community, governments, private sector and the civil society through innovative partnerships".

3. Women's engineering groups' response to COVID-19

BIE has continued to promote the role of women in engineering and includes a women's chapter, which is in charge of organising and delivering learning events, such as workshops and seminars, to promote female participation in STEM and, specifically, engineering. Women Engineers Botswana (WEB) is a community of young women that was set up in order to create a network and platform for knowledge exchange and mentorship, aiming to "give back to the community". According to the WEB website, the platform serves as:

- A motivational tool to meet the intellectual needs and aspirations of young women in Botswana.
- An opportunity to share stories that inspire and motivate youth to pursue careers in science and engineering.
- An organisation to create science clubs in Botswana to expose youth to STEM.
- An opportunity to provide mentorship programmes for young people in primary and secondary schools.

At the time of writing this chapter, there do not appear to be any programmes specifically run by women's engineering groups in direct response to COVID-19. However, the Botswana Women in Construction Organisation (BWICO), a non-profit organisation registered under the Society Act of Botswana and formed in June 2019, has been proactive in communicating and sharing ERB updates and other health protocols to remind its followers that remote services are still available. BWICO aims to promote the active participation of women in the construction sector, including via webinars run to explore the impact of COVID-19 on the built environment in the country.

4. Post-crisis outlook

Proactive engagement with the private sector and cross-country collaboration, endorsed and proactively planned early by the government, have been instrumental in helping Botswana's economy and engineering profession to remain afloat. The government has continued to prioritise public health and the social protection of workers in key industries above economic considerations, which in the longer term may secure a more stable post-crisis outlook for engineers.

However, PEIs have expressed the view that the engineering profession requires more cross-sectoral engagement to tackle the longer-term impact of the pandemic on society at large. It is felt by PEIs that it is incumbent for them to work directly with government and other sectoral experts to exchange best practices, as the pandemic evolves in an unpredictable manner. WASH services are a prime example of this. Botswana is a landlocked country with a vulnerable population that is at further risk of lack of clean water, particularly for large households where social distancing is a challenge. Alongside sectors that are more traditionally associated with engineering, WASH is a key aspect of Botswana's COVID-19 action plan, under which further partnerships can be fostered, and engineers can assist in real time to address population health needs at a more systemic level.

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Cameroon

1. Context/background

Overall impact of the COVID-19 crisis in Cameroon

Government's immediate response

According to the WHO COVID-19 dashboard, as of 21 October 2020, there were 21,570 confirmed cases of COVID-19 in Cameroon, with 425 deaths. The first case of the virus was detected in early March 2020 and on 18 March, Prime Minister Joseph Dion Ngute closed Cameroon's borders. On 30 March, the Minister of Health announced the imminent launch of a COVID-19 testing campaign in the city of Douala, where dedicated teams went door to door from 2 to 6 April. On 10 April, the government took 7 additional measures to stop the spread of COVID-19 in Cameroon, including:

- Wearing of masks in all open public areas.
- Local production of drugs, screening tests, protective masks, and hydro-alcoholic gels.
- Establishment of specialised COVID-19 treatment centres in all regional capitals.
- Intensification of the screening campaign with the collaboration of the Pasteur Centre.
- Intensification of the awareness campaign in urban and rural areas in both official languages.
- Continuation of activities essential to the economy in strict compliance with the Directives of 17 March 2020.
- Sanctions, including arresting those that disobey the regulations.

On 5 May, the Minister of Health announced the provision of 50,000 coveralls, 320,000 surgical masks, 220 backpack sprayers, and 10,000 pairs of shoe covers for healthcare personnel.

As detailed in a report by the Joint UN Programme on Human immunodeficiency virus/Acquired immune deficiency syndrome (HIV/AIDS) from May 2020, the Cameroonian response has faced significant constraints, not least the lack of capacity to scale up testing and expand contact tracing, and the inability to provide Intensive Care Unit (ICU)/ventilation support for the seriously ill, as well as adequate PPE for medical staff.

The rapid implementation of community education programmes, emphasising hand hygiene and social distancing, is an ongoing challenge, especially in poor, often overcrowded urban areas. This is indeed a major challenge in Cameroon, as there is a lack of consistent water supply in many urban and rural communities. Furthermore, the use of hand sanitiser is not an affordable option for most people, and the locally produced product is not necessarily quality assured and safe for use. There are also legitimate concerns about how a full lockdown could affect the majority of people, as more than 80% of the population work in the informal sector and live hand to mouth. Yet, from a public health perspective, lockdowns are a must, and balancing concerns is a major challenge.

Even though the implementation of the Risk Communication and Community Engagement strategy resulted in greater awareness among urban and rural communities, community resistance remains the main impediment to slowing down the spread of the pandemic. Although now compulsory, the wearing of masks and social distancing are hardly complied with, both in rural and urban areas. Discrimination and stigmatisation are rampant when COVID-19 is mentioned. Meanwhile, the lifting of major restrictive measures has given ground to all kinds of fake news, spurious information, and rumours, which, ultimately, further exacerbate the risk of rapid spread of the virus. According to the Human Rights Watch, Cameroon's ruling party was using the pandemic to settle scores and punish the opposition, not allowing them to participate in the response to COVID-19. On 11 May, 6 volunteers from the Survival Initiative, a fundraising initiative launched by opposition leader Maurice Kamto to respond to the health emergency, were arrested while giving away free protective masks and sanitising gel to people in the capital Yaoundé. The volunteers face charges of rebellion and remain in detention; if found guilty, they could face up to 4 years in prison.
In addition, in May, the Minister of Health rejected a donation by Maurice Kamto's Survival Initiative of 16,000 protective and surgical masks and 950 COVID-19 screening tests, claiming the initiative had not been legally established. On 7 April, the Minister of Territorial Administration, Paul Atanga Nji, told those fundraising to fight COVID-19 to stop and urged citizens to make contributions to the Special Fund of National Solidarity, created by Cameroon's president, Paul Biya. On 9 April, Nji ordered the accounts of the Survival Initiative to be closed and its money frozen, and later called for an investigation into the initiative. He also told communication companies to close the mobile accounts opened to support the fund.
The arrest of the 6 volunteers shows the steps the government is willing to take to crack down on any efforts by the opposition, fuelling political divisions when joint efforts are most crucial.

Refugees

For several years now, Cameroon has been affected by the conflict in neighbouring North East Nigeria, and the continuous violence in Cameroon's Northwest and Southwest regions. According to Doctors Without Borders, these crises have led to the displacement of hundreds of thousands of people, caused humanitarian needs to soar, and drastically reduced access to healthcare in these regions, which have become particularly vulnerable.
There are more than 350,000 refugees in Cameroon, and the overcrowded and unhygienic conditions, which are common in the refugee camps in those regions, increase the potential for the rapid spread of COVID-19. The population in refugee camps has to rely on public hygiene infrastructure, potentially exposing people to contagion due to physical proximity and lack of hygiene.

Brief overview of the key engineering stakeholders in Cameroon

There are various engineering stakeholders in Cameroon:

- **The Ministry of Scientific Research and Innovation** is responsible for the development and implementation of the government's policy in the field of scientific research and innovation for the promotion of economic, social, and cultural development.

- **The Ministry of Public Works** is responsible for the technical supervision of all infrastructure projects. Among others, the Ministry is in charge of the country's motorway infrastructure, extending the network of asphalt roads, and fighting against the overload of large goods vehicles, which are prejudicial to the lifespan of the roads.

- **The National Order of Civil Engineers** was established by Law no. 2000/09 of 13 July 2000 relating to the organisation and practice of the profession of Civil Engineer. Placed under the supervision of the Ministry of Public Works, it has 2 main bodies: the General Assembly and the Council of the Order. The mission of the Order is to maintain the principles of morality and dedication, essential to practising civil engineering. The vision of the Order is to become a unifying body and a benchmark for professionalism and expertise in civil engineering.

- **The Professional Association of Consulting Engineers and Engineering Companies of Cameroon** brings together engineering service providers who are legally constituted as companies and whose mission is to provide, at the request of customers, assistance for the realisation of projects in the fields of civil engineering, building, energy, environment, hydraulics, computer engineering, climate engineering, etc.

- **The Cameroon Welding Association** is a group of professionals in mechanical engineering and welding, whose mission is to organise the dissemination of framework research and to develop training tools that will enable its members to meet the competitive requirements of the labour market. The association has one office in the university of Douala and aims to have offices in every region in Cameroon.

- **Engineers Without Borders (EWB) Cameroon** is a non-profit association, founded in 2003 by young engineers who wish to contribute to human development through access to technology. The organisation is composed of active engineers and engineering students who would like to improve the quality of life of communities with the help of sustainable engineering projects that directly meet their needs, while preserving natural resources.

- **The University Agency for Innovation (AUI Techno)** is a pan-African company, which started its activities in Cameroon in 2016. Its vision is to see Africa emerging through innovation and locally-made products. The city of Yaoundé hosts the company's headquarters and commercial office. As for the production workshop, it is located in Bafoussam, the capital of the Western administrative region.

- **The National Advanced School of Engineering of Yaoundé** was founded in 1971. The university is one of the most prestigious technological higher education institutions in SSA. Its aim is to train engineers and senior executives in engineering trades, promote research in its fields of training, and develop support in the form of service delivery.

2. Engineering response in Cameroon

The position of key engineering actors

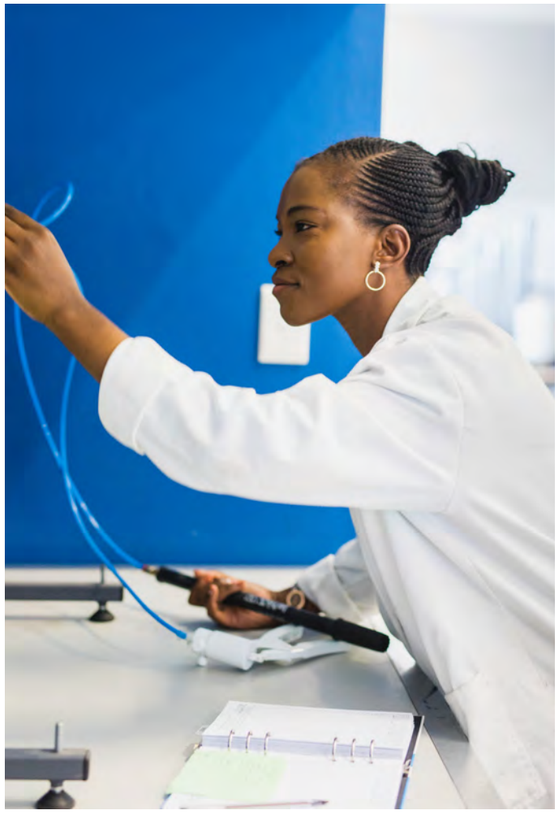
Not all the key stakeholders mentioned above have published their position/stance on the pandemic on their websites or social media platforms. However, 2 actors have been regularly updating their websites with content related to COVID-19. The Ministry of Scientific Research and Innovation has published a number of small case studies on its website, detailing the efforts made to mobilise a response to the pandemic, led by Minister Dr Madeleine Tchuinté. This includes setting up the Cameroon Academy of Sciences week (6 to 8 October 2020), a three-day conference bringing together researchers to discuss science and the fight against COVID-19. According to the Ministry, this was an opportunity to reward Cameroonian researchers who have excelled in recent years with the relevance of their research, and to see new perspectives on scientific research and its contribution to the development of well-being. Professors Leke and Mbatcham, and Dr Sobngwi presented the results of the implementation of a vaccine and the care for patients with COVID-19.

In addition, AUI Techno has dedicated a section of its website to its 'anti-COVID technologies'.

The contribution of engineers to tackling the crisis

Ventilators

Arthur Zang, a bio-medical engineering graduate from the National Advanced School of Engineering of Yaoundé, created the Oxygen National Network (Oxynnet). Oxynnet is a medical oxygen-producing station, which is vital for patients with COVID-19. According to the United Nations Development Programme's (UNDP) *Africa Innovates* magazine, an hour of access to a ventilator costs roughly £14 (XAF Fr 10,000), which is unaffordable to many. According to Arthur, Oxynnet, which is a set of interconnected medical oxygen generators, will allow each hospital to produce its own oxygen. Each Oxynnet station is connected to the electricity network and produces 93% pure oxygen from the natural air. The station has a battery and a solar panel and is 3G-enabled, granting users and operators the ability to monitor it effectively, even remotely by using mobile phones. Oxynnet is a big boost in the COVID-19 fight, as it is affordable, easy to assemble, and adaptable for both cities and remote regions. Zang won the Africa Prize for Engineering Innovation in 2016.



In addition, AUI Techno has been highly active in its response to the COVID-19 pandemic. The organisation's teams have designed a respirator for infected critical patients, a portico for disinfecting people in public buildings, and an autoclave for the sterilisation of medical equipment in hospitals.

Disinfection portico

The Cameroonian engineer Serge Armel Ndjidjou (manager at AUI Techno) and his team created a disinfection portico, which disinfects people upon entering a public building. Therefore, if someone is carrying the virus, they will no longer be able to transmit the disease because their clothes, shoes, and skin are decontaminated. This constitutes an effective way to fight the exponential spread of the virus and contributes to the health security of citizens. The machine costs €400 (XAF 260,000). In the second half of July 2020, the company had already delivered it to about 50 large customers: ports, banks, schools and universities, travel agencies, hospitals, radio stations, leisure 'establishments,' and cement factories, among others.

Use of drones to map out COVID-19-infected areas

According to the Ministry of Scientific Research and Innovation's website, on 25 March 2020, the Minister, Dr Madeleine Tchuinté, met with a team of young innovators to propose a protocol for the use of drones and related technologies in the fight against COVID-19 in Cameroon. The team of young researchers proposed a range of solutions, including:

- Urgently mapping the infected areas or areas with high infection potential.
- Carrying out a campaign to disinfect public spaces and large gathering areas (such as markets) using aerial spraying.
- Carrying out a dissemination and awareness campaign through airborne messages.
- Detecting potential carriers of COVID-19 using aerial and terrestrial thermography techniques.
- Delivering survival kits and medicine by drones, where appropriate.

The OuiCare platform

Emmanuel Assom's OuiCare is a simple and scalable health platform that allows users to securely save their medical data, access it at any time, and make appointments with health professionals for consultations. OuiCare is also a digital health record that allows health facilities to quickly have reliable and up-to-date information on patients. The platform is designed so that healthcare personnel have minimal loss of time when accessing patients' medical data and, therefore, treat patients more quickly. According to the founder, the idea came about from the fact that the majority of deaths in SSA were due to a lack of access to patients' medical history, which greatly hinders their management. The lack of medical information is one of the major challenges for public authorities and health facilities. At present, there is still a lack of medical data and statistics in SSA in general, and in Cameroon in particular.

According to an interview with Assom, in response to the pandemic OuiCare now includes statistics on the disease in Cameroon and the rest of the world, as well as advice to protect people from the pandemic. In addition, the platform now shows informative articles and has 2 new features: the forum, which allows doctors to respond to users' concerns, and the tele-consultation module, which allows users to contact doctors directly by video. The second feature allows individuals to ask healthcare professionals questions about COVID-19, and to describe their symptoms, so that doctors can determine whether hospital treatment is necessary. This feature has a direct impact on limiting travel for patients that can be diagnosed and treated remotely, giving doctors more time to concentrate on people with COVID-19. According to Assom, the pandemic has increased the use rate of OuiCare, from an average of 53% to 82%.

Masks

The National Advanced School of Engineering of Yaoundé is printing 3D protective visors, designed by Israeli engineers. These protective visors are intended for Cameroonian healthcare workers on the frontline of the fight against COVID-19. It is important to emphasise that this initiative is led by the Embassy of Israel in collaboration with the United Nations Office for the Coordination of Humanitarian Affairs (OCHA), the National Advanced School of Engineering of Yaoundé, and the Ministry of Health. Thanks to the cooperation with the State of Israel, the High-Tech Centre for 3D Printing has become Cameroon's engineering incubator. It has fully developed software for the production of visors and respiratory devices for hospitals in Cameroon, with the potential to equip the entire Central African sub-region with protective visors and other medical equipment. As the COVID-19 pandemic spreads, Cameroon wants to produce its own masks in cooperation with Israel. Thanks to its 3D printing centre, the National Advanced School of Engineering of Yaoundé can produce 400 masks per day.

How engineers have collaborated during the crisis

According to the Research and Analysis Initiative for Sustainable Development in Cameroon (IRADDAC), a Cameroonian think tank on sustainable development issues in Central Africa, the pandemic has provided an excellent opportunity to strengthen cooperation links between the government, its international partners, as well as several companies and civil society.

National collaboration

The Ministry of Scientific Research and Innovation has collaborated with a number of ministries during the pandemic, including with the Ministry of Health and the Ministry of Higher Education, to join forces (including knowledge and resources) against COVID-19. For example, on 15 July 2020, an inter-ministerial consultation meeting took place, which included the Minister of Scientific Research and Innovation, the Minister of Higher Education, the Minister of Public Health, the Minister of Basic Education, and the Minister of Mines, Industry and Technological Development. The aim of the meeting was to "lay the foundations for rich collaboration between private research actors working in the field of alternative medicine and those of institutional research with the supervision of the government".

International collaboration

In addition, the Minister of Scientific Research and Innovation of Cameroon held meetings with ambassadors from several countries, including Israel, France, and Turkey, to strengthen their collaboration with Cameroon during the pandemic. On 14 April 2020, Turkey provided Cameroon with equipment consisting of safety glasses, PPE suits, shoe covers, gloves, contactless thermometers, and hydro-alcoholic gel.

The Minister of Scientific Research and Innovation also met with the Ambassador of Israel to Cameroon on 19 May 2020 to review their cooperation in various areas, including the pharmaceutical industry, agriculture and energy research, and the training of young researchers. The Ambassador said he was ready to continue to support Cameroonian scientific research and innovation. The diplomat also promised that Israel would spare no effort to advance this cooperation in these difficult times. In addition, the Israeli Embassy showed its support for Cameroon through a donation of medical equipment.

On 1 July 2020, Cameroon's Minister of Scientific Research and Innovation met with the Ambassador of France to Cameroon to discuss the scientific and technical cooperation between the 2 countries. It was an opportunity for the 2 parties to explore ways and means of collaboration in the field of manufacturing vaccines and other improved drugs. The aim of this cooperation is to strengthen Cameroon's capacities for an effective and efficient response to COVID-19 and other diseases.

Finally, Cameroon also received several donations from the United Nations Children's Fund (UNICEF) and the International Monetary Fund (IMF). IMF has donated 2 instalments of emergency disbursement under the Rapid Credit Facility (RCF) to the country, bringing total IMF emergency support since the outbreak of the pandemic to SDR 276 million (about $382 million (SDR 276 million, 100% of quota). Additional resources under the RCF will help address urgent financing needs to mitigate the impact of the pandemic, including spending on health, social protection, and to support the most vulnerable, as well as catalyse additional donor resources.

3. Women's engineering groups' response to COVID-19

Women's engineering groups are still not very active in Cameroon. There are a couple of women's groups dedicated to the overall promotion of women in STEM. These include the Association of Women Engineers and Scientists in Cameroon, and the Organisation for Women in Science for the Developing World (OWSD) Cameroon national chapter (established in March 2019), hosted at the University of Yaoundé. However, these groups have not mobilised a response to the pandemic. That is not to say that individual women engineers have not contributed, however.

4. Impact of the COVID-19 crisis on young engineers, education and skills

The pandemic saw the closure of all public and private training establishments in Cameroon, including vocational training centres, moving their activities online. As seen all over the world, this is likely to exacerbate existing inequalities between richer and poorer communities, as poor communities are more likely to lack the adequate infrastructure to pursue their studies online.

However, in a press release from 20 March 2020, the Minister of Higher Education in Cameroon claimed he saw the pandemic as an opportunity to showcase the country's potential in the field of distance education and remote assessment, and released an e-learning platform to ensure the continuity of teaching. Indeed, various universities have successfully moved their activities to e-learning platforms. Moreover, the African Institute of Informatics developed **Invite Test** – a first-of-its-kind mobile app that can monitor students' workstations during an assessment and uses facial recognition to allow virtual examiners to detect more than 20 types of cheating.

5. Post-crisis outlook

Between April and May 2020, an analysis of the socio-economic impact of the pandemic was carried out under UNDP leadership in Cameroon, and the results show that overall, 82.6% of business leaders reported a drop in production. However, this situation is more pronounced in formal sector enterprises than in the informal sector. In terms of impact, almost half of the negatively affected companies say they have recorded a drop of more than 50% in their production. Regarding the impact of this pandemic on households, the study highlights that 62.7% of households are experiencing a deterioration in their standard of living. Although most of the individuals surveyed have not lost their jobs, many are experiencing critical slowdown of their activity (74%) and a dramatic drop in their income (65%).

According to UNDP, urban sectors of the economy (manufacturing and services) are expected to be hit hard, leading to substantial losses in productive jobs. Urban consumption and expenditure (of food, manufactured goods, utilities, transport, energy, and services) is likely to experience a sharp fall considering COVID-19-related lockdowns and restrictions. Vulnerable groups, including small-scale farmers, pastoralists, and fishers, might be hindered from working their land, caring for their livestock, or fishing. They will also face challenges accessing markets to sell their products and buy essential items, due to higher food prices and limited purchasing power.

Engineers will play a critical role in deciding Cameroon's post-crisis outlook. According to a governmental press release statement of July 2020, public action for the period 2021–2023 will focus on controlling the health crisis and mitigating the impact of COVID-19.

Evaluation of the local industry

Another key vision for 2021 to 2023, according to the Prime Minister's website, is based on the import substitution policy and the reduction, or gradual abolition, of exemptions on certain products that burden the balance of trade. This will promote local production on a larger scale.

In addition, various types of facilities will be granted to national producers to promote the 'Made in Cameroon' label, with special emphasis on improving the profitability and competitiveness of public enterprises. According to IRADDAC, COVID-19 has enabled the enhancement of local production.

The Association of Students of the School of Engineering, at the Faculty of Industrial Engineering, University of Douala, has opened a laboratory to manufacture hand sanitiser products that meet WHO standards. The same goes for the chemistry laboratory of the Faculty of Sciences at the University of Maroua.

The founder of Oxynnet said: "To produce each Oxynnet station, we use 75% local material and 25% material imported from Asia. The biggest challenge for us will be to get the materials we need and to deliver the product to rural hospitals. We need financial assistance to deliver the essential product. My hope is to launch a factory in 2020 and produce 400 Oxynnet stations per year, as well as many other life-saving medical appliances like ultrasound, Electrocardiogram (ECG), and Electromyography (EMG) devices."

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Ghana

1. Context/background

Overall impact of the COVID-19 crisis in Ghana

Building on lessons learned from the 2014–2016 Ebola outbreak in West Africa, Ghana was better prepared than other countries to deal with the COVID-19 outbreak. In February 2020, the use of alcohol-based hand sanitisers and gloves, and temperature monitoring, were already common in most public service places and airports. In February, when cases of COVID-19 was spreading, health ministers from the 15 member Economic Community of West African States (ECOWAS) met in Mali to develop a **regional preparedness plan and boost cross-border collaboration** to promote rapid diagnosis and containment. The African Union's Africa Centres for Disease Control and Prevention agency is taking a leading role in the response to the virus outbreak. However, COVID-19 is likely to cause disruptions in supply chains for drugs and PPE at global level, subsequently threatening the supply of important medicine and equipment in Ghana. This has forced the country to harness local resources in order to design and produce essential materials.

The **government's response** has been rapid and multipronged. According to Ghana's president, Nana Akufo-Addo, the COVID-19 pandemic has highlighted flaws in the health system resulting from years of underinvestment. There are around 9 hospitals for every 10,000 Ghanaians, according to the WHO. On this basis, the President has announced plans to build 88 district hospitals, 6 regional hospitals and 3 infectious disease centres in coastal, central, and northern Ghana.

The Ghana Health Service (GHS) is the body responsible for implementing **health-related national policies** under the control of the Ministry of Health. It advises the government in decision-making in relation to the COVID-19 pandemic, including strategies for effective contact tracing. The GHS runs a real-time online monitoring system for COVID-19 in Ghana. It has partnered with the Ghana Medical Association on public education and with telecommunications companies to gather the necessary data for effective contact tracing.

Health experts advised a total lockdown as key to eradicating community spread in the epicentres of the outbreak, but such a decision would have posed threats to the survival of many and would have had substantial economic implications. For this reason, the length and severity of the lockdown was limited, and the government put in place a range of **social and economic mitigation measures**. These include countless cash and kind donations from individuals, churches, private and public bodies to hospitals, research centres, prisons, communities, etc. The Ministry of Gender and Social Protection in collaboration with the National Disaster Management Organisation, metropolitan, municipal and district chief executives, and faith-based organisations, have been involved in the distribution of food and other supplies to vulnerable groups in the community under lockdown measures. In April, the President of Ghana announced the provision of a free water supply and a 50% waiver on electricity consumption for these residents for the period between April and June 2020. Frontline health workers have been offered a 50% increase in basic salary and life insurance cover.

The COVID-19 pandemic poses a significant economic risk to Ghana, given the country's economic and fiscal exposure to downturns in the oil and tourism sectors. Exports, such as gold and cocoa, have been negatively affected by the crisis. As a result, the Bank of Ghana has implemented measures to boost liquidity, such as cutting the monetary policy rate and interest rates. In addition, the government of Ghana has requested support from the IMF and the World Bank in an attempt to close the financing gap in the 2020 budget.

The World Bank is providing a £75.7 million loan to Ghana to assist the country in tackling the COVID-19 pandemic, in the form of short-, medium-, and long-term support to the government and the population. This funding includes the **Ghana COVID-19 Emergency Preparedness and Response Project**[35], which will help strengthen Ghana's national laboratories by providing robust systems for the early detection of COVID-19 cases, as well as real-time disease surveillance and reporting systems for outbreaks. It will also improve response systems by providing social and financial support and free health services to COVID-19 patients and families who are isolated or quarantined. The project will focus on risk communication and community engagement for increased awareness and compliance with prevention measures, engaging the Ministry of Health, the GHS, the Ministry of Information, and other agencies. Through the emergency component of the Greater Accra Resilient and Integrated Development project (GARID), the World Bank will finance laboratory equipment and chemicals, essential medical equipment, and supplies, including test kits and PPE.

35 'Ghana COVID-19 Emergency Preparedness and Response Project', World Bank, 24 May 2021.

Brief overview of the key engineering stakeholders in Ghana

The 2 PEIs that license engineering practitioners are GhIE and the Institute of Engineering and Technology Ghana (IETG). GhIE organises the engineering profession in the country by ensuring that it is conducted in accordance with ethical and quality standards. It sets and upgrades these standards and uses them to coordinate the profession, as well as guiding the professional development of its members through seminars, courses, and events. GhIE has had a Women in Engineering branch since 1999. This is mostly composed of young women engineers, who regularly organise activities such as career guidance events and sessions in basic and tertiary education schools, and offer advice to partner institutions on how to promote the profession among women.

The focus of IETG is the professional development of local engineers. To this aim, IETG organises courses, seminars and conferences, builds strategic partnerships with country stakeholders, and engages with the government at all levels in an attempt to influence policymaking.

At government level, the main engineering stakeholders are the Ministry of Roads and Highways, the Ministry of Works and Housing, the Ministry of Transport, and the Ministry of Trade and Industry. During COVID-19, the government of Ghana has interacted with faith- based organisations, traditional rulers, market women[36], owners of public transport, pharmaceutical manufacturers and industries, leadership of parliament and others on how best to partner and address the country's needs in fields such as public education, expansion of infrastructure, and local manufacturing of PPE and other materials. Among the top technical universities in Ghana, renowned for their engineering departments, are the Kwame Nkrumah University of Science and Technology, the Accra Institute of Technology, the University of Ghana, the Regent University College of Science and Technology, the Ashesi University, and the Ghana Communication Technology University.

Impact of the COVID-19 crisis on the engineering industry in Ghana

Society as a whole, and the engineering industry as part of it, has been affected by COVID-19 and the related lockdown measures. However, some engineering disciplines have been more affected than others, be it positively or negatively. Firms and businesses in African cities are highly vulnerable to COVID-19-related effects, especially SMEs, which account for 80% of employment in Africa. **Civil engineering** has suffered from lockdown and health and safety measures, as well as spending cuts, which have stopped works on critical road and infrastructure projects. Given the importance of providing basic drinking water and sanitation services during the pandemic, engineers have had a critical role to play in strengthening water production and distribution systems, as well as quality controls, to ensure adequate service levels in terms of continuity, quantity, and quality. **Transport engineering** will have to deal with the challenges that social distancing and health protocol practices pose to fleet availability and the operational sustainability of public transport.

At the same time, disciplines such as **computer, electronic, and geospatial engineering** have thrived during the crisis, as geographic information systems and big data have played an important role in the tracking, modelling, and monitoring of COVID-19 cases and hotspots.

In addition, the pandemic has revealed Ghana's reliance and dependence on international trade, and has shown how vulnerable supply chains are to sudden and unexpected disruption, which can result in a disruption of economic activities. However, this disruption to global supply chains and the impact of depreciating currencies on import costs might have a positive impact on local manufacturing. This in turn could re-emphasise the importance of building domestic capacity and drive up **industrial construction** as a result.

Finally, engineering disciplines and industries that are highly reliant on **digital skills**, or have been able to adapt more quickly to remote ways of working, have been able to mitigate the negative effects of the pandemic, or even take advantage of it.

36 Most traders in Ghana's open marketplaces are women. Overa, R. (2007). When men do women's work: structural adjustment, unemployment and changing gender relations in the informal economy of Accra, Ghana. J. of Modern African Studies, 45, 4.

2. Engineering response in Ghana

The position of key engineering actors

As shown in the sub-section below, GhIE has collaborated with both the government and the private sector to equip the country with a much-needed health facility to treat COVID-19 patients. In light of this, GhIE Executive Director Kwabena Agyei Agyepong said: "This pandemic has brought the best out of Ghanaians." According to Agyepong, collaboration between GhIE, the government, and the private sector "shows the Ghanaian that in times of need, we can rally together and put the nation first. In this struggle against this very deadly pandemic that we cannot see, the Ghanaian has shown that we can work together, rally around, and support ourselves."

The contribution of engineers to tackling the crisis

The contribution of engineers to fighting the COVID-19 outbreak in Ghana has been diverse – from mobile applications, to drones, infrastructure and equipment, and dashboards and webinars. In the sub-sections below, we describe some of these initiatives, categorised by type of intervention.

App-based solutions

Cognate Systems

Cognate Systems is a Ghanaian software engineering company that is using technology to track COVID-19 symptoms and hotspots in the country. Through a platform called Opine Health Assistant (OHA), and using the accessible mobile technology USSD, people can self-report their possible COVID-19 symptoms and location. By dialling a USSD code on their mobile phones, users can answer questions about symptoms and other COVID-19 risk factors (as established by WHO), who they have been in contact with, their age, and travel history. Users are also asked if they need essential supplies such as food and shelter in the wake of the pandemic. The platform is free to use and can be accessed via any mobile device, even without credit or internet connection. This helps to remove many of the barriers to adopting technology for symptom tracking. So far, 6,000 people have used OHA.

Thanks to the team's expertise in software engineering, data science, and AI, the platform is able to gain important insights from the data collected. Based on the information given by users, the team can predict if a person is likely to be infected by the virus, as well as identify new regions that are likely to see a spike ininfections.

Data collected from USSD is stored in OHA and visualised on maps and graphs to make it easier to understand, monitor, and share information. The data collected can be shared with public health experts, data scientists, relief providers, and disease surveillance teams, who can use it to provide local solutions to COVID-19, including preventative measures. For example, using data from OHA, medical experts can get in touch with users who report symptoms to assist and reassure them amid the psychological stress that comes with self-isolation. Using the location of users who have expressed need for food or shelter, OHA links them with agencies, churches, and non-profit organisations that are in the company's database and can provide those services in the region. Details of nearby food banks or shelters are provided to users via Short Messaging Service (SMS).

Cognate Systems has been in contact with the government of Ghana, with the aim of urging it to use the OHA platform to identify COVID-19 symptoms and hotspots. In the future, the platform has the potential to be used to monitor different diseases in Ghana.

Redbird

To counter the spread of COVID-19 on the African continent, the Ghanaian e-health startup Redbird has launched the COVID-19 Daily Check-in app and Symptom Tracker. Founded in 2018, Redbird is a medical diagnostics distributor providing access to health monitoring through community pharmacies (it was previously located only in centralised hospitals). In particular, the startup offers in-pharmacy testing for various chronic and acute conditions and enables pharmacists to track the results of their customers over time and manage their stock accordingly. The startup received funding from Gray Matters Capital (GMC) through GMC coLABS in 2018, and part of that is now being reused for the COVID-19 app.

Potentially providing a substitute for the overwhelmed hotlines for triage and follow-up, the Redbird COVID-19 app is accessible via browser. Users are identified via phone number and location and can self-report their symptoms. The solution will enable officials from the GHS to see a real-time map of where patients are self-reporting symptoms in order to follow up directly with high-risk patients. The Redbird COVID-19 app provides hospitals with the opportunity to digitally record data and potentially conduct triage remotely, so that people do not need to go to the hospital and put themselves and others at risk. The app also alleviates pressure on hospitals. In the future, the app has the potential to be used for sample collection and test scheduling to minimise unnecessary patient interactions.

Zipline

Zipline is a tech company, based in the US, that has engineered autonomous drones that travel hundreds of kilometres to deliver vital medical supplies to around 2,600 rural hospitals and health centres in Rwanda and Ghana. Medication can also be delivered directly to patients or ambulatory clinics in their neighbourhoods. Through an app, doctors and health facilities can order blood, vaccines, and PPE and can track shipments. Drones can be launched 5 to 7 minutes after an order is received, with flight times ranging from 15 to 30 minutes. As cases began to rise in Ghana, the company started delivering vital COVID-19 tests and samples to test facilities.

Part medical warehouses, part drone airports, Zipline's distribution centres are placed at the centre of each region of service, with the potential to create a nationwide delivery network. Trained staff, including licensed pharmacists, can pick and pack orders on clients' behalf, selecting products that are held in distribution centres to minimise the time between order and delivery. In other cases, pre-packaged orders are consolidated and sent to Zipline, before proceeding to delivery.

Each Zipline distribution centre can make hundreds of deliveries per day anywhere across an 8,000-square-mile area. Each drone's flight is fully automated and monitored from its distribution centre. Drones can travel through any weather conditions and undertake round trips of close to 190 miles. With a small parachute, the drone releases the package above a predetermined point convenient to the customer. The drone adjusts its release point based on real-time wind data so that the package floats safely and precisely to its destination.

The Zipline logistics system not only enables a faster response to the outbreak, but it also enables the identification of where an outbreak is occurring, as more orders will be placed from that location. Zipline reduces unnecessary hospital visits and lowers the risk of exposure for non-infected and vulnerable patients, enabling them to receive medications closer to their home. Zipline can respond to demand surges and prevent stocks from running out by immediately delivering critical medication. Zipline has the potential to scale its operations in the US as well, but the Federal Aviation Administration is struggling with the formulation of a unified law for a new and largely unknown piece of tech.

Equipment

LOCOVENT4AFRICA

In Ghana, there are 67 ventilators available, a number that is inadequate in terms of matching the rapid increase in positive cases being recorded. The high demand for ventilators has caused a significant increase in costs, with ventilators now sold at £37.8 million (GHS 305,000) and £41.6 million (GHS 336,000), compared to £15,135 (GHS 122,000) and £16,649 (GHS 134,000) before the pandemic. To address this need and provide health facilities with much needed ventilators, Professor Fred McBagonluri, a renowned Ghanaian engineer and President of Academic City University College, is leading a team of volunteers and second-year engineering students from Academic City to produce low-cost ventilators as part of the LOCOVENT4AFRICA project. 2 working prototypes have already been built using locally available and off-the-shelf materials, including leather, plastic pipes, wood, and vehicle parts. The prototypes are set for testing in consultation with healthcare practitioners. Once validated and certified, the low-cost ventilators produced by the project will be ready for mass production.

Hand-washing machine

In May, Stichting Nederlandse Vrijwilligers (SNV) Netherlands Development Organisation started a competition, the GrEEn COVID-19 Innovation challenge, which was targeted at young people in the Ashanti and Western regions of Ghana. The challenge was part of the Boosting Green Employment and Enterprise Opportunities in Ghana (GrEEn) project and was organised together with I-Code in the Western region and Kumasi Hive in the Ashanti region. The aim of the challenge was to support entrepreneurs and developers who had innovative ideas and solutions for addressing the COVID-19 pandemic.

One of the winners from the Ashanti region was 34-year-old engineer John Mark Addo, who developed a foot pedal hand-washing machine and a related business plan. As a winner of the challenge, he received training on how to build and grow his business, based on a good value proposition, and how to develop strong partnerships and advertise his products. Other ideas included solar lanterns, solar home systems, and clean cookstoves.

Infrastructure

GhIE is one of the key institutions partnering with the Ghana COVID-19 Private Sector Fund (GCPS Fund) to build the first-ever infectious disease treatment facility in Ghana, located at the Ga East Hospital in Accra, at a cost of £5.7 million (GHS 45 million). The construction of the facility is aligned with the government's 'Ghana Beyond Aid' vision statement. GhIE collaborated with other built environment professionals (including the Ghana Institute of Architects, Ghana Institute of Planners, and the Ghana Institute of Surveyors) from conceptualisation to execution of the project. The Ghana Employers Association has donated £12,930 (GHS 100,000) towards the management and administration of Ghana's first infectious disease centre.

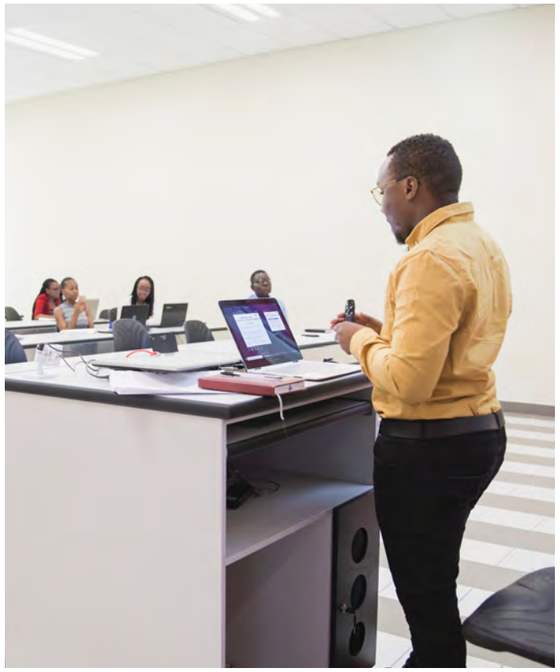
The GhIE team, composed of mechanical, electrical and structural engineers, was responsible for the mechanical, electrical, plumbing, sanitation and engineering services relating to the centre. Using local expertise and inputs, the team managed to deliver this 100-bed facility within 3 months using the environmentally friendly expanded polystyrene system (EPS). This EPS system has superior thermal efficiency, offers a high strength-to-weight ratio and is quick to install. The EPS system was an attractive option for this infectious disease facility, as it is virtually airtight and prevents harmful pollutants and allergens from entering.

The centre was launched on 24 July by Vice-President of Ghana Dr Mahamudu Bawumia, and will be used to isolate and treat critically ill COVID-19 patients. Once the pandemic is over, the facility will be used to provide treatment and care for other infectious disease patients. The GCPS Fund is raising funds to build 3 more such facilities in Kumasi, Tamale, and Takoradi.

Dashboards

The government of Ghana has been using dashboards to present information and to show the trends relating to COVID-19 in the country. These dashboards are run by the Ghana Statistical Service and the GHS. The Ghana Statistical Service dashboard, called the Ghana COVID-19 Monitoring Dashboard, is made up of 5 panes. The Cases pane presents data on the cumulative case count. The Map pane indicates the spatial distribution of the cases. The Trends pane presents trend analyses of cases (cumulated, active, recovered, and death). The News pane provides explanatory information relating to the cases reported, and the Health pane provides information on health hot spots in the country.

The dashboard of the GHS, powered by Sanbus Geospatial Limited, has 4 parts. The first part gives a regional breakdown of the confirmed cases. The second part presents the aggregated figures for confirmed, recovered, and death cases at the time of publication. The third part presents the spatial distribution of the confirmed cases on a choropleth map, with data symbolised per category and given in proportional circles that indicate the intensity of the phenomenon per region. The fourth part gives information on COVID-19 according to gender distribution.



Webinars

In order to address some of the most pressing challenges generated by the COVID-19 pandemic, GhIE has adapted its series of webinars to make them relevant to the current situation. In July 2020, GhIE hosted a webinar on the role that engineers and built environmental professionals can play to ensure that **COVID-19 health and safety/hygiene guidelines and procedures**, including social distancing, are implemented on construction sites. This is important to guarantee that new, repair and maintenance works continue even in the midst of the pandemic, while ensuring workers' health and safety. Ben Richard Aniagyei led the presentation, building on his more than 30 years of experience working in the industry.

Another webinar, hosted by GhIE in August 2020, focused on **project leadership in the 'new normal'**. Some of the questions that the webinar addressed concerned what we mean by 'new normal', what additional challenges will arise for project leaders, and whether they need to adopt new approaches and perspectives to work effectively in these difficult circumstances. The speaker was Professor Mias De Klerk, Head of Research and of the Leadership Group at the University of Stellenbosch Business School (USB) in South Africa. This showed how, even during times of crisis (and perhaps especially during these times), intra-Africa collaboration and sharing of learning can continue and enrich the course offer of PEIs.

In addition, the **2020 Ghana Infrastructure Conference on Planning and Implementation of Sustainable Transportation Infrastructure** was conducted virtually, due to COVID-19 restrictions, from 11 to 14 August. This event was co-sponsored by the Ghana Transportation Professionals Forum of North America, GhIE, and the Regional Transportation Research and Education Centre, Kumasi of the Kwame Nkrumah University of Science and Technology. The conference brought together consultants, agencies, policymakers, and researchers to discuss sustainable and innovative solutions for transportation-related and general infrastructure issues. In line with current global concerns, professionals also presented on the relationship between infrastructure and the COVID-19 pandemic.

One session indeed focused on **the impact of COVID-19 lockdown on mobility and the environment**, while another was on **social distancing in public transport and its impact on safety, security, and operational sustainability**.

Both sessions were held by civil and geomatic engineers, as well as researchers from the Department of Geography and Rural Development at Kwame Nkrumah University of Science and Technology. The former session illustrated the space–time variation of the COVID-19 infection and its impact on urban mobility, road traffic situation and environmental quality brought about by the lockdown in the Greater Accra and Greater Kumasi metropolitan areas. The latter was based on an ongoing COVID-19 pandemic public transport survey in selected cities in SSA. The survey and related study are trying to elicit data about transport operations in the pre-lockdown and lockdown periods, including COVID-19's impact on fleet availability and revenue from passenger fares due to social distancing and pandemic health protocols.

How engineers have collaborated during the crisis

The country's first-ever infectious disease treatment facility is one of the main results of collaboration that has been achieved during the pandemic. The construction of the centre is based on one of the recommendations that GhIE presented to the GHS, and was launched by the government in July. It is funded by the private sector through the Ghana COVID-19 Private Sector Fund, and was conceptualised and brought to life by a GhIE team in collaboration with other built environment professionals, as mentioned above. This voluntary contribution is part of a coordinated interdisciplinary effort to support the Ghanaian government's response to the COVID-19 pandemic.

GhIE Executive Director Kwabena Agyei Agyepong said: "The fact that the private sector can pull together funding for the public good, and as built environment professionals we are also chipping in, is a very healthy sign."

As shown by the examples above, the contribution of the engineering industry to the fight against the pandemic has been prompt and critical. The objective of startups, such as Cognate Systems and Redbird, is to inform the government's response with the data they collect and process, which they make available to the GHS and the Ghana Statistical Service. Hospitals will also benefit from this data, as well as from the drone scheme set up by Zipline.

In addition to this, universities and individual engineering researchers have stepped in, working on the development of critical equipment and collaborating with healthcare practitioners, as in the case of the ventilators, described above.

3. Women's engineering groups' response to COVID-19

Women in Engineering (WinE) is a network of female Ghanaian engineering practitioners and student members within GhIE. It has donated COVID-19 items to 3 market centres in Accra (Mallam Atta Market), Tema (Tema Community One Market) and Kumasi (Ejisu Market). Donations included face masks, Veronica Buckets with stands, soap, hand sanitisers and baskets to avoid the placing of food and other products on the floor. The initiative was well received by market directors.

In April 2020, the President of WinE, Dr Enyonam Kpekpena, also led a group of women engineers to present a proposal for reshaping markets in the country to the Ministry of Sanitation and Water Resources, the Ministry of Local Government, and the Ministry of Gender, Children and Social Protection.

4. Impact of the COVID-19 crisis on young engineers, education and skills

In March 2020, the President of Ghana asked universities to close, in respect of the COVID- 19 response measures. Access to campuses was therefore restricted and most classes were moved online. The majority of universities provided students with updated guidelines on how to avoid risks and deliver presentations and assignments, how to protect their mental health, and how to practice hygiene measures. Ashesi University even recommended that students contact its counselling, coaching and academic advisory team, if needed, and supported disadvantaged students with 10GB of data per month for 2 months.

In spite of the challenges stemming from the lockdown and remote learning, Ghanaian students have stepped in to help the country respond to the pandemic. As mentioned, engineers and students from the Academic City University College worked on the design and production of low-cost ventilators, as part of the LOCOVENT4AFRICA project.

5. Post-crisis outlook

COVID-19 has revealed **inefficiencies in the healthcare sector** and the **potential for technology** to fill existing gaps, for example through online pharmacies, electronic payment, online healthcare systems and testing, and online doctors. As a result, established industry players and engineers in Ghana have already started investing more in digital infrastructure to deliver more and better e-health solutions. This includes **technological solutions related to the management of the entire water cycle**, which can guarantee the continuity of technical, commercial and financial operations of drinking water and basic sanitation service providers, thanks to a continuous and integrated flow of data. According to Guillerm Gallego, key account manager for Africa at Idrica, the pandemic will bring about major changes in the way water services are managed across the entire continent. On the one hand, more attention will be paid to improving the resilience of water infrastructure through the implementation of early warning systems to deal with episodes caused by climate change, migratory movements, and pandemics. On the other hand, greater financial resources will have to be allocated to the **renewal of infrastructure and the optimisation of the services** provided, strengthening both the use of water resources (which are increasingly scarce) and the use of treated water for environmental and other human-related purposes.

The COVID-19 outbreak has also revealed the importance of investment in **communications infrastructure**, a sector already seeing rapid growth in SSA. The functioning of many firms was compromised because of the impossibility for employees to work from home, due to unreliable internet connection.

The need to protect lives during a pandemic also means that the application of **geographic information systems and remote sensing** is invaluable in terms of tracking and combating contagion. Overall, applications that are able to track and understand the spread of the disease and display results in interactive and real-time (or near real-time) dashboards have a key role to play in informing government decision-making. The engineering industry has been able to provide these solutions in a relatively short time span, supporting the government in its efforts to fight COVID-19.

Prediction of possible trends and outcomes is indispensable for planning and influencing policy direction. Therefore, it is expected that fields such as **computer, electronic, and geomatic engineering**, among others, will be particularly important over the next months and years. This is due to the need to use technology, including geospatial systems, to model the spread of the disease, track current and future health threats and infected cases, identify and predict hotspots, and present this information to the government and the population in effective ways.

As mentioned above, data on urban mobility and road traffic, and how these were impacted by the lockdown measures, are, and will continue to be, important for pandemic management and mitigating related disruptions.

In addition to the tools currently in use, the engineering industry in Ghana could play a role in contributing to the fight against COVID-19 by supporting the development of **infrared scanners** for the quick detection of infected people and contact tracing, and the collection of further **geospatial data** in various forms to inform policy formulation and interventions.

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Kenya

1. Context/background

Overall impact of the COVID-19 crisis in Kenya

Government response

Kenya is facing numerous development challenges, from the ongoing locust infestation to persistent youth unemployment, poverty, and inequality, among others. The COVID-19 pandemic has put additional burden on the government and the people of Kenya. However, the Kenyan government, led by President Uhuru Kenyatta, has acted quickly to contain the COVID-19 outbreak. The pandemic hit Kenya on 15 March 2020, with the first cases reported in the capital, Nairobi, and the coastal Mombasa County. The National Emergency Response Committee (NERC), a multisectoral taskforce comprising the health, security, education, transport, finance, and trade sectors, has been responsible for the overall coordination of the COVID-19 response. NERC identified health facilities, public and private laboratories and isolation centres and developed guidelines for case management, infection prevention and control, and surveillance.

In response to the rise of COVID-19 cases in Kenya, on 15 March the government of Kenya closed all schools and advised all public and private sector workers to work from home, wherever possible. Travel restrictions were later imposed to prevent non-residents from entry, and Kenyan nationals and residents were required to self-quarantine for a minimum of 14 days. Moreover, a 7pm to 5am curfew was announced on 25 March. This was accompanied by reports of police brutality, which has disproportionately affected lower-class Kenyans. On 6 August, the Cabinet Secretary at the Ministry of Health, Hon. Mutahi Kagwe, officially opened an Infectious Disease Unit and ICU at Kenyatta University Teaching, Referral and Research Hospital. The Kenya Medical Research Institute and the Ministry of Health's Emergency Operation Centre use the 'test, track and treat' approach. According to the latest government statistics, the total number of confirmed cases in Kenya is 44,196 (as of 17 October 2020).

According to the Centre for Strategic and International Studies, the government also unveiled measures to buffer Kenyans against financial hardships arising from movement restrictions associated with the COVID-19 crisis, including tax relief and increased allocation of funds for healthcare, along with other fiscal adjustments to the economy. The effectiveness of this stimulus is not yet clear.

Moreover, whole sectors of the economy have shut down, including the tourism and hospitality industry, as well as agricultural exports. An estimated 50% of the Kenyan workforce is either laid off or locked out from their jobs.

The World Bank Group donated the equivalent of £37.5 million in immediate funding to support Kenya's response to the global COVID-19 pandemic under the Kenya COVID-19 Emergency Response Project. The project provides emergency funding for medical diagnostic services, medical waste disposal, risk communications and community engagement amongst others. Moreover, the EU through its Civil Protection and Humanitarian Aid Operations department (ECHO) has donated approximately £1,820,193 to WHO Kenya. WHO Kenya will boost the response effort by training frontline health workers at national and county levels and strengthen the current work being done by the COVID-19 rapid response and clinical teams across all counties.

Brief overview of the key engineering stakeholders in Kenya

The main PEIs in Kenya are the following:

- **The Institution of Engineers of Kenya (IEK)** is a professional and learning body that works in conjunction with other institutions and organisations (independent of the government) that seek to promote and develop the engineering profession and best practices. IEK provides a service to its members by means of seminars, lectures, publications, and training, to enable them to keep up to date with technical and industrial developments, management aspects of engineering, changes in technology, and relevant developments in Kenya and elsewhere. *The Kenya Engineer* is the bi-monthly journal of the IEK and is distributed to all members.

- **The Association of Consulting Engineers of Kenya (ACEK)** is the public watchdog on engineering issues in Kenya, established in 1968. ACEK's main objective is to advocate for the business and professional interests of consulting engineers and to promote the advancement of professionalism within the consulting engineering industry, as well as cooperation among consulting engineers.

- **The Engineers Board of Kenya** is a statutory body, established under Section 3(1) of the Engineers Act of 2011. The board is mandated with the responsibility of regulating standards in the engineering profession and building capacity for individual engineers and engineering firms. The board also registers engineers and engineering firms and regulates their conduct for improved performance of the engineering profession.

The following ministries oversee engineering in Kenya:

- **The Ministry of Transport, Infrastructure, Housing, Urban Development, and Public Works** aims to be a global leader in providing transportation and logistics services for improved quality of life. One of the functions of the State Department for Infrastructure is to conduct the registration of engineers with support from the Engineers Registration Board (ERB) of Kenya.

- **The Ministry of Lands and Physical Planning** aims to contribute to improving the livelihood of Kenyans through efficient land administration, equitable access, secure tenure and sustainable management of land resources.

Kenya Vision 2030

Kenya Vision 2030 aims to transform Kenya into a newly industrialised, middle-income country that provides a high quality of life to all its citizens in a clean and secure environment by 2030. According to the strategy document, infrastructure development is paramount to realising Kenya Vision 2030, and engineers are integral to this; they need to enhance their capacity in terms of linking educational institutions with the industry, especially the private sector. Kenya Vision 2030 also includes an emphasis on improving STEM education and training, including:

- **The establishment of the Kenya Advanced Institute of Science and Technology:** The establishment of an advanced research institute in Kenya will provide for specialised training in various engineering and science fields.

- **Repackaging STEM in Education and Training:** The project is expected to promote experiential learning, innovation, creativity and attraction to STEM-related disciplines through well-coordinated programmes in education, research and development, and training in all aspects of science, technology and innovation and at all levels – from early childhood, primary and secondary education, to university.

- **The integration of Science, Technology and Innovation in Education Management:** The project will establish a sector-wide education and training management information system, linking all education-related agencies in the public and private sectors.

- **Conducting a national skills inventory and audit for science, technology, and innovation:** A National Critical Skills Development Strategy will be formulated and implemented to increase the number of researchers, scientists, and engineers for the industry. This project will include an audit of the existing science, engineering, and technology skills, and of the requirements for the country, and will draw up a strategy for closing the gap.

2. Engineering response in Kenya

The position of key engineering actors

Like many other industries, the engineering industry took a significant hit due to the COVID-19 outbreak. Several engineering jobs were halted due to movement restrictions, and companies were forced to downsize to be able to stay in business. Nonetheless, there appears to have been a significant amount of activity from universities and private companies in Kenya in tackling the pandemic (see next section). In terms of PEIs, IEK has been particularly active in its engineering response. In April 2020, IEK held its first ever virtual Annual General Meeting, where the council resolved to put together an emergency kit to help in the fight against COVID-19 and its socio-economic impact.

It raised over approximately £14,000 (KES 2 million) to support the production and supply of vital protective and medical equipment, as well as distribute food and other household essentials to families in need.

The contribution of engineers to tackling the crisis

Incinerators

According to British Broadcasting Corporation (BBC) statistics, more than 50% of Nairobi's waste does not get collected and less than 10% is recycled. Catherine Wanjoya was one of the 3 entrepreneurs in Kenya that was awarded roughly £4,700 to help her expand her business model to combat COVID-19 in Kenya, thanks to the Royal Academy of Engineering. In 2018, Catherine created an eco-friendly incinerator for the disposal of sanitary pads and diapers, which she sold to schools. Unfortunately, schools were the first institutions to be shut down when the pandemic hit, which placed a big financial burden on her business. Catherine re-worked the incinerators to be suitable for disposal of used PPE, including masks and gloves, in order to stop the spread of the virus. The incinerators are portable and are meant for small health centres. She created different sizes of the incinerator; the smaller sized incinerator can dispose of up to 80 masks per day and the bigger incinerator can dispose of up to 20 kilos of waste in one go. According to Catherine, there have been difficulties in getting the government to finance and support her incinerators. However, she mentions that she has received a lot of interest and enquiries about her product and has been networking with individuals from other countries (including Botswana, the Democratic Republic of Congo, Mozambique, the Republic of Congo and Uganda).

Ventilators

Fifteen students at Kenyatta University recently unveiled a prototype ventilator that helps COVID-19 patients with breathing difficulties. The ventilator would only cost about £3,788, a quarter of the cost of a conventional machine. The university's engineering and biomedical engineering departments will be able to produce 50 devices every week, according to Vice-Chancellor Paul Wainaina. The team from Kenyatta University have now joined fellow students in Ghana and Uganda, who have taken the lead in producing ventilators. The innovation has given a directive to the government to support local manufacturing industries and has inspired Kenyans to come up with local solutions to the COVID-19 pandemic.

Similarly, Jomo Kenyatta University of Agriculture and Technology (JKUAT) has also developed a variety of COVID-19 fighting tools, including a portable solar-powered ventilator, a contact-tracing mobile application, and an automatic solar-powered hand-washing station.

Contact tracing

Fablab Winam is an open-access laboratory, which provides access to makers and innovators (including engineers) to share their tools, along with technical and business training, for them to establish a clear path from conception to deployment to market. Supported by the Kenyan government, it developed the application mSafari, which helps with contact tracing for commuters that use public transport. The app allows citizens to find out if they have travelled with people with COVID-19. All public service vehicle operators and their passengers are required to register on the platform. The app also records the number of passengers per vehicle, to make sure that only the permitted maximum numbers of passengers are allowed on board.

Water, sanitation and hygiene

Engineers at the Nairobi City Water and Sewerage Company were tasked with fixing the water line to restore running water supplies, which fell by as much as 20% due to a landslide in April. The landslide destroyed a major water pipe in central Kenya, cutting off running water to entire Nairobi neighbourhoods. The Nairobi City Water and Sewerage Company have reduced the water loss to about 10% and are installing a new line to remedy the shortage.

The need for water has increased due to the COVID-19 pandemic, as more people are encouraged to wash their hands regularly to limit the spread of the virus. To address this, the School of Engineering and Technology in South Eastern Kenya University (SEKU) has fabricated a manually operated soap and water dispenser.

Masks

IEK is supporting Dedan Kimathi University of Technology (DeKUT) in manufacturing KN95 masks, which are highly efficient in providing protection against COVID-19. DeKUT is also working on making a ventilator. Similarly, the School of Engineering and Technology in SEKU has made a design for textile masks.

3. Women's engineering groups' response to COVID-19

Men still dominate the engineering profession in Kenya. Statistics from IEK indicate that out of 6,444 engineers, only 436 are women (7%). In 2014, IEK launched the highly successful Women Engineers Chapter. The objective is to provide forums to support women engineers, create a platform where women engineers can network, organise scholarships and awards for outstanding students, and have more women engineers both locally and internationally. Moreover, a branch of WinE is active in Kenya. The organisation's mission is to develop a more gender-diverse engineering and tech workforce. According to interviews and desk research, women's engineering groups do not appear to have had a strong collective response to the COVID-19 pandemic. However, that is not to say that women engineers have not participated in the country's response. For instance, Christine Were, a fourth-year biomedical engineering student at Kenyatta University, was part of the team who developed portable ventilators to help fight the pandemic, with the help of various mentors including Dr. June Madete, a biomedical engineer, and Dr. Priscilla Kabue Dean from the School of Nursing.

4. Impact of the COVID-19 crisis on young engineers, education and skills

Teaching in Kenya (and all over the world) has been moved online, and many Kenyan universities (especially public universities) are unable to provide efficient e-learning systems for their students. Moreover, state funding for public universities in Kenya has been on the decline, as the government expects universities to generate their revenues internally. According to an interview with Paul Kioko, Dean of the School of Engineering and Technology in SEKU, the pandemic has highlighted the urgent need to embrace information technologies (IT) and the use of technology in engineering in order to avoid a gap in engineering education and, subsequently, a shortage of engineers in the workforce. The Kenya Education Network, a government initiative, is an example of an organisation that has embraced the use of technology in engineering as they have provided an online learning platform for use by public universities.

However, it is difficult to teach engineering online because of the practical and hands-on nature of the curricula. Training at companies and construction sites has been cancelled, and technical checks cannot be done remotely.

According to University World News (Africa Edition), one final-year student at JKUAT, Valerie Owino, said: "My course involves a lot of practical activities right from the very first year of study, and it is thus impossible for students in our department to be able to study online as the current situation demands. Projects such as my own require daily monitoring, meaning that I have to be present to be able to get the necessary data that I need."

According to Mr Kioko, one option is to look to the UK or Japan for a best practice model of delivering remote engineering education. In addition, he highlighted the inequalities that can result from young people (particularly from disadvantaged backgrounds) spending more time at home. This includes increased childcare and household responsibilities for young women and employment/labour responsibilities for young men. Furthermore, not all students have the required infrastructure to pursue their studies online. Mr Kioko anticipates the institutionalisation of online teaching and learning, and calls for a formal policy, financed by the government. He claims there ought to be policies on online examinations due to the challenges of administering them online. e-learning will forever change the way engineering is taught, and students should expect new methods of learning, such as virtual labs. The School of Engineering and Technology in SEKU is continuing its efforts to teach online, admitting new students, and carrying out matriculation exams through an online platform, which is being tested for teaching engineering subjects. In addition, it develops videos and uploads them online, to keep students connected with the university and aware of any decisions/changes made by the board.

Young engineers have stepped up during the crisis. Some engineering initiatives have received a lot of media coverage, helping to promote engineering careers among young people. Stephen, a nine-year-old student in Western Kenya, has developed a wooden foot-operated hand-washing station to help curb the spread of COVID-19, for which he received a presidential award. The idea for the machine came from the realisation that people could still get infected from touching the taps after washing their hands. The story was widely covered in the media, including on the BBC, where the young boy shared his dream to become an engineer, which resulted in the county Governor promising him a scholarship. This showcases engineering in a positive light and is likely to trigger greater interest in the profession among young people.

5. Post-crisis outlook

The significant impact of the virus has been felt differently across the Kenyan population, posing extreme challenges for some and opportunities for others. The hardship from the crisis will disproportionately affect the poorest and the most vulnerable households in Kenya. In terms of lessons learned, the pandemic has reinforced the importance of coordinated and collaborative approaches among communities, counties, sectors, industry, countries, and global institutions. According to key stakeholder interviews, the government needs to work closely with engineering actors and institutions to discuss the impact of the pandemic and make predictions for the future. Often, parts needed for construction are not manufactured locally, and outsourcing to other countries during the pandemic proved difficult due to lockdown constraints. It is important to produce locally for similar situations in the future and to ensure there is sufficient stock. Moreover, as the sponsor of public universities, the government needs to upgrade the digital infrastructure in these institutions, especially among those recently chartered and constituent colleges. There is no longer doubt that the future of education is in e-learning and universities must adapt accordingly.

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Lesotho

1. Context/background

Overall impact of the COVID-19 crisis in Lesotho

Country context

Lesotho is a landlocked country with a small domestic market and private sector. According to the World Food Programme, more than half (57%) of Lesotho's population live on less than a dollar per day. In addition, the population's high vulnerability is exacerbated by recurring climatic hazards, including droughts, early frost, and a low-performing economy. Agriculture, which contributes 7% of Lesotho's Gross Domestic Product (GDP), is a major source of livelihood for 80% of the population living in rural areas, and life expectancy stands at 49 years. Overall, 29% of people below the age of 35 are unemployed. The health system is already overburdened and lacks the requisite infrastructure, as it traditionally relies on South Africa to provide complementary secondary and tertiary healthcare.

The country is also characterised by an extremely high HIV prevalence rate (25.6%: 30.4% for women and 20.8% for men), with care needed for more than 250,000 orphaned children, most of whom have lost their parents to AIDS. According to the UNDP Lesotho Social Economic Assessment, due to COVID-19 lockdown measures, adolescents and young people could be more vulnerable to sexual and gender-based violence, early and unwanted pregnancy, and child marriage. The risk of HIV and unplanned pregnancy is heightened by the absence of supportive services and education programmes, as these have not been considered critical under the pandemic.

Government response to COVID-19

Lesotho was the last country in Africa to report a COVID-19 case in mid-May 2020, and is one of the countries in Africa that maintains a low number of cases compared to the rest of the continent.

Lesotho government COVID-19 statistics as of 10 October 2020

	Total
Positive cases	31,394
Recoveries	70,768
Deaths	84,361

The government of Lesotho closed its borders with South Africa in March 2020 to avoid contamination, as the country did not have the ability to test for the virus, and launched the National Emergency Command Centre (NECC), led by a cabinet sub-committee and the Ministry of Health. The government declared a national emergency on 18 March 2020, followed by a compulsory lockdown for all non-essential services from 29 March 2020. The lockdown was relaxed on 19 May 2020, to be reviewed on a fortnightly basis, while retaining rules on compulsory use of masks in public spaces and restrictions in high-risk sectors, such as tourism, sit-in restaurants, entertainment, as well as for assemblies of more than 50 people. According to government guidelines, only registered logistics companies delivering goods in South Africa or Lesotho were allowed at the borders during this period. All businesses were required to cease operations during the lockdown period, except for businesses involved in the manufacturing, supply, or provision of essential goods and services. In addition, those who broke the rules and failed to confine themselves in accordance with the regulations could be liable to a fine of up to roughly £925 (LSL 19,000) or imprisonment for a period of up to 2 months.

The government set up a testing centre, as well as sites to specifically handle COVID-19 patients, and in June 2020, there were 24 ventilators in the country. The government is also training frontline staff and medical personnel. For example, the Lesotho Evangelical Church in Southern Africa (LECSA) has had workers from its 3 institutions, including those in rural areas, attend these training sessions. But these institutions are still trying to figure out the logistics of how to handle suspected cases, and how to protect their staff and patients, as they were already often overfilled and understaffed. The situation has shown that the country has limited state capacity – among others – to identify, test for, trace, and treat COVID-19. It has also illustrated the limitations on the provision of water and sanitation services, which are crucial as precautionary measures to prevent the spread of the pandemic. The UNDP predicts that COVID-19 is likely to have a devastatingsocio-economic impact on the country, including sharp increases in unemployment, vulnerability, and poverty.

Brief overview of the key engineering stakeholders in Lesotho

There are a number of engineering stakeholders in Lesotho:

- **The Lesotho Association of Engineers** (LAE) was registered in 1982, and after a period of reduced activity from 1993 to 2014, the association was re-launched on 28 August 2014. LAE is intended to foster and promote the art and science of engineering and its application in Lesotho, and to facilitate the exchange of information for that purpose.

- **The Ministry of Education and Training's** mission is to develop and implement policies that ensure acquisition of functional literacy among all Basotho, and the development of a productive, quality human resource base through education and training. On the ministry's website, there is no reference made to a specific strategy in relation to the engineering profession, however technical and vocational education training (TVET) is mentioned as a key area of focus, which includes TVET in engineering.

- **The National University of Lesotho** is one of the few universities in Lesotho that offers an engineering degree. This development will cut costs for students who would otherwise have to pursue engineering studies outside the country, while motivating more Basotho to enrol in the programme. It is officially recognised by the Ministry of Education and Training of Lesotho.

- **The Lesotho Association for the Advancement of Science and Engineering (LAASE)** is an independent, non-governmental institution, which is intended to promote science and engineering and strengthen their influence in Lesotho. LAASE's members use a Facebook group, as it is not an official institution.

- **The Lesotho Young Academy of Science (LesYAS)** has not been officially launched yet, but it will follow the South African Young Academy of Science. It aims to provide a platform for young scientists to influence policy decisions, contribute to the development of scientific capacity in Lesotho through mentoring and role-modelling of future scientists, and foster opportunities for interdisciplinary collaborations among young scientists.

In addition, Lesotho has a **National Strategic Development plan for 2018/2019 to 2022/2023**, which highlights 4 key priority areas to lead to inclusive growth and poverty reduction.

- promoting inclusive and sustainable economic growth and private-sector-led job creation.
- strengthening human capital.
- building an enabling infrastructure.
- strengthening the national governance and accountability systems.

The plan recognises that there is a shortage of STEM skills in Lesotho, and urges for the training of scientists and engineers, in particular women and girls, as well as for the creation of a conducive environment that promotes climate change and STEM.

Impact of the COVID-19 crisis on the engineering industry in Lesotho

The engineering industry in Lesotho is fragile, and it has (along with all industries) been negatively affected due to the pandemic. According to interviews carried out for this research, a key issue for engineers in Lesotho is the lack of regulations and accreditation mechanisms. There is no ranking system to categorise engineers by their level of expertise and ensure that they have been trained to the required standards. As a result, there are poor procurement practices, infrastructure projects are not always built correctly, and money is not being spent properly, which paves the way for corruption. According to an interview, engineers from China have been heavily active on the ground in Lesotho, including during the pandemic. Chinese engineers are regulated and bring their own equipment and workforce to Lesotho, using local engineers as labourers and putting them at a great disadvantage. As a result of these constraining factors, the engineering community has been unable to respond effectively to the pandemic. In addition, the nationwide lockdown has forced engineering companies to close, and young engineers' education has been halted.

2. Engineering response in Lesotho

The position of key engineering actors

Few of the engineering actors mentioned above have communicated their position and response to the pandemic. It is worth noting that, in May 2020, LAASE released a paper on their Facebook page, titled *'What every Mosotho should know about COVID-19'*, taking a strong stance against NECC's response to the pandemic. For instance, the paper pointed out the lack of research done by scientists and academics in the NECC team, and argued that the NECC team was largely made up of politicians and public servants "paying lip service". The paper also criticised the government's lack of preparation in relation to resource allocation and management. While the NECC team did not know how many ventilators were available in the country, they nevertheless put a budget in place to be used in response to the pandemic.

Another key standpoint of engineers was criticism of the slow roll-out of screening and testing initiatives, and Lesotho's over-reliance on WHO recommendations. The latter was striking in light of the issue of the use of face masks and face shields in public. The initial recommendation from WHO discouraged the wearing of face masks in public spaces. At the time, very little was known about COVID-19, and WHO wanted to discourage the hoarding of protective masks. However, once it became clear that it was beneficial to wear face masks in public spaces in order to reduce the spread of the virus, the government continued to refrain from implementing this crucial protective measure because WHO did not give a definite green light on the use of face masks.

As previously mentioned, Lesotho has limited resources and capacity to effectively manage the COVID-19 pandemic, which has put a strain on its already fragile engineering industry. While LAE has created a foot-operated hand sanitising station and engaged in awareness-raising activities, the remainder of the country's COVID-19 response has largely been supported by international aid.

According to ReliefWeb, the Board of Directors of the African Development Fund approved nearly £6.9 million in grant funding in June 2020 to bolster COVID-19-related control measures in 6 Southern African Development Community (SADC) countries, including Lesotho. The funds are intended to facilitate the procurement of laboratory and medical supplies, including testing kits, personal protective gear, and noninvasive ventilators. Moreover, the IMF approved roughly £38 million in emergency support under the Rapid Credit Facility and the Rapid Financing Instrument to help Lesotho meet urgent needs stemming from the COVID-19 pandemic.

According to Global Ministries, Lesotho has also received at least 2 consignments of PPE from China, and these have benefited many of the health institutions in Lesotho, including those that belong to the Christian Health Association of Lesotho, 3 of which are under LECSA. However, such goods are hard to find, as they were never readily available in Lesotho to begin with, they are in-demand all over the world currently, and getting goods from neighbouring South Africa (where virtually all of Lesotho's goods come from or through) has been increasingly difficult and costly. According to Global Ministries, LECSA's institutions are prioritising masks, gowns, gloves, and boots, and LECSA has received some funding from several international partners to do so, but again this takes a lot of logistical work.

3. Women's engineering groups' response to COVID-19

There are no women's engineering groups in Lesotho. However, according to the president of LAE, there is acute awareness of the lack of diversity in engineering and efforts to make engineering more inclusive. LAE is currently in discussion with the FAEO about having more female representation for engineers in Lesotho. At the time of writing this report, we were not aware of any women-led engineering initiatives on tackling COVID-19.

4. Post-crisis outlook

According to ReliefWeb, labour opportunities remain below typical levels in Lesotho because of the below-average 2020 harvest, border closures limiting economic migration, and the general slowdown of the economy following COVID-19 control measures in Lesotho and South Africa. While poverty is expected to increase across the whole country, the most significant increase in poverty in 2020 is expected in the Senqu region and in the mountain areas, where it is expected to rise by 2.6% and 2.9% respectively, in comparison to pre-crisis projections. According to an interview with the president of LAE, the silver lining of this pandemic for engineers is that it has forced the government to take stock of their own human capital and put a plan into action on how to best use and support Lesotho's engineers. Indeed, at present, various ministries (including the Ministry of Energy, Meteorology and Water Affairs and Ministry of Finance) are all examining the barriers for engineers in Lesotho, including the lack of national regulations. Local engineers will be needed in recovery efforts for the country, and it is vital that they are regulated moving forwards.

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Interviews

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- Seriti L. Phate, President of the LAE and Managing Director of Tsoelopele Consultants & Contractors (pty) Ltd.

Nigeria

1. Context/background

Overall impact of the COVID-19 crisis in Nigeria

In February 2020, health ministers of the 15-member Economic Community of West African States met in Mali to develop a **regional preparedness plan and boost cross-border collaboration** to promote rapid diagnosis and containment of COVID-19. To facilitate these efforts, the Africa CDC has taken a leading role.

However, well before the pandemic, the Nigerian debt profile was a source of concern, as the government had been grappling with weak recovery from the 2014 oil price shock. These pre-existing issues have aggravated the economic impact of the COVID-19 outbreak. Government expenditure has increased to support fiscal stimulus measures aimed at counteracting the fall in consumer spending. However, **the fall in the global demand for commodities** resulting from the pandemic has significantly increased the fiscal deficits of countries like Nigeria, which are commodity dependent.

According to the Brookings Institution, Nigeria **was not sufficiently prepared** to respond to the current COVID-19 pandemic. This has been demonstrated by Nigeria's low testing rates for COVID-19 (2,500 tests a day as of August 2020), only half of which were administered because of the shortage of human resources, testing kits, laboratories, and case definition for testing that prioritises symptomatic cases and their contacts. Nigeria had just 350 ventilators and 350 ICU beds for its entire population before the outbreak. In April 2020, the country acquired 100 more ventilators, but this was unlikely to be enough, given the growing caseload. At the federal level and in most states, social distancing and 'test and trace' approaches have been implemented inefficiently, due to weak health systems, sluggish emergency response, poor accountability systems, and fragmented data and information monitoring systems.

The Nigerian government has taken numerous **health, social, and economic measures** to mitigate the impact of COVID-19. This includes travel bans and lockdown measures; cash transfers and food donations to poor and vulnerable households; economic stimuli to households and SMEs particularly affected by the pandemic, as well as the health and manufacturing sectors; mandatory face masks; night curfews; import duty waivers for pharmaceutical companies and increased efforts toward ensuring that they receive foreign exchange; and calls for private donations and attempts to raise multilateral funding.

According to the federal government of Nigeria, it will require roughly £250.1 million (NGN 145.2 million) to procure medical equipment, PPE, and medicines for COVID-19 control. The government has committed to investing some of this amount, borrowing from the domestic stock market, the World Bank, and the African Development Bank. Private, bilateral, and multilateral institutions have made financial commitments to raise the remaining funds. The IMF approved £2.5 billion of emergency support to Nigeria to tackle the economic impact of the pandemic.

Nevertheless, these measures have been **considered insufficient** to tackle the magnitude of the challenge. Among the main criticisms was the fact that the **Emergency Economic Stimulus Bill 2020**, which has provided support for businesses and individual citizens, has not provided cover for the informal sector, which employs 90% of the workforce. Second, **cash transfers** are unlikely to reach the majority of Nigerians, who live on less than £1.40 (NGN 813) a day, and who are not registered in the National Social Register. Also, the country's information management system is not sufficiently developed to favour efficient electronic payments, which has prevented many people from receiving the promised government support.

As for the credit of roughly £ 6,000 (NGN 3 million) that the **Central Bank of Nigeria** offers to poor families impacted by COVID-19, the loan requires collateral and is not interest-free, limiting its reach and effectiveness, together with the fact that many poor households and businesses in the informal sector do not know about it.

According to Brookings, **a more integrated response** spanning several sectors, including the health, finance, and trade sectors, would have been required to address the structural issues that make the country less resilient to shocks and limit the range of policy responses it could adopt. The engineering industry can offer an important contribution to the national response to the crisis, as explored below.

Brief overview of the key engineering stakeholders in Nigeria

In Nigeria, the 4 main PEIs are the Nigeria Academy of Engineering (NAE), the Council for the Regulation of Engineering (COREN), the NSE, and the Association of Professional Women Engineers of Nigeria (APWEN). NAE's priority is to promote the quality of engineering education. COREN's key objective is to regulate the practice of engineering in Nigeria. NSE's goal is to promote engineering education, research, and practices, according to professional standards and ethical practices, and across discipline-specific PEIs. The focus of APWEN is on promoting the role of women in the engineering profession. The top universities for studying engineering in Nigeria include the Federal University of Technology Akure, the Federal University of Technology Owerri, the University of Ilorin, and the University of Lagos.

At government level, the ministries that are more relevant to the engineering works are the Ministry of Power, Works and Housing, the Ministry of Water Resources, the Ministry of Transport, the Ministry of Science and Technology, and the Ministry of Petroleum Resources, among others. Governmental bodies, such as the Department of Petroleum Resources (DPR, Oil and Gas Regulatory Agency), the Nigerian National Petroleum Corporation, the National Solar Power Authority and the Nigeria Communications Commission, are also relevant engineering stakeholders. The relationship between government stakeholders and local PEIs could be improved, as our interviewees highlighted the lack of recognition of Nigerian engineers among government stakeholders. Previous consultations conducted as part of our research have revealed that the Nigerian government often resorts to foreign firms and products instead of relying on local resources.

Impact of the COVID-19 crisis on the engineering industry in Nigeria

Firms and businesses in African cities are highly vulnerable to COVID-19-related effects, especially SMEs, which account for 80% of employment in Africa. Additionally, urban consumption and expenditure (of food, manufactured goods, utilities, transport, energy, and services) is likely to experience a sharp fall due to COVID-19-related lockdowns and restrictions. Contracting jobs and engineering services have been negatively affected.

To mitigate these impacts, as mentioned above, the Central Bank of Nigeria has arranged a fiscal stimulus package that includes a £105.17 million (NGN 50 billion) credit facility to households and SMEs most affected by the pandemic, a £210.33 million (NGN 100 billion) loan to the health sector, and a £2.11 billion (NGN 1 trillion) loan to the manufacturing sector. In spite of this, inflation, sharp spending cuts, widening fiscal slippages, and project suspensions (including housing and road projects) are all curtailing growth in the construction sector in Nigeria. Some states will probably not generate enough revenue to cover their current spending. In addition to this, possible supply chain bottlenecks of equipment and materials from China could cause project delays in currently funded projects or reduce spending on future projects. However, GlobalData expects increased investor attention towards some sectors even long after the pandemic, including healthcare infrastructure.

The COVID-19 pandemic has also had a severe impact on the operations of **marine vessels**, which support upstream oil and gas activities in Nigeria. Regulatory agencies, such as the DPR and the Nigerian Maritime Administration and Safety Agency, have issued several directives and regulations to curtail the impact of COVID-19 on offshore operations. This includes directives to ensure business continuity, while guaranteeing the safety and welfare of all personnel, and extension of the validity of the statutory and trading certificates for all Nigeria-registered vessels.

In Nigeria, engineering industries that rely on IT are likely to have performed better than others in these challenging times, as they are dependent on digital skills and tools, and remote working and communication. Similarly, **chemical engineers** have been heavily involved in the production of face masks and PPE, while **mechanical engineers** have significantly contributed to the production and repair of ventilators and hand-washing devices, as described in the sections below. In order to obtain a full picture of the impact of COVID-19 on the various engineering disciplines, NSE has started to collect information from its network of state-level branches and discipline-specific institutions. This will help to develop a comprehensive understanding of the situation, which will then inform a scenario analysis and orient NSE operations to support the engineering industry.

In general, the NSE Executive Director, Dr Alex Okopi Momoh, believes that COVID-19 has so far had 2 main positive impacts on engineering. Firstly, it has **triggered innovation**, and secondly, it has **made Nigerians look inwards**, to see what can be done internally, for example by engaging local engineers to solve social and development issues.

Prior to COVID-19, the government did not recognise Nigerian engineers as playing an active role in national economic activities and preferred foreign engineers to handle national infrastructure projects. However, COVID-19 restrictions have forced the government and firms to look inwards and see what can be done locally.

This has allowed Nigerian engineers to demonstrate that they have the capacity and capability to contribute to the social and economic development of the country. The government is yet to make an active endorsement, but the engineering contribution to fighting the pandemic is in the public domain. According to Momoh, even more can be done by engineers to prove they are able to contribute to the country's development and trigger greater and more sustained government recognition.

2. Engineering response in Nigeria

The position of key engineering actors

Momoh's view that COVID-19 has offered the opportunity to reconsider the value of local engineers resonates with that of other renowned Nigerian engineers. According to the chair of the NSE Apapa branch, the government should harness local potential by financially supporting Nigerian engineers in the production of ventilators, hand sanitiser, and PPE, rather than resorting to foreign products and resources. Cheap solutions are particularly needed, at a time of a fall in oil prices and expected low government revenue. Former Vice President of NSE, Tunde Zedomi, presented NSE members' efforts to manufacture critical equipment to fight the pandemic (described below) as a demonstration of the potential of local engineers to solve the country's challenges.

The contribution of engineers to tackling the crisis

Not only have engineers had to adapt to a new, remote way of working, but they have also realised how to employ their skills for the benefit of society. The NSE called its members to action, at divisional and branch level, in industry and academia, in a **coordinated effort** to assist the government and society as a whole in the fight against the pandemic. Encouraged by the call, universities and professionals have developed different models of automatic hand-washing stations to be distributed for community use, and engineers who had never worked with respiratory machines before having started designing or repairing ventilators for hospitals.

Donations and advocacy campaigns, setting up of food stalls, and distribution of medical supplies have also been part of NSE branches' and divisions' collective effort. NSE is now exploring methods of mass-producing the equipment that NSE members have manufactured. However, in spite of its activism, the range of NSE activities is limited by the lack of funding, given its nature as a Non-Governmental Organisation (NGO) and full reliance on membership fees.

In the subsections below, we describe some of these interventions in more detail.

Equipment

Hand sanitiser

At the beginning of the initial lockdown period, the Nigeria Society of Engineers Victoria Island Branch (NSE-VI) procured and distributed 500 bottles of hand sanitiser to security officers who were enforcing the lockdown at checkpoints on Victoria Island's major roads and highways. NSE-VI also distributed hand sanitiser to security operatives at the GTBank Headquarters, the Automated teller machine (ATM) gallery at Adeyemo Alakija Street, Victoria Island, and market women at Oyingbo Market. However, it was noted that a few women were not aware of the importance of hand sanitiser and how to use it. Therefore, NSE-VI advised conducting more awareness and information campaigns, especially for older people.

A private Nigerian company, Macjames, one of the grantees of the Royal Academy of Engineering.-funded **Project CARE**, was also involved in the production of hand sanitiser. The company, which specialises in chemical product research and development, was contacted by customers looking for affordable and reliable hand sanitisers. Building on its experience in producing hand sanitiser during the Ebola outbreak in Nigeria in 2014, the company started reformulating the Macjames hand sanitiser to improve its quality and effectiveness to meet the present needs. Macjames's first challenge was to manufacture affordable and effective hand sanitiser and disinfectant, as the prices of the raw materials had increased by over 50%. Expertise in chemical engineering and a track record of producing similar products for over 8 years allowed the company to design a production process in just 2 weeks, which uses the same quantity of raw materials to give a high yield of the product. The Macjames Advanced Instant Hand Sanitizer Gel contains 70% alcohol, sanitising up to 99.99% of pathogens, moisturises the skin, and meets WHO standards, based on laboratory quality control analysis. The newly designed production process enabled Macjames to reduce the price of the hand sanitiser by 50%, compared to similar brands' current market prices.

Also, with the help of funding from Project CARE, Macjames's goal is now to ensure that the newly developed economic and efficient production and distribution processes are up to speed and updated, to sustain the manufacturing and supply of affordable and effective sanitiser and disinfectant to vulnerable groups through partners and distributors. Partnering with an NGO, Macjames has reached over 11,000 people with its hand sanitiser, and has supplied government agencies, hospitals, corporate organisations, and individuals in over 6 Nigerian states.

Hand-washing device

A graduate member of APWEN and a colleague have designed and manufactured a hand-washing device to protect people from COVID-19 and other transmittable germs and diseases. The device is mobile, operated by foot, and incorporates automatic water, soap, and sanitiser dispensers. The 2 engineers have donated the device to strategic locations and stakeholders, including the Ogun State Government, to complement the government's effort to curb the spread of the virus.

Similarly, a mechanical engineer, Ahmed Ayinla, member of the Ikeja Branch of NSE, has designed a foot-operated hand-washing and soap dispensing machine for public places. The device is made from a drum, includes a washbasin, and has pipes that are connected to a water tank. This allows users to activate either soap or water sources through pedals operated by foot (see picture above).

Similarly, NIMechE designed automatic and foot-operated hand-washing devices that were made available to the government for distribution, and awarded funding to the most promising ideas for addressing COVID-19 related challenges by engineering students.

Ventilators

Responding to the call of the chair of the NSE Apapa branch to **harness the potential of local engineers**, Ibrahim Aledu – Apapa chief inspector at the COREN Engineering Regulation and Monitoring Inspectorate – designed a manufactured mechanical ventilator. The device is constructed using over 80% local materials, including wood, a motorcycle dry cell battery, and a wiper motor disc. The prototype cost Aledu about £260 (NGN 130,000) to produce, and he has the capacity to produce up to 50 devices per day in his works lab in Ijora. Aledu presented the mechanical ventilator to the Lagos State Ministry of Works and Infrastructure to obtain approval for mass production. This solution can help to reduce the nation's reliance on expensive foreign products and professionals, while boosting Nigeria's provision of ventilators. As of August 2020, the country had only 450 ventilators despite its large population.

In an attempt to address the same challenge, 2 Nigerian software engineers who have experience in carrying out electrical repairs, Mr Williams Gyang and Mr Nura Jibrin, found out that there were 40 faulty ventilators at Jos University Teaching Hospital, Northern Nigeria. The 2 engineers have already fixed 2 ventilators for free and are now working on the others.

Financial support

At the end of March, NSE launched an appeal to its members, to collect funds aimed at supporting the national response to COVID-19. NSE managed to collect roughly £36,120 (NGN 18 million), which was donated to the Nigerian CDC in the form of roughly £20,00000 (NGN 10 million), 2,000 hand sanitisers produced by the Nigerian Society of Chemical Engineers, and 2,000 face masks produced by NSE members, as well as a handwashing station. £6,015 (NGN 3 million) was set aside to buy food items for distribution to vulnerable NSE members.

Following the extension of the lockdown period in Nigeria, and in line with the Enhanced Welfare Initiative launched by the chair of NSE-VI, John Audu, the executive committee of NSE-VI implemented a **cash transfer scheme** targeting its most vulnerable members, such as young people and SMEs. The NSE-VI COVID-19 Palliative Scheme transferred roughly £10 (NGN 5,000) to 50 members. The sum was awarded on a first-come-first-served basis.

Online education

When COVID-19 hit, NIMechE decided to move all the activities delivered through its the Royal Academy of Engineering-funded bootcamp online, thus creating a **virtual school on engineering and entrepreneurship**, called ENGentrepreneur. Operating on Coursera, the ENGentrepreneur platform offers undergraduate and graduate students courses on a variety of topics, such as accounting, proposal writing for engineers, and emotional intelligence. Other divisions of NSE will also be able to upload their courses on the platforms. The expected launch date is 1 December 2020, and courses will be free for the first 100 people, while the following participants will pay. Attendants will receive a certificate if they pass a test.

To promote the initiative, NIMechE has implemented a multipronged marketing strategy, the National Secretariat opened a call for facilitators, and the NIMechE National Student Forum and student branches (in 33 Nigerian universities) were involved in reaching out to potential participants. The PEI also posted on its Facebook account, used Google Ads, and involved NSE in the marketing campaign.

The NIMechE **National Student Forum** was involved in providing information on what students may expect and need, as well as in providing feedback. Academia and industry were also involved in designing and coordinating the digital school team. According to Oduwa Agboneni, working with the right team and incorporating professionals' and students' feedback into course design were the main success factors for the initiative.

NiMechE has also digitised its mentoring scheme, which provides flexible communication between mentors and mentees who may be based in different locations. Mentors come from industry and academia, even from outside the country. Due to its success, the scheme received more funding from abroad for mentee's project development.

Online competitions

During COVID-19, NIMechE also continued the Royal Academy of Engineering-funded **Innovation Challenge**. In August, participants pitched their ideas and were given the opportunity to receive funding for prototypes, with mentors providing online support. Due to accessibility challenges, NIMechE provided participants with access to internet and IT devices, using the funding that it would have normally used to subsidise transportation to the physical bootcamp.

School online

TheReformers initiative is a non-profit organisation formed by mechanical engineering students who have held leadership positions in NIMechE at different levels to organise capacity-building initiatives with a focus on quality education, poverty eradication, and gender equality. During COVID-19, in response to the closure of all secondary schools, TheReformers created the **School Online Initiative**.

The group recruited more than **50 tutors and 1,000 secondary school students** on a volunteer basis among public school lecturers, teachers, undergraduates, NIMechE volunteers, and engineers to teach free classes via WhatsApp and Telegram. The choice of these platforms was motivated by their low data consumption rate, their user-friendliness, and their ability to run on almost every internet-enabled device. This allowed the initiative to reach even the most poor and remote communities.

WhatsApp groups of up to 30 students were created, with each tutor administering a different subject depending on their expertise. The focus was to prepare students for the West African Examination Council (WAEC) (an exam for all west African students to gain admission into higher education). A **Telegram group** was set up to serve as a school hall, provide general information, and deliver extracurricular training. TheReformers also ran seminars on exam preparation, higher education, and careers, which received positive feedback.

Skill Up

TheReformers also introduced **Skill Up 1.0**, an initiative to develop skills that are essential in the workplace and that engineering students do not usually learn at university, such as graphic design, 3D animation, and 3D explainer videos. Through WhatsApp groups (gathering over 600 participants), TheReformers' team ran a five-day training for these desired skills, with a focus on those which are particularly needed within a 'socially distanced' world and require minimal initial capital.

Due to the initiatives' success, TheReformers organised a second version, **Skill Up 2.0,** where trainees learned how to make the most of their smartphones. The one-day training was initially planned for 7 applications, but was later extended to 3 days and covered over 20 applications including Microsoft Word, Microsoft Excel, and Adobe Reader.

A member of TheReformers, Richard Seun Lawal, explained that his experience as former president of NIMechE's National Students Forum was crucial to successfully running the initiatives. The group still works closely with NIMechE, which provides credibility, sponsorships and advisors. The past national chairman of NIMechE, for example, is one of TheReformers' advisors and Richard's mentor.

Webinars

The NSE has adapted to the 'new normal' by **moving lectures, continuing professional development courses and other events online**. NSE organised webinars and weekly lectures on issues such as entrepreneurship, leadership, how to engage with members and other stakeholders via digital platforms, the post-COVID-19 green revolution, and other technical issues. The NSE annual conference also took place in a hybrid format: partly in person and partly online. Most of the events are free of charge, and attendance has been high. Online functions have generated cost savings, they are convenient for attendees, and have increased collaboration between branches, divisions, and members that are based in different locations. Thus, moving forwards, NSE will move all activities online.

How engineers have collaborated during the crisis

According to Dr Alex Okopi Momoh, **collaboration between stakeholders active in the engineering industry** is improving. In general, interviewees reported high levels of collaboration between the public, private, non-governmental and university actors, all motivated by the same goal of fighting the pandemic and guided by national policy. These kinds of collaboration are necessary to fight COVID-19, but are expected to be useful during future crises as well.

The crisis and the online ways of working and communicating have forced everyone to adapt and have **improved communication and collaboration between NSE branches and divisions**. For NSE members, it is usually difficult to physically attend all the events organised by the society. At the same time, NSE members based in Nigeria, Germany, the UK, and the US have now been able to attend webinars and distinguished lectures.

3. Women's engineering groups' response to COVID-19

APWEN is the main women's engineering group in Nigeria. Guided by the country's national policy on COVID-19, APWEN has moved most of its activities online. This was challenging because the national ICT infrastructure is poor, but APWEN has managed to make the online modality work, and even experienced some advantages.

APWEN set up an **e-learning platform**, to run weekly business and entrepreneurship committee e-learning sessions to build the capacity of its members. The first event was paid (£10) and the following events were free of charge, with the aim of building a base and incentivising participants, as people are not used to online training events. At least 200 people have attended APWEN webinars, which in the future might generate a source of revenue for the institution. The online modality means that a wider audience can be reached compared to face-to-face courses, including members from Germany and the UK. Given its success, the e-learning platform will continue to be operated after the pandemic.

As part of the **'Invent It, Build It' programme**, which is sponsored by the Royal Academy of Engineering, APWEN was scheduled to organise workshops in March/April to train teachers to teach STEM subjects through practical activities. These workshops were cancelled due to COVID-19, but later, in August, successfully organised in an online format: APWEN shipped electronic devices to 18 local branches, where trainees could gather work together on STEM-related activities, such as building a solar windmill. Thanks to the online mode, APWEN managed to reach 70 instead of 60 engineers.

During COVID-19, APWEN also launched its **mentorship programme** for university students, which is sponsored by the Australian company Wally. APWEN invited engaged companies, such as Nestlé, Shell, Unilever, and Guinness Nigeria, to understand what skills are required in the labour market and to encourage students to develop these skills. Online communication between mentors and mentees, which is more practical and accessible than face-to-face communication, has succeeded in engaging more mentors and mentees in the programme.

The SheEngineer Family Fun Workshop took place via Zoom in August 2020, as part of APWEN SheEngineer Invent it Built it Project, sponsored by the Royal Academy of Engineering in collaboration with the University of West of Scotland and the Institution of Engineering and Technology UK. The activity was aimed **at bringing families together at home**, with parents and children using everyday materials – previously shipped to their homes by event organisers to conduct experiments in the fields of science and engineering. This event helped to familiarise people with these topics, by letting them see the physics behind normal things, such as the science behind baking a cake, and using everyday materials.

4. Impact of the COVID-19 crisis on young engineers, education and skills

COVID-19 has generated many changes in engineering education and training. Firstly, it has required education institutions to **move classes and exams online**. Apart from private schools and universities, education institutions have not been able to hold classes online, especially in rural areas and poor communities. Internet connectivity is weak in many Nigerian regions, and universities have not supported students with bundles of data. On the other hand, COVID-19 has highlighted the importance of digital skills for young engineers. For example, faculty entry tests have been held online for first time. Any engineering discipline will require these skills, which according to Dr Felicia Agubata, member of APWEN and Director of the SheEngineer Invent it, Built it Project, should now be integrated into the university curriculum.

COVID-19 has increased NSE's potential to **reach and recruit new members**. Membership examinations and interviews were previously held face-to-face, which prevented many potential candidates from applying. COVID-19 forced the NSE to hold all membership examinations and interviews through a virtual platform, which was carried out successfully with over 1,000 candidates. Going forward, this will be a permanent feature of the NSE membership process, as it will allow the society to go beyond Nigeria, reaching out to candidates from the UK, Germany, and the US.

5. Post-crisis outlook

Unlike other African countries, Nigeria has an umbrella PEI, NSE, that has **managed to coordinate the efforts of its members from different states and disciplines**. This has resulted in engineers using their skills to design and repair critical equipment and provide food and financial support to the most vulnerable groups within society, as well as improving collaboration between industry and academia. Engineers' public engagement stemming from NSE's call to action has increased the visibility of local engineers and showed their potential to contribute to the country's sustainable development. In the future, this might lead to greater recognition of the local engineering industry from the government, and improved collaboration as a result. Lack of recognition from the government towards the local engineering industry is common across African countries, and therefore engineers from other countries might want to join forces – across disciplines and locations – and use COVID-19 as an opportunity to prove the value of local resources to address country challenges.

NSE is already playing a role in the post-crisis recovery. For example, it is encouraging its members to take advantage of funds made available by the government to spur entrepreneurship development. To recover from the crisis, Nigeria is looking at **new ways to create jobs**, and engineering is well placed to rise to this challenge. NSE is therefore encouraging members to obtain funds and develop innovations and enterprises that can help the nation to grow.

TheReformers member, Richard Seun Lawal, agrees on the importance of entrepreneurship for the recovery. He believes that engineers are natural innovators, but they lack the entrepreneurship skills needed to turn innovations and ideas into businesses.

Going forward, the jobs market will inevitably be affected by the impact that COVID-19 has had on business methods. Interviewees agreed that, from now on, there will be an increased focus on **digital technologies and skills**. Many firms in Nigeria were forced to stop their operations because people were unable to work from home, due to their own lack of digital literacy or the weak ICT infrastructure in the country. COVID-19 is forcing businesses and individuals to change their skill set in order to learn how to work and continue their operations online. The COVID-19 outbreak has also revealed the importance of investment in communications infrastructure, a sector already seeing rapid growth in SSA. This is highly important for people, who could then be able to work from home, and for schools, which could take advantage of e-learning platforms.

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- Eng. Chinenye Justin Nwaogwugwu, Member of the Nigerian Society of Engineers (MNSE), Managing Director and Founder, MACJAMES Global Resources Ltd. and MACJAMES Ikiomoye Technologies Ltd.
- Engr. Dr Alex Okopi Momoh, NSE Executive Secretary
- Engr. Felicia Nnenna Agubata, Fonds National de Solidarité pour l'Eau (FNSE) , member of APWEN, COREN and NSE, SheEngineer, Invent it, Built it Project Director
- Engr. Oduwa Agboneni, member of NIMechE
- Richard Seun Lawal, member of TheReformers and former President of NIMechE – National Students Forum

South Africa

1. Context/background

Overall impact of the COVID-19 crisis in South Africa

South Africa registered its first COVID-19 case on 5 March 2020. On 15 March, President Cyril Ramaphosa declared a national state of disaster and on 27 March initiated a three-week national lockdown. Measures aimed at countering the spread of the virus included one of the **toughest lockdowns** in the world, enforced by the military; limits on the size of public gatherings; travel restrictions; and the closure of schools, ports of entry, and non-essential industries. These restrictions were gradually reduced between May and October, when South Africa planned to reopen its borders to international travellers. By the 20 October, South Africa registered 706,304 cases and 18,656 COVID-19-related deaths, with one of the world's highest COVID-19 infection rates, despite having in place some of the harshest measures to contain the pandemic. South Africa ranks 12th (as of 21 October 2020) in the world **by the number of cases** and is the **hardest-hit country** in the **African continent**.

South Africa entered the COVID-19 crisis and the lockdown with an **already frail economy**, with real GDP growth estimated at 0.3% and 0.9% for 2019 and 2020, respectively. Fiscal revenues have also deteriorated in recent years, and the debt-to-GDP ratio has been steadily rising, leading to downgrades and a debt service burden that accounts for nearly 15% of public revenues[37]. The economy suffers from high unemployment and low investment. COVID-19 has had **devastating effects** on the **South African economy**: the national lockdown resulted in a reduction in production by non-essential business, the demand for goods and services plummeted, exports were affected by the disruption of global supply chains, and the uncertain environment limited business investment. With most workers confined at home and many losing their jobs, incomes decreased by an average of about 30%. Income and unemployment effects disproportionately burdened workers with lower education levels, primarily occupied in unskilled and informal jobs.

The South African government announced a **massive social relief and economic support package** of almost £25 billion (ZAR 500 billion), amounting to around 10% of GDP. The UNDP has predicted that **GDP will decrease by between 5% and 8% in 2020**, and that South Africa's economy will recover slowly through to 2024. UNDP estimates more than 80,000 people will have lost their jobs during the pandemic.

In July, the **IMF approved** Special Drawing Rights of **£3.2 billion (SDR 3.1 billion)** for South Africa through the Rapid Financing Instrument. The Development Bank of Southern Africa has launched £7.5 million (ZAR 150 million) in COVID-19 response programmes in South Africa and the SADC has coordinated regional actions in response to COVID-19 within its 16 Member States, and further coordinated with the Tripartite Free Trade Area (an umbrella organisation consisting of 3 of Africa's Regional Economic Communities) to contain the spread of COVID-19 while facilitating trade and transport for the safe, efficient, and cost-effective, movement of goods and services across the region.

COVID-19 has overwhelmed South Africa's **weak health system**, which is unable to deliver primary care to remote communities, faces challenges in terms of governance and management, and experiences severe shortages, especially in rural areas, of skilled healthcare workers and equipment.

The system was already overwhelmed prior to the pandemic, and is now struggling to meet testing requirements, as well as demand for ICU beds and ventilators. When the National Ventilator Project (NVP), a Department of Trade and Industry and Competition (DTIC) initiative, began in March, it was announced that there was a total of 3,216 ventilators in South Africa – 17,000 fewer than what the country was estimated to need at the peak of the virus. Of those ventilators, 2,105 were sited in private hospitals. Oxygen concentrators were also hard to procure, as private businesses and individuals were buying them up.

Nevertheless, South Africa is experienced with testing for HIV and TB, and was thus able to rapidly deploy **60,000** community health workers **for door-to-door screening** of people in rural areas. Having experienced how to live with infectious diseases like TB and HIV, the country is more likely to be resilient to living with COVID-19 on a long-term basis. An additional element exacerbating the crisis is the **rampant inequality** and disparities in South Africa (with the Gini Index predicted to rise due to the economic shock), which is reflected in a huge gap in care. South Africa is considered one of the most unequal countries in the world in terms of the treatment of COVID-19 patients.

37 'Impact of COVID-19 on the South African economy: An initial analysis', *SA-TIED Working Paper 111*, Arndt, C., Davies, R., Gabriel, S., Harris, L., Makrelov, K., Modise, B., Robinson, S., Simbanegavi, W., van Seventer, D. and Anderson, L., April 2020.

Brief overview of the key engineering stakeholders in South Africa

South Africa's leading engineering organisation is the South African Academy of Engineering (SAAE). Its key function is pooling engineering expertise for the technological welfare of South Africa, South African Voluntary Associations (VAs) include the Institution of Municipal Engineering of Southern Africa; Consulting Engineers South Africa (CESA); the Institute of Electrical and Electronics Engineers South Africa (IEEE South Africa); the South African Institution of Civil Engineering; the Clinical Engineering Association of South Africa; and the South African Institute of Agricultural Engineers (SAIAE).

These organisations interact with a wide range of **national government departments,** including trade and industry, science and technology, environmental affairs, energy, water, and sanitation, rural development, agriculture, and communications. Scientific collaborations also exist, for example between SAAE and the Academy of Science of South Africa.

Impact of the COVID-19 crisis on the engineering industry in South Africa

Even before the COVID-19 health crisis hit South Africa, its economic effects were already being felt due to a fall in demand for Africa's raw materials and commodities in China, and a decrease in the access to industrial components and manufactured goods from the region. An SAAE member remarked that the overall economic sustainability of the industry has been severely damaged by the crisis, as most contractors were not in a position to weather another economic storm. The respondent believed that COVID-19 had worsened the **civil industry's** loss of skills to other countries. Professor Ian Jandrell, from the University of Witwatersrand, stated that COVID-19 had had a **massive impact** on the **consulting engineer profession,** but also on the **manufacturing, construction, and transport sectors**.

Interviewees reported that the industry's contractors and manufacturers had come to a total standstill for a month under Level 5 (the highest level) restrictions. The disruptions had an impact in terms of accessibility to factories and sites, the increased sick leave when COVID-19 is diagnosed or suspected, and additional health and safety screening requirements for access to sites and factories. Many companies closed due to the economic crisis.

Most construction projects have been put on hold, resulting in unforeseen delays, disruptions, and additional costs. It is estimated that the construction sector experienced 'a collapse of more than 30% in the second quarter of the year' compared to the same quarter in 2019, and Statistics South Africa noted 'a nominal decline in gross domestic product overall of 14.8% year-on-year'. It is expected that the recovery of the sector will be further affected in the post-lockdown phase by high national debt, labour shortages, and little infrastructure spending in the context of a depressed economy.

Electricity demand also fell due to lower industrial demand. Other sectors have been significantly affected, including **mining** and **quarrying**, with the imposed closures of certain mines and a temporary decrease in global demand, especially from China. Some smelters remained operational during the lockdown period, although not at full capacity, and were only fed by ore stockpiles. Moreover, **petrochemicals** production was able to continue during the lockdown period, fuel demand decreased, due to a temporary lack of private vehicle and passenger transport, and a lower level of freight transport during the lockdown.

Chris Campbell from CESA believed that consulting engineering companies were likely to be **less affected** as they had previously adopted a **work-from-home** policy. Furthermore, a small amount of construction activity continued to provide the necessary infrastructure to support medical efforts (building temporary medical and quarantine facilities) and enforce containment, and some sectors might continue to receive investor attention long after the pandemic, including healthcare infrastructure.

The crisis has created some valuable collaborations between the engineering industry, the government, and universities, resulting in innovative solutions to tackling the crisis. Consequently, the engineering profession has gained more public attention than it traditionally receives. According to Databuild's Chief executive officer (CEO), the pandemic could have created an opportunity for the construction industry with the "recapture of local supply chains and the use of locally produced materials".

Professor Teresa Hattingh from the North-West University claimed that COVID-19 had negatively affected **engineering university education** because of the switch to online learning, reduction in laboratory work, and reduced exposure to the working environment. The crisis has also significantly impacted the availability of employment for young engineering graduates.

On a positive note, another SAAE member stated that there was a rapid response in switching to different methods of teaching, that people are now familiarised with **remote working,** and that VAs' conferences have moved online. Many professionals in the engineering industry and academia appreciated **the enhanced virtual collaboration** boosted by COVID-19, especially as it exposes engineers to **more training opportunities**.

2. Engineering response in South Africa

The position of key engineering actors

Professor Ian Jandrell found that, in general, engineers were able to deal with the crisis, and demonstrated that they had good capacity to work remotely. On the other hand, Professor Teresa Hattingh from the North-West University and Chris Campbell from CESA believe that South Africa's **engineering community** is quite **fractured** and there are **poor networks**, which means that it is difficult to understand what other key engineering actors are doing. Professor Hattingh believes that more could be done by the government to engage with the engineering community through VAs to identify and solve challenges during the crisis.

The contribution of engineers to tackling the crisis

Despite the lack of cohesion within the South African engineering community, many have admired how some of its members – including some of the younger ones – have stepped up to **contribute to tackling the health crisis** with their expertise. In the words of an SAAE member, COVID-19 has "forced the engineering community to **look for alternative ways of doing engineering**". Several VAs are publishing guidance – especially on safety and contractual topics – on their websites and, even though they have switched to remote working, they have remained available to their members with some offering webinars. Some VAs were able to assist, through their member practitioners, with innovations in water supply and handwashing facilities in informal settlements.

Practitioners in member companies were involved in statistical analysis and projections on infection rates that assisted in informing South Africa's National Department of Health (NDoH) in its response to the pandemic. Engineers with expertise in healthcare facilities were involved in the design and set up of temporary emergency facilities. Engineering practitioners were even involved in the design and 3D printing of ventilator adaptor pieces for use in these emergency units. Additionally, engineers and water scientists succeeded in proving how testing of wastewater at treatment facilities could be used to trace the origins of COVID-19 infections so that more targeted testing could be conducted. This is especially important in the context of the limited resources and time available for broad, random testing. Many of these products and services will have value long after the pandemic.

Another SAAE member reported that the biggest contribution of the engineering community was the quick adaptation to the 'new normal'. The respondent found that most civil contractors were able to "quickly develop and roll out revised standard procedures of operation", which allowed the resumption of some economic activity and helped the workforce to start earning a living again. Nonetheless, dealing with the contractual challenges once restrictions started being lifted has been difficult due to the scant clarity regarding what is allowed and what is not.

Medical equipment

Ventilators

South Africa has not traditionally been very involved in the production of medical equipment, and faced COVID-19 with an insufficient stockpile of it. In April, DTIC mandated the **South African Radio Astronomy Observatory (SARAO)** to manage the national effort required for the local design, development, and manufacture of respiratory ventilators. The **National Ventilator Project** started with SARAO's call for proposals for companies to design, develop, and produce ventilators. Most of the ventilators in South Africa were invasive ventilators (involving tracheal intubation), and so the NVP focused on producing noninvasive ventilators (consisting of a mask attached over the patient's mouth and nose).

95 companies responded to the call. The Solidarity Fund allocated resources for the development of prototypes and the production of the machines. Justin Jonas, Professor of Physics and Electronics at **Rhodes** University, praised the capacity present in South Africa, with many small companies that had never produced medical equipment before being able to do this during the pandemic. The non-invasive ventilators are estimated to cost between £500 and £623 each to produce (between ZAR 10,000 and ZAR 12,500), well below the cost of invasive ventilators (around £50,000 or ZAR 1 million).

Devices funded by the Solidarity Fund are destined for public hospitals, but private hospitals can also source devices from companies and universities that were involved in the NVP. NVP manager Willem Esterhuyse collaborated with Stellenbosch University to test a continuous positive airway pressure (CPAP) device.

The university managed to source items such as medical oxygen, oxygen sensors, tubing, flow sensors and regulators, but other components had to be manufactured in the mechanical and mechatronic engineering department. The specific CPAP device that was tested was manufactured from a design that was published online by engineers from University College London and Mercedes Formula One. The tests showed that the device performed as expected. The goal of the NVP was to roll out 10,000 ventilators by June, but delays in getting approval for prototypes from health authorities have slowed production down. A further £12 million (ZAR 250 million) was approved for the local production of up to 20,000 non-invasive CPAP ventilators, although the usefulness of the delayed production, coming after the peak of COVID-19, has been questioned.

The **South African Ventilator Emergency Project (SAVE-P)** team anticipated a ventilator shortage. The team came together, consisting of over 100 South Africans from across the country, including engineers, designers, technologists and medical professionals. They redesigned an affordable CPAP device that 'can be manufactured using existing local technology' and locally sourced materials.

Personal protective equipment (PPE)

Engineering students, technicians, and lecturers at Stellenbosch University have also been involved in 3D printing of face shields and other PPE, including headbands for plastic face shields.

Teams from the Digital Incubator at the Wits Tshimologong Precinct produced ventilators and developed a **laser-cut solution** to produce full transparent **visors** to be worn on the frontline, thanks to donations and the collaborative and volunteer work of the engineers. Alex Ernst, who runs The MakerSpace for the Wits Tshimologong Precinct, reported that "after fabricating thousands of face shields from PETG plastic [they] soon realised the need to start looking at an **eco-friendly** solution", and that The MakerSpace in Durban adopted the same system and started making PPE from recycled plastic. Engineers concerned about the environmental impact of PPE produced visors for rural areas from plastic sourced by unemployed people who collect plastic for recycling. They also inform people who receive their visors on how to dispose of them in an environmentally friendly way.

The MakerSpace, founded by the engineer Steve Gray, is a co-working space and a short- and long-term innovation training centre for young engineers and technicians, mostly coming from a challenging upbringing. COVID-19 had a massive negative impact on their revenues and, when they became aware of the PPE shortages in other countries affected first, they started getting ready to produce them locally. They improved a production machine from a model they acquired from abroad, stocked some components for production, and produced 20,000 face shields with virgin plastic once they received an order.

Mask decontamination

Researchers from the UCT Chemical Engineering Department and the UCT Faculty of Health Sciences are working together with researchers from Cape Catalytix (Pty) Ltd. to develop an N95 mask decontamination device that will enable re-use of N95 masks. The self-contained system will be made from inexpensive and readily available components. The first design will have a working volume of approximately 100 litres and will be able to treat 40 to 50 masks per cycle. It is aimed at South African medical facilities dealing with COVID-19 infections, and the team plans to develop larger installations for emergency COVID-19 field hospitals.

Digital services

Praekelt.org

Praekelt.org is an NGO based in South Africa and active in several countries; it has worked in more than 10 countries and in collaboration with the WHO during the COVID-19 crisis. Praekelt.org felt that it was well positioned to support ministries of health and other organisations in tackling COVID-19, thanks to its experience over the past 13 years in developing mobile tools and services that connect actors in the health ecosystem. In South Africa, Praekelt.org developed a service called **ContactNDoH** to keep citizens informed.

NDoH is a WhatsApp-based helpline, leveraging **Turn.io** technology, that disseminates accurate, timely information on COVID-19 to the public through a chatbot. The service took one week to launch in March 2020 and has since reached 8 million users in South Africa. Praekelt.org has also partnered with WHO and Facebook to provide free information on the COVID-19 pandemic in different languages to vulnerable communities across the globe through WHO's HealthAlert.

Additionally, Praekelt.org has developed **COVID-19 HealthCheck**, a digital COVID-19 health assessment tool that helps assess the risk of contagion, allowing for early detection, mapping, and management of COVID-19 cases.

The user answers questions (aligned with NDoH guidelines and protocols) about their symptoms and characteristics either on WhatsApp or via a USSD protocol (to extend accessibility to those who do not have smartphones). They are then assessed as being at high, low, or medium risk of having contracted the virus. People identified as having high or medium risk will receive guidelines related to self-isolation or testing. **HealthWorkerAlert** is the third tool developed by Praekelt.org during the pandemic. It provides psychosocial support and official up-to-date COVID-19 guidance and information to frontline healthcare workers.

Countries and organisations can roll out their own versions of the 3 services in local languages, and with country-specific information that is trusted and up to date. Praekelt.org admitted that it faced some challenges, such as the **changing nature of COVID-19 information** and **keeping users engaged** with the platform through valuable and updated content, rather than static information.

Afrikan Research Initiative

The Afrikan Research Initiative (ARI) provides epidemiological information about COVID-19 to keep Africans informed about the prevalence and spread of the pandemic. ARI established the COVID-19 project to map and track the spread of the disease and its burden on the continent. It also suggests targeted interventions on how the continent should deal with the virus. The founder flagged that the initiative is also aimed at meeting "the growing need for Afrocentric information and data on pertinent issues that affect our country and the continent."

Young engineers

The University of the **Witwatersrand** promoted a university-wide **COVID-19 Fund** to support initiatives (across disciplines) in alleviating human suffering and difficulties arising from COVID-19. Witwatersrand's expertise was made available through its extensive teaching and clinical services within the Witwatersrand health network of public and private training hospitals and other partners. Professor Robert Reid, Head of Wits University School of Mechanical, Industrial and Aeronautical Engineering, was inspired by the response and contribution of young engineers to the crisis. He believes this can give hope in terms of engineers' role in tackling the next challenges that society is likely to face.

Within the University of **Cape Town's (UCT)** Faculty of Engineering and the Built Environment, many students and alumni have stepped in to develop solutions to assist with the COVID-19 pandemic, responding to Professor Amit Mishra's challenge to come up with **ideas to tackle COVID-19**. For example:

- A student in the School of Architecture, Planning and Geomatics has been 3D printing devices to help stop the spread of the virus, including a device to open doors without touching handles.
- A senior undergraduate electrical engineering student designed an affordable, smart short-wavelength UV-C light system that disinfects surfaces, air, large rooms, and even face masks, making them reusable.
- A team, led by a chemical engineering student, developed a portable distillation vessel to make hand sanitiser. With sales of alcohol prohibited, the device puts surpluses to good use and could prove useful in repurposing breweries and distilleries towards the production of affordable hand sanitisers at a time of supply shortages.

Nelson Mandela University's Advanced Engineering Design Group students designed and delivered intubation units to the anaesthesiology staff at Livingstone Hospital after their effectiveness was tested in in-theatre training sessions.

Steve Gray from the MakerSpace in Durban found that, while COVID-19 caused even more unemployment among young engineers, it also had some positive effects: the young mechatronic technicians attending his innovation training could see first-hand that engineers at the MakerSpace are not just talking about innovation, they are doing it.

This has boosted the credibility of innovation among young engineers and inspired them to be independent and entrepreneurial, shifting the emphasis to innovation and upskilling. Gray is confident that this opportunity for young engineers to learn how to find solutions to very concrete problems will translate into having better engineers in the future.

Virtual hackathons and learning

Zindi is a social enterprise based in Cape Town, Johannesburg, and Accra. It is the first data science competition platform in Africa, a space for data scientists to compete with ideas for the common good and win money, by submitting **AI and machine learning models** to solve **African challenges** with African datasets. Paul Kennedy, Zindi's Community and Communication Manager, stated that Zindi did not see the pandemic as a major opportunity or risk, but started looking at how it could help and work with users, considering that its situation had changed dramatically. He explained that the transition to virtual events was smooth, and made Zindi realise that it had the opportunity to provide a place for **virtual learning** and **participation** during a time when students were not able to go out.

Throughout April and June 2020, the Zindi team hosted data-driven challenges and #ZindiWeekendz, namely **virtual** weekend **hackathons** that focused specifically on COVID-19, intending to spur innovations in the fight against the virus. Monetary prizes were assigned, and participants received access to valuable online data science learning content. All winning solutions have been shared as a public good on GitHub, with Zindi expressing the commitment to supporting partners in the implementation of these solutions. The winning solutions could prove very useful to policymakers and health workers in taking appropriate actions to contain and mitigate the impact of COVID-19. The crisis revealed an urgent need to invest in connectivity infrastructure, as students moved back to their hometowns and struggled with connectivity. Zindi tackled this problem by sponsoring mobile connections for some users to participate in virtual events.

Notwithstanding the efforts of different members of the engineering community in South Africa in proposing solutions to confront COVID-19, there were some challenges. Professor Teresa Hattingh from the North-West University highlighted that COVID-19 response projects faced tremendous challenges, including a disconnect between technology and design and the intended users; although the outputs were good, they were sometimes not a good fit for the final user and the context in which they operated.

How engineers have collaborated during the crisis

COVID-19 has created novel collaboration and teamwork between different actors in the engineering community, including the government, academia and industry, with the aim of finding practical solutions to the crisis.

Professor Ian Jandrell reported that Wits's chemical and metallurgical engineers had been collaborating with biomedical engineers in Australia to develop alternative tools to respirators to oxygenate blood. A fellow graduate transferred his high-tech skills from the automotive sector to build a robot to help people in hospitals. Engineers from the university made the design of the aforementioned laser-cut visors available nationally, and collaborated with other universities by offering their labs and workforce. Private industry, the region's technical university, and the University of Cape Peninsula took the model and began to produce PPE themselves. This collaborative effort turned into an **alliance** to achieve **national solutions**.

Chris Campbell from CESA reported that for the first time in the history of South Africa, 32 engineering associations joined associations of architects, quantity surveyors, project managers, construction, health and safety professionals, as well as civil engineering and building contractor organisations, and construction materials supplier organisations, to collaborate under the banner of the **CC19RRTT**. CC19RRTT aimed to develop a **liaison forum with government decision-makers** on how to safely get the engineering industry back to work, mitigate the damage to the economy, and stem the tide of unemployment.

CC19RRTT is working on a continued post-COVID-19 collaboration with the government, as the challenges plaguing industry and the engineering profession were present before the threat of the pandemic and are expected to remain in the longer term.

Some initiatives within the engineering community mentioned above are also examples of **collaboration between government, academia, and industry, including the private sector**. The NVP is a clear case of this, and **Praekelt.org** collaborated with the government, specifically NDoH, as well as with WHO, to implement its WhatsApp services in South Africa and globally. Through Praekelt.org's HealthCheck service, data on possible cases is fed directly into the government database. Educational institutions can also use Praekelt.org's services to screen students when campuses reopen. **Zindi** is also partnering with private sector organisations to implement the ideas from the Zindi virtual challenges.

Business 4 South Africa (B4SA) is an innovation and manufacturing private sector working group which aims to assist the government with the COVID-19 response. This is a multi-stakeholder approach working to solve local issues around the pandemic, in particular bringing resources to bear to rapidly close the gap between supply and demand of required health goods and services. The B4SA portal, in collaboration with the Solidarity Fund, was 'able to acquire 41 million pieces of PPE, while a myriad of SMEs have donated PPE stock and offered to assist with manufacturing'.

Colin Little, an engineer involved in B4SA Mask stream, recognised that engineers (from all disciplines) from the private sector did the 'heavy lifting'. Steve Gray from The MakerSpace worked within several B4SA working groups offering innovation/technical support and services to tackle the humanitarian crisis. He felt that the real problem in South Africa was not the lack of protective equipment or its localised production, but a **disconnected supply chain**. With his team, he developed a software app to link the demand and supply of PPE for the local government for free. However, the service never took off – Gray believes this was due to the government's lack of ownership of the service, and its consequent scarce use or promotion. At the same time, he felt that the main challenges in putting the PPE prototypes in production were not of a technical nature, but were related to miscommunication, bureaucracy, procurement, certification, and testing, which often blocked the processes before the actual production. He found that engineers, who are "makers" working on "hard stuff", and the local government, failed at establishing an efficient relationship.

Gray collaborated with Colin Little in repurposing a sausage clips manufacturer to aluminium nose clips production for masks. Regrettably, even though many South African manufacturers succeeded in localising the production of medical devices (or some of their components) while the global supply chains were disrupted, when imports started to flow again, most of the procurement and sourcing shifted back to China's cheaper supply. However, Little emphasised that there is "renewed ambition to localise more manufacture using the success of the B4SA medical equipment production efforts".

3. Women's engineering groups' response to COVID-19

Chris Campbell from CESA highlighted that women's engineering groups, including the South African Women in Construction (SAWIC), were part of the CC19RRTT initiative, so the role they played was no different from that of any other volunteer participants.

Monique Schoombie is a Senior Engineer at the Council for Scientific and Industrial Research (CSIR), who worked with her team to design a CPAP ventilator. They submitted their application in April 2020 as a response to the NVP call for proposals. The device provides respiratory assistance to certain COVID-19 patients and 'uses an innovative design to provide a mild level of oxygenated air pressure to keep the airways open and assist with breathing'.

4. Post-crisis outlook

An SAAE respondent believes that "the crisis has highlighted the ability of the **construction industry** (including **civil engineering**) to be a **catalyst in reviving economic activity**", but many companies have closed down and will not be able to restart, and the public authorities are not bringing sufficient projects to the market at present. He also reported that some concern existed about whether funds previously earmarked for civil projects had been diverted to deal with the crisis.

Colin Little stated that "many, many things in South Africa need huge engineering input to fix them (power stations, road, rail and water infrastructure, housing)". Fortunately, he said, the government has "announced a big infrastructure spend to get the economy moving" and create jobs. Another SAAE member reported that "long-term planning, development of new appropriate infrastructure and training of stable, versatile, **resilient workforce** is required to address and adapt when circumstances change".

Professor Ian Jandrell, noted that a positive effect of COVID-19 was that specialist colleagues had become much more familiar with working seamlessly in teams, even from different countries, thanks to the increased use of online tools. Steve Gray from The MakerSpace also believed that COVID-19 had boosted **digital transformation**, with engineers having more opportunities to collaborate, be mentored, and meet virtually, and that this had been massively adopted. Professor Jandrell explained that shortly after classes were fully moved online, people became very comfortable with online technologies, with rapid uptake and familiarisation with the tools. Nonetheless, he noted that it was challenging for universities to assess students online in an objective validated way, as engineering education and training had an important practical component.

Professor Jandrell further acknowledged the importance of engineers and the true role of engineers to **facilitate human** and **capacity development** and to **help society**. He argued that the COVID-19 crisis had created a **new sense** of **innovation** and **purpose** within the engineering community, with professionals stepping in with solutions for the common good. A SAAE member found that COVID-19 had made engineering visible, and Gray believes that it has made the broad public realise the importance of engineers in society. Professor Jandrell also feels that the **future** looks **bright for some specialist engineering sectors**, such as renewable energy and the new development of independent properties. Moreover, another member thinks that COVID-19 has highlighted the value of education and the availability of skills to respond to challenges. Professor Jandrell believes that developing economies in particular need the competencies, skills, and capacities of professionals trained in engineering who understand technology, to step up and help build the economy. He sees the current times as an opportunity for engineers to solve the country's collective problems through **collaboration between disciplines**.

Chris Campbell from CESA hopes that the South African engineering community will continue to **join forces** and stay united for the greater good, as it did with CC19RRTT. He believes that, through CC19RRTT, the engineering community has gained recognition, and that this body should represent the engineering community and take the role of coordinating concerns and proposals to the government on revitalising the economy through infrastructure development.

Another interviewee from the SAAE believes that to best contribute to meeting the post-COVID-19 needs of society, PEIs and the engineering community should focus on resilience and planning, and on communicating "essential maintenance programmes and long-term vision to **ensure** that a **stable baseload** of **engineering work** is conducted continuously". This will allow "skills development and building of **strong, resilient capable organisations** to tackle engineering challenges". Moreover, they should communicate the essential minimum needs of the community that should be met, including water, electricity, sewage, communications, and transportation.

Professor Hattingh also finds that the government should learn from the COVID-19 lessons to engage more with VAs and the broader engineering community, especially in terms of delivering infrastructure in South Africa. The government itself sees this as a focus area,

and there is a strong appetite to develop a healthy partnership between the public and private sector for **capacity building and professionalising** the **resources** in the **state**. This could be the time to **overcome** the **fractured past of VAs**, mistrust between the government and the engineering community, and subsequent lack of recognition, and to address other issues. However, Professor Hattingh fears that many engineers are likely to emigrate and therefore, the government should counter this by supporting the development of new businesses to support the economy.

Furthermore, Zindi points out that COVID-19 has made more people aware of the importance of data science, digital skills, and AI, due to their important role in the response to the crisis, and thus, the interest in building these skills has raised. As unskilled workers were most affected by the crisis, interventions aimed at re-skilling them should be a priority. Furthermore, the role of the private sector and SMEs in the recovery process cannot be underestimated and should include supporting the transition to digital technologies and improving digital skills.

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- Paul Kennedy, Community and Communication Manager, Zindi
- Steve Gray, Founder, The MakerSpace Durban
- Teresa Hattingh, Lecturer, North-West University
- Several SAAE member

Uganda

1. Context/background

Overall impact of the COVID-19 crisis in Uganda

Context

The first COVID-19 case in Uganda was detected on 13 March 2020. To prevent a wide spread of the disease, the government of Uganda came up with preventative measures that saw the total lockdown of the country on 30 March for almost 3 months, which included the closure of all public gathering spaces, such as schools, churches, and restaurants. The transport of goods and services was also negatively affected, as no public or private cars were allowed to operate for a certain period of time. In June 2020, the government of Uganda eased the lockdown with strict guidelines in place.

In response to the outbreak, the government set up an online COVID-19 Response Information Hub to provide response actors working on the COVID-19 outbreak in Uganda with the most up-to-date data, information, and resources. The Ugandan response to the COVID-19 pandemic is laid out in the national COVID-19 preparedness and response plan of June 2020. According to a COVID-19 situation report published in August 2020 by the government, the key principles for preparedness and response to COVID-19 encompass the use of ICT innovations, a community-led approach, and 24-hour surge capacity. Moreover, the challenges that the government is currently facing in its response to the pandemic include a lack of transportation to evacuate cases from their communities and limited resources to support response activities, resulting in very low contact follow-up rates.

According to Development Initiatives, over 8 million Ugandans (19.7%) live below the national poverty line, and the government's COVID-19 relief programmes, like food and other relief aid, have been directed primarily at the 1.5 million people living in urban areas in the Kampala and Wakiso districts, rather than those in rural areas. Similarly, the government's response measures are focused on the formal sector, meaning that they will not reach the poorest and most vulnerable citizens who work in the informal sector and are unable to access government loans and tax benefits. This is likely to cause further inequality between rural and urban populations, and exacerbate poverty and vulnerability. Furthermore, Ugandans living in poverty who rely on the government's free healthcare programmes have experienced reduced access to primary healthcare during the COVID-19 pandemic. As a result, Uganda has registered an increase in the number of preventable deaths during childbirth and other health emergencies, and an increased occurrence of deaths from preventable diseases, like Malaria. Access to family planning and other healthcare programmes has also been compromised.

Furthermore, Development Initiatives contends that major shortfalls in revenue collection have pushed the government into high levels of borrowing to cover its fiscal deficit for both financial year 2019/2020 and 2020/2021. If this continues, it will contribute to a further increase in the total public debt, which has grown from 22.4% in 2010 to a projected 41% of GDP by the end of 2019/2020. As a result, Uganda's debt-servicing commitments will continue increasing, as rising external public loan financing requires high commitment fees, and non-concessional domestic borrowing attracts huge interests. Interest payments alone will take up 9% of the total resource envelope for 2020/2021, thus more money is being allocated to interest payment and away from service delivery or development spending that could benefit people living in poverty.

Brief overview of the key engineering stakeholders in Uganda

The ERB is established under the Engineers Registration Act Cap 271 as a statutory body with a mission to regulate and control engineers and their profession in Uganda. The board regulates and controls engineers and their activities in Uganda, and advises the government in relation to this. It has wide-ranging powers to register, deregister, restore registration, suspend registration, hold inquiries, hear appeals, and appear as a respondent in cases brought against it in the High Court.

The UIPE promotes the general advancement of the science and practice of engineering and its applications. It facilitates the exchange of information and ideas on those subjects among the members of the institution.

The Uganda Association of Consulting Engineers (UACE) was founded in 1993 as the body responsible for representing the professional concerns and general business interests of its members in the field of consulting engineering in Uganda. Accordingly, UACE caters for its members regarding engineering professional ethics, standards, and client–consultant contractor relationships. In 2001, UACE was formally registered with the registrar of companies as private limited company limited by guarantee.

The Uganda National Association of Building and Civil Engineering Contractors (UNABCEC) aims to promote and protect the shared interests of its members and the construction industry as a whole, through mobilisation, advocacy, networking, and innovative service provision.

Engineers without Borders USA (EWB-USA) has been present in Uganda since 2005, with numerous programmes and community partnerships. The organisation opened its first Country Office on the African continent in Uganda in 2019. EWB-USA aims to increase long-term local capacity through the provision of engineering expertise.

Relevant ministries that work in engineering

The Ministry of Works and Transport formulates policies and plans, sets standards, builds capacity, carries out advocacy, and regulates, monitors and evaluates the works and transport sector. In terms of mechanical engineering services, the ministry oversees developing policies, laws, standards, and guidelines for models of vehicles for government and public use, and provides technical advice to the government and wider public on mechanical engineering equipment. The department is headed by the Commissioner for Mechanical Engineering Services.

The Ministry of Science, Technology and Innovation is a government institution. It was created in June 2016 in recognition of the need of the government to explicitly prioritise issues related to science, technology, and innovation as a key driver for economic development. It is mandated to provide overall guidance and coordination for scientific research, development, and the whole national innovation system in Uganda. The ministry works with agencies to achieve its overall mission, including the Uganda National Council for Science and Technology, Kiira Motors Corporation, and the Uganda Industrial Research Institute (among others), all of which place a strong emphasis on the role of engineering to advance national priorities in this area.

2. Engineering response in Uganda

The position of key engineering actors

Not all of the key engineering actors above have released statements on their websites or social media accounts explaining their organisations' stance in relation to the pandemic. However, the following organisations have released statements.

In March, **UIPE** posted a COVID-19 awareness-raising message for its members on its Facebook page. According to their Facebook page, they also held a workshop on 8 October for young engineers and students titled 'Leveraging engineering to combat COVID-19'. The objectives of the session were to raise awareness of engineering opportunities, and motivate ideation and innovation by holding a mini-essay challenge.

UNABCEC developed and published a set of guidelines on its website to provide construction contractors with practical recommendations on how to operate construction sites amid COVID-19. It also highlighted its contribution of 43 tonnes of maize flour and 14.2 tonnes of beans as part of its efforts to support the COVID-19 response in Uganda. **Kiira Motors Corporation** (working under the Ministry of Science, Innovation and Technology) created a separate tab on its website, dedicated to showcasing its Bulamu ventilator, which was created in partnership with Makerere University (further details are provided in the next section) to bolster the country's capacity to provide critical care during the pandemic.

According to an interview with Brian Turyabagye (see section below on biomedical smart jacket) **the Uganda Industrial Research Institute (UIRI)** helped with funding and manufacturing most of Uganda's PPE. It released the following statement on its website on 29 September 2020:

"At the onset of the Coronavirus outbreak, the Uganda industrial Research institute put prevention high-up on its agenda kick-starting a mask making project and currently a sanitizer production initiative. In the period between July and August 2020, UIRI produced 1,000,000 masks which were supplied to the Ministry of Health. Additionally, the Institute has set up a quality assurance procedure to ensure quality control in facial masks. Recently, the Institute has innovated equipment able to produce 1,750 litres of sanitizers and is gearing at mass production of sanitizers to facilitate disinfection."

Finally, EWB-USA focused its efforts on strengthening the water, sanitation and hygiene (WASH) sector in Uganda by improving water supply systems. According to an interview with the head of EWB in Uganda, the pandemic has drawn international attention to the serious need for infrastructure improvements related to WASH. EWB's efforts have remained concentrated on stepping up WASH interventions during the pandemic (see more details in the next section).

Despite having good plans and strategies, the WASH sector in Uganda struggles with a lack of funding from the government. According to the WHO, the current budget allocation is less than half of the sector investment plan targets, and the situation is worse for hygiene and sanitation (0.001% of the national budget). In addition, according to the *Water and environment sector performance report 2018*, published by EWB-USA, over 64% of Ugandan households do not wash their hands with soap and water. Studies indicate that soap is not widely used for handwashing but rather for laundry and bathing, and that soap is frequently seen as a non-essential item. This poses a problem in times of COVID-19, where handwashing has been deemed an essential measure to combat the spread of the virus.

The contribution of engineers to tackling the crisis

Ventilators

Makerere University has received various grants from the government and has been heavily involved in creating technologies to help combat the spread of the disease. For instance, the university and the Ministry of Science, Technology and Innovation are collaborating on the development of a low-cost open-design ventilator that can be manufactured locally. The several colleges involved at Makerere University are coordinated through the Resilient Africa Network project at the School of Public Health, while the Ministry of Science, Technology and Innovation is acting through Kiira Motors Corporation. The team has developed a fully functional prototype. The project will develop a regulatory-compliant ventilator model with all necessary animal and clinical trials and associated certifications. This initiative will inform interventions in developing Uganda's capacity for manufacturing key medical equipment for import substitution and regional export.

Face masks and handwashing kits

In addition, the university has also worked in partnership with CODEK Engineering Ltd, a private partner, to develop a self-sanitising face mask with built-in sanitiser. The mask offers real-time disinfection while at work, and it can be reused. Makerere University has also launched a touchless handwashing kit, resulting from the need to limit contact with surfaces while ensuring diligent hand hygiene. The sanitiser has already gone through the required tests at UIRI and the Uganda National Bureau of Standards. As a result, at least 1,000 litres of the Covi-Mak sanitiser are already on the Ugandan market.

Biomedical smart jacket

Brian Turyabagye is the co-inventor of a biomedical smart jacket (MamaOpe) that helps doctors to quickly diagnose pneumonia and improve the treatment process in affected children below the age of 5. When the COVID-19 pandemic hit Uganda, Brian and his team re-designed the jacket to fit patients of different sizes and age groups to monitor the health condition of COVID-19 patients. According to Brian, since the start of the pandemic, the jacket has been supplied to a number of health workers. Brian was the winner of the competition Pitch@Palace Africa 2017 and was shortlisted by the Royal Academy of Engineering for the Africa Prize for Engineering Innovation. The device was profiled by the BBC among the 5 African inventions to watch out for in 2017, and was considered by CNN one of the 12 African innovations that could change the world. It is hence a remarkable achievement that the innovation could be adapted so swiftly to meet the challenges brought about by COVID-19.

Handwashing stations

According to Charlene Cabot, Innovation Lab manager for Uganda, when COVID-19 struck, innovators quickly realised that their communities were at risk and that they could potentially address the situation. "Ugandans are quite creative and resourceful and there are large networks of skilled inventors working within the country," she said. Cabot tapped into that community.

In response to the pandemic, EWB-USA partnered with the Response Innovation Lab (RIL) in Uganda to put out a call for solid soap for public handwashing stations in Uganda. The aim of this intervention was to install handwashing stations in densely populated markets and other public spaces. RIL has a network of innovators (mostly young entrepreneurs in the field of engineering and technology) and supports them through working with them on different projects that come through from calls for proposals. EWB-USA's call caught the attention of 45 people, who attended its webinar on the challenges of providing soap in highly trafficked public spaces and what an effective solution could look like.

3 primary criteria for the challenge were identified:

1. People should not come into physical contact with the bar of soap.
2. The soap needs to be in a lockable container.
3. The dispenser has to be easy to use.

According to EWB-USA's news coverage, within 10 days of launching the call, the Innovation Lab received 31 applications. The teams were required to build prototypes or submit videos of their inventions in action. After deliberation, 3 teams were invited to pitch their designs. Ali Kabona was awarded first prize, Tugume Clever received second, and Emmanuel Achelu received third, respectively. Kabona's highly detailed presentation and use of low-cost, locally sourced materials in a simple and effective design landed him at the top.

Kayoola electric buses

The Ugandan automotive company Kiira Motors Corporation Ltd. has rolled out its brand new Kayoola electric buses (EVS). With these vehicles, the indigenous company wants to showcase its home-grown green mobility technologies and prove that the vehicles are compliant with all health and safety guidelines issued by President Yoweri Museveni and the Ministry of Health. The Kayoola EVS buses, which operate in and around Kampala, have been equipped with automated disinfectant sprinkler systems designed to eliminate the spread of COVID-19.

The vehicles are awaiting President Museveni's announcement of a partial lifting of the two-month nationwide lockdown and curfew.

Trainings

Finally, there have been some examples of increased UK-Africa collaboration to tackle the pandemic. Working with UIPE and the College of Engineering, Design, Art and Technology at Makerere University, RedR UK is building in-country capacity to respond to developing humanitarian needs. The organisation provides training to local engineers, so that they can transfer their technical skills to a humanitarian context. UIPE is the leading professional body for engineers in Uganda, through which the project will reach over 2,000 engineers. In addition to this, a selection of 100 engineers, technicians, and technologists will receive targeted training on humanitarian principles and standards, disaster risk reduction, urban humanitarianism, and the application of engineering skills in response to urgent humanitarian needs. The project is targeted to work in 4 locations in Uganda – Kampala, Bidibidi, Rhino Camp, and Nakivale – and will run from May 2020 to April 2021. The work is funded by the Royal Academy of Engineering through its 'Engineering Skills Where they are Most Needed' programme.

3. Women's engineering groups' response to COVID-19

Although there is an increasing number of women studying engineering in the higher education system, women only comprise a fifth of Uganda's total stock of engineers and there are few women's engineering groups in Uganda. However, many schools, government agencies and private companies have started creating programmes targeted at attracting women to engineering. For instance, the Women Engineers, Technologists and Technicians (WETT) committee, which together with ERB and funding from the Royal Academy of Engineering, has supported the promotion of women participation in UIPE and other engineering activities as a whole. UIPE has also contributed to strengthening diversity and inclusion in Uganda's engineering profession through a series of activities, including mentoring, outreach activities and grants.

According to interviews and desk research, women's engineering groups in Uganda do not appear to have had a strong collective response to the COVID-19 pandemic. However, that is not to say that women engineers have not participated in the country's response. For instance, UIRI conducted training of over 200 women in different skills, including meat and bone meal processing, tailoring, and the production of quality face masks. A total of 170 women participated in the production of three-layered masks. Each woman produced about 100 masks per day and was given an allowance for her work.

According to UIRI, after this engagement, the women went back to their communities and were able to train others to produce masks.

4. Impact of the COVID-19 crisis on young engineers, education and skills

According to the Uganda National Council for Science and Technology, over the last decade, the number of graduates across Uganda's higher education system has been increasing. This has been coupled with several pro-science policies across Uganda's education system that have been spurred by a general recognition of the contribution of science to economic development. The growth in higher education and the continuous demand for people with science, technology, and innovation skills is an indication of how Uganda is gradually transforming into a knowledge-based and skills-driven economy.

Higher education institutions are now charged with the task of producing graduates who are capable of applying technology and knowledge-based information to the nature and demands of their work environment. When COVID-19 hit Uganda and lockdown was enforced, schools and universities closed, and classes were quickly moved online. While most universities managed to continue distance-learning, slow internet speeds, lack of equipment, and data costs posed a challenge for some learners.

Nonetheless, young engineers continued to innovate during this period. For instance, Ugandan engineer and innovator Arthur Woniala founded Khainza Energy in 2007 with 2 friends. The small business was committed to providing clean, safe, and affordable cooking fuel to replace the wood and charcoal fuels that cause respiratory diseases and environmental damage, and lead to the destruction of forests and erosion of soils. When the pandemic hit, the company struggled to remain in business and retain its staff, and received £69,349 from the United States African Development Foundation (USADF) to develop the Khainza Energy app. With USADF support, it acquired a pickup truck to facilitate home deliveries of liquefied petroleum gas, briquettes, and improved cook stoves. The company is also in the process of acquiring a freight tricycle to facilitate last-mile deliveries.

PhD student Paige Balcom from the University of California, Berkeley, and Peter Okwoko, a Ugandan environmental and community activist, are the co-founders of Takataka Plastics, a social enterprise in Gulu, Uganda. The company recycles plastic waste into affordable construction materials and, in response to the COVID-19 crisis, face shields for medical centres.

Moreover, on 25 August 2020, 10 young people (4 women and 6 men) from the different districts of the Tooro Kingdom enrolled in a one-month training in tailoring at UIRI, which included a tour of both the Machining Manufacturing Industrial Skills Development Centre in Namanve and UIRI. This enlightened the young people on the opportunities they could tap into and promote in their respective communities.

5. Post-crisis outlook

According to Development Initiatives, the economy is projected to slow down by nearly half for the financial year 2019/2020, with further uncertainties for 2020/2021 due to the pandemic. Many people are facing a reduction in their income due to job and livelihood losses, reduced flow of remittances, and loss of market and demand for domestic products. However, COVID-19 has provided an opportunity for engineers and young innovators to use their skills and knowledge to mobilise a response to the pandemic. In addition, while addressing the recent Private Sector Foundation Uganda e-conference, President Yoweri Museveni emphasised the need for the government to prioritise post-COVID-19 interventions to boost the economy by supporting 9 key sectors, including transport, with local manufacturers like Kiira Motors Corporation Ltd. taking the lead. On the other hand, according to an interviewee, there is still a need for further discussion and unison among the engineering community. This dialogue needs to include other sectors and ministries, to build resilience for future pandemics. Across the board, there is an opportunity for the Royal Academy of Engineering and other actors to come together and develop a unified response to such emergencies, and there is a big opportunity to share learning through dissemination.

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Zambia

1. Context/background

Overall impact of the COVID-19 crisis in Zambia

The COVID-19 pandemic is understood to have reached Zambia in March 2020. Zambia reported its first 36 cases of the virus in late March, and total cases continued to rise, with 13,539 reported cases confirmed in mid-September 2020. Since March, the government has proceeded to shut down most businesses and educational institutions and has put in place restrictions on foreign travel. The national lockdown and the subsequent closure of international airports and trade borders are expected to have devastating effects on economic activities, with sectors such as manufacturing, construction, mining, transportation, retail, hospitality, and other commodity supply chains being severely disrupted.

Several measures have been proposed by the government, including setting up an Epidemic Preparedness Fund under the Ministry of Health, approving a COVID-19 Contingency and Response Plan under the Disaster Management and Mitigation Unit, and mobilising funds through engagement with various local and international stakeholders.

According to the UN Office for the Coordination of Humanitarian Affairs, COVID-19 is likely to have a lasting impact on the livelihoods of vulnerable populations. For example, food insecurity and malnutrition, an increasingly pressing problem due to the recent drought and floods, are expected to be exacerbated by limited availability of, and access to, basic commodities and services. According to the preliminary results of a rapid assessment by World Vision and the World Food Programme, the majority of communities across more than 58 districts have indicated that the food harvested will last for an average of 6 months. Children are further vulnerable to malnutrition due to the closure of school feeding programmes, and 85% of organisations working in the education sector are reportedly closed.

The pandemic has taken a notable toll on the country's economy overall. The Zambian government recently commissioned a study in collaboration with the United Nations Development Programme. The study found that business operations were adversely affected by COVID-19 in 71% of the companies surveyed, and that 14% of businesses had closed altogether.

It is understood that the transportation, education, catering and accommodation sectors are being affected most severely, with 85% of organisations working in the education sector reported to be completely closed, according to the study. As with many African countries, the informal sector is expected to be hit hard by the lockdown measures. Over 65% of Zambians work in the informal sector, including vulnerable groups who rely on informal work to support their basic needs. It is estimated that the lockdown could result in up to 1.2 million households falling further behind in economic terms, nearly 230,000 of which are women-headed.

Zambia's health system is expected to be stretched with regard to limits on human resources and health supplies, which are consistently being diverted to the COVID-19 response. According to the WHO, Zambian health workers noticed early that hospitals were facing capacity issues, and responded rapidly by implementing home management systems for infected patients (supported by community-based volunteers) to reduce the burden on the health system. The home-based care approach was a strategy reflected in Zambia's national response plan, which became operational in May 2020.

From the perspective of social impact, it is possible that COVID-19 will further deepen conflicts and inequalities within Zambian society, such as increased stigmatisation and discrimination against migrants and refugees, who are perceived as having brought the pandemic across borders. With most migrants living and working in urban settlements, such stigma has the potential to further exacerbate morbidity and mortality among vulnerable and marginalised groups because of a reluctance to seek care immediately or access basic services, such as common water and sanitation facilities.

Brief overview of the key engineering stakeholders in Zambia

The 2 main professional engineering stakeholders in Zambia are the Engineering Institution of Zambia (EIZ) and the Association of Consulting Engineers of Zambia (ACEZ). EIZ is responsible for regulating engineering practice through registration and licensing (compulsory through the EIZ Act).

Key activities of EIZ include:

- providing support for continuing professional development through learning opportunities.
- publishing professional journals and magazines.
- providing networks for professionals to meet and discuss their field of expertise.
- enforcing a Code of Ethics to guide professional behaviour.
- dealing with complaints against professionals and implementing disciplinary procedures through the Disciplinary Code.
- providing career support and opportunities for young people.
- accrediting engineering programmes.

ACEZ, by contrast, is a body that promotes joint interests and quality assurance for engineering clients specifically. Member firms carry a required level of professional indemnity insurance, which provides clients with financial resources in the event of non-performance, insufficient design, failure, or neglect caused by the engineer. The association is affiliated to the Group of African Member Associations and the International Federation of Consulting Engineers.

EIZ requires that consulting engineers practising in Zambia are registered with the Engineering Registration Board and are members of ACEZ in advance.

In terms of academic stakeholders, a major body is the School of Engineering at the University of Zambia. The school itself consists of the departments of agricultural engineering, civil and environmental engineering, electrical and electronic engineering, geomatic engineering, and mechanical engineering. The school undertakes extensive surveys and consultations with notable engineering stakeholders at government, industry, and donor level, as well as other tertiary institutions in the country. With a view to growing the relevance and effectiveness of engineering education in Zambia, the school has a mandate to develop collaborative relationships with industry and government. This collaborative approach is partly reflected through external government and industry members sitting on the School of Engineering's Advisory Board and various academic staff equally sitting on governmental committees.

At government level, the main stakeholders include the Ministry of Works and Supply, the Ministry of Energy and Water, the Ministry of Finance, and the Ministry of Health.

Impact of the COVID-19 crisis on the engineering industry in Zambia

With regard to how the engineering industry itself has been impacted by the pandemic, according to KPMG, there have been schedule delays, workforce disruptions, equipment and supply chain disruptions, and reduced productivity overall due to the need for on-site social distancing and the knock-on effects on individual salaries. PEIs are reporting a reduction in operational engineering activities, fewer workers and customers on their premises, and a scale-down of production among SMEs.

Due to the lockdown measures, many engineering projects have been suspended. Opportunities to find new or existing work in the engineering profession may also be reduced because existing sites are closing, or new sites are not being fully established. Even when operations are running, there is a limited supply of masks, sanitiser and other PPE, which is essential for workers to safely undertake activities.

Construction work has been hit the hardest, as this sector requires intensive work in groups, with employees often working in close proximity.

Fortunately, the mining industry appears to be less impacted by the pandemic. In Zambia, there are only 4 mines, which have been producing at nearly 100% capacity because of the avoidance of restrictions on current practices. It is believed that Zambia can leverage its renewable natural resources for sustainable recovery from the economic crisis associated with COVID-19. Built into its first development strategy is the aim to diversify the economy from mining through renewable capital (agricultural land, forests, water), which can produce longer-term economic gain.

2. Engineering response in Zambia

The position of key engineering actors

As outlined above, the key stakeholders within the Zambian government are taking clear preventative measures in response to the spread of COVID-19, including setting up an Epidemic Preparedness Fund under the Ministry of Health and developing a COVID-19 Contingency and Response Plan. In a statement by the Minister of Finance of March 2020, specific measures were outlined, including employment-related measures (for example, state compensation schemes and training), economic stimulus and monetary policy measures (such as waived charges for electronic money transfers, and increased transactions and balance limits for individuals, small-scale farmers and enterprises), and tax measures (for example, payment deferrals and rate reductions). PEIs have reported a proactive reaction on the part of the government in terms of its response to the pandemic, with a view to employing a multisectoral response, engaging multiple industries, including engineering.

In terms of PEI's response specifically, EIZ has stated that it has a responsibility to directly support the government to ensure that the immediate needs of the population are met, and to help tackle this crisis via provision of services and equipment by the engineering community. A statement by the Registrar and CEO of EIZ on the institution's Facebook page states that it is time for EIZ to "rise to the occasion and make its contribution to demonstrate that its members are equally affected, concerned, and alive to play its corporate social responsibility".

The contribution of engineers to tackling the crisis

EIZ has used key social media platforms, such as Facebook and Twitter, to invite the engineering community to offer monetary contributions to channel through the Ministry of Health. In order to ensure that the payments are clearly identified, it is required that donations are accompanied by an EIZ membership number and logged as 'FIGHT COVID-19'. These donations will be used to source expertise, essential equipment and services, and will add to EIZ's existing efforts to donate equipment and PPE directly to health facilities and households to meet immediate needs. In late April 2020, it was confirmed by EIZ that the proceeds of the fundraising venture were approved for channelling towards procurement and branding of PPE for frontline medical and health staff at Levy Mwanawasa University Teaching Hospital.

Furthermore, as well as spreading awareness and developing guidance on how engineers should care for themselves and others to minimise the spread of the virus, EIZ has arranged virtual meetings through Facebook Live to discuss the implications of COVID-19, including one titled 'How to cope with the COVID-19 outbreak', hosted on 30 April 2020.

While PEIs' specific COVID-19 response is in the early phases of development, collaboration with the FAEO has been a key first step in identifying ways to best maintain the functioning of important services and critical infrastructure during the pandemic.

How engineers have collaborated during the crisis

Engineers are collaborating with the Ministry of Health to mobilise funds for the purposes outlined above, and it is expected that further, clearer collaboration will materialise in the coming months, as COVID-19 approaches its peak in the country.

3. Women's engineering groups' response to COVID-19

The Zambia Women in Engineering Section (ZWES) was developed in response to a call to increase and retain the number of women in the engineering profession in Zambia. ZWES is a section under the EIZ, described by the EIZ president as "an initiative by women engineers to increase women's participation in engineering activities and also encourage more girls to take up engineering as a career". ZWES sets out to collaborate with, and affiliate to, other regional and international women's engineering institutions to exchange key knowledge and lesson learning, and to identify and mitigate the complex challenges that prevent girls from pursuing careers in STEM. It further seeks to directly enhance the national competitiveness of EIZ by driving forward this inclusion agenda.

Because ZWES members are already involved in cross-cutting activities (such as working specifically on water and sanitation assignments and addressing the immediate infrastructure needs of health facilities), EIZ recognises that the section is well placed to respond directly to COVID-19 challenges. However, an official position on responding to the crisis has not yet been determined.

4. Post-crisis outlook

PEIs recognise that there are both challenges and opportunities for the engineering industry in Zambia in the aftermath of COVID-19. EIZ has expressed a view that mechanical, civil, biochemical, electrical, management, and geotechnical engineering will certainly have to change and adapt to this crisis, notably through more regular and meaningful collaboration with, among others, the health and emergency services, the water and sanitation, oil and gas, renewable energy, digital and technology, defence and marine sectors, and the education system at large.

Furthermore, the requirement for home working that has resulted from the lockdown measures has presented new opportunities. Some engineering companies have experienced positive effects on performance. These types of efficiencies should continue to be drawn on in the future. EIZ has highlighted the importance of investing heavily in new technology to facilitate remote working and collaboration-for example, virtual call software or focus group/qualitative research and survey technologies that allow real – time data capturing and enable the brainstorming of ideas and strategies, and the development of prototypes, to take place in virtual rooms.

As with professional engineering in other African countries, it is felt by PEIs that COVID-19 offers a unique opportunity to increase the visibility of PEIs and engineering academics, and an increased opportunity to influence policy, by virtue of responding directly to a very public crisis and highlighting to society how necessary engineers are. This is particularly the case where rapid mobilisation and practical intervention is required, and has indeed been requested by the government.

A lesson highlighted by EIZ is that skills must now be adapted so that future crises can be tackled in a sustainable way. This would relate to a revamping of the curriculum in schools and universities to reflect specialised training in digital technologies, and a focus on renewable energies (as has been the case, more notably, in the mining sector). Investing more heavily in technology in engineering expands the potential for innovative products, prototypes, and complex interventions, and it also enables engineers and PEI members from all over the country, as well as PEIs across the African continent, to remotely exchange best practices and lessons learned for future pandemics or similar outbreaks.

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Interviews

- Rev. Eng. Happy Musumali, Deputy Registrar & Director of Operations, Engineering Institution of Zambia (EIZ)

Zimbabwe

1. Context/background

Overall impact of the COVID-19 crisis in Zimbabwe

Following the WHO declaration of COVID-19 as a pandemic, a state of disaster was declared in Zimbabwe on 20 March 2020. Zimbabwe has been on a nationwide lockdown since this date, and this was extended indefinitely on 16 May 2020. In October 2020, 7,850 cases and 228 deaths were reported, according to Worldometer.

As it is the case with many countries in Africa affected by the pandemic, this has increased uncertainty in the national economy. According to the World Bank, a combination of local currency depreciation, disruption of trade and limited access to external financing, as well as growing humanitarian needs, is likely to further escalate inflation in 2020. Informal businesses in Zimbabwe primarily take the form of flea and social markets, small-scale manufacturing, foreign currency exchange, vending, retail microenterprises, as well as more physical work, such as repair services and metalwork. These businesses have remained largely closed, and the customer base has been limited due to restrictions on trading between cities and towns. This has had a particularly significant impact in Zimbabwe, as it is estimated that 90% of Zimbabweans are working in the informal economy.

The high-density conditions found in the suburbs of Harare (resulting, in part, from rapid migration after Zimbabwe's War of Independence in the 1970s, as well as droughts and other economic factors) are, unfortunately, ideal for the rapid spread of communicable disease, making it more challenging to isolate within and between households and exercise social distancing.

The pandemic and rise of cases through rapid community transmission have affected all health services, and the capacity within hospitals is currently overstretched. It is apparent that hospitals and other health facilities are lacking in essential PPE, and a lack of other essential items, such as beds and ventilators, has meant that some patients are turned away, or experience severe treatment delays, which can further morbidity. Approximately 15,000 nurses have been on strike over wages that have been impacted by inflation, which has further affected both service delivery for COVID-19 and wider health services. In August 2020, Zimbabwe reported 4,649 cases of COVID-19, but this is thought to be a significant underestimate.

Brief overview of the key engineering stakeholders in the country

The key stakeholders in the engineering industry in Zimbabwe include the Engineering Council of Zimbabwe (ECZ), the ZIE, the Zimbabwe Association of Consulting Engineers, the Architects Council of Zimbabwe, the Institute of Architects of Zimbabwe, the Zimbabwe Institute of Quantity Surveyors, the Zimbabwe Building Contractors Association, and the Construction Industry Federation of Zimbabwe. The main academic stakeholders include the School of Engineering and Technology, Harare Polytechnic College, and the Faculty of Industrial Technology at the National University of Science and Technology.

The 2 main PEIs are ZIE and ECZ. ECZ is responsible for issuing practising certificates, providing accreditation of courses to registered people, and ensuring that constituent bodies have adequate procedures to enforce ethical practice and discipline among engineers and technicians registered under the Engineering Council Act. While ZIE holds a similar mandate to ECZ in terms of setting and maintaining appropriate standards of engineering and technical competence and ethics, and promoting the advancement of engineering and relevant knowledge dissemination, it is a multidisciplinary professional organisation of engineers with graded membership. Accordingly, ZIE membership must be gained as a pre-requisite before engineers can proceed to register with ECZ and obtain a practising licence.

At government level, the Ministry of Health and Child Care, the City of Harare Health Department, and the Environmental Management Agency are key actors in the development of engineering-related policy and regulation. In response to the pandemic, the government of Zimbabwe launched the Zimbabwe National Preparedness and Response Plan for COVID-19 in March 2020. It also established an Inter-Ministerial Task Force, chaired by the vice president, led through the Ministry of Health and Child Care and the Ministry of Local Government and Public Works. A key focus of the plan is a multisectoral response to tackling the virus. The Ministry of Health and Child Care intends to work closely with stakeholders to mobilise support for infection prevention and control practices, operational, logistics and supply management, and development of equipment and supplies for COVID-19 preparedness and response activities. This includes collaboration with actors in the government, the private sector, civil society, academia, professional associations, the private not-for-profit sector, community-based organisations, religious leaders, traditional leaders (elected in specific districts through lineage via the government of Zimbabwe to help promote cultural values and community-level dispute resolution), and international organisations.

Impact of the COVID-19 crisis on the engineering industry Zimbabwe

COVID-19 has affected much of the activity in construction, manufacturing, tourism, mining and international trade, which has slowed down or ceased altogether. The lockdown has impacted the construction sector most notably, reducing its ability to compete as usual on the global market, as well as directly with key strategic African countries, to sell and receive engineering-related supplies. For example, Botswana, an essential engineering and construction market for Zimbabwe, has strictly enforced the closure of borders, with only cargo and essential items being able to pass. Furthermore, Zimbabwe's biggest import country, South Africa, has experienced a forced reduction in production and restrictions on business operations in the construction sector due to a national lockdown, which has resulted in the inability to provide supplies to local Zimbabwean manufacturers.

Any trade restriction on non-essential commodities is felt hardest by the construction sector, as it uses goods that are typically not classified as essential in traditional export markets. In addition, local engineering companies are facing the challenge of meeting existing production schedules because of an inability to acquire raw materials. This is expected to further affect exports on existing orders.

However, within this, there has been an opportunity for the engineering industry to directly address some of the most pressing issues that have resulted from COVID-19, namely within the health sector. The government appears to be increasingly requesting the engineering and technology capacity and services of tertiary institutions, such as the University of Zimbabwe, Chinhoyi University of Technology, Great Zimbabwe University, Midlands State University, and the Harare Institute of Technology, for the production and development of key supplies and innovations to meet local needs.

There is a sense among some engineers that the engineering profession is being taken more seriously by the government and society more widely in the face of this crisis, as it is recognised that engineers possess the skills and capacity to address emergency needs across relevant sectors. This is partly reflected in the fact that the Zimbabwean government has reached out to PEIs and other stakeholders to mobilise an immediate solution, namely the construction of a COVID-19 isolation facility (discussed below). This venture is in the early stages of development, but has provided the opportunity for multiple stakeholders, including professional engineering bodies, government departments, management agencies and potential donors, to collaborate on a shared project and mobilise funding.

2. Engineering response in Zimbabwe

The position of key engineering actors in Zimbabwe

The overall goal of Zimbabwe's national preparedness and response plan is to 'minimise morbidity and mortality of COVID-19 in Zimbabwe and associated adverse socio-economic impact in a manner that would strengthen national core capacities under IHR (2005) and contribute to overall health system strengthening' via a cross-sectoral approach that requires collaboration across all government departments and a 'whole-ofsociety' approach.

As discussed below, professional engineering organisations and associations represented through built environment professionals have a chance to contribute towards the government's efforts to tackle the rate at which COVID-19 is spreading, and in the longer term, provide sustainable improvements in the management of infectious diseases after the virus has passed. Built environment professionals have resolved to give back to the community by freely offering their services to construct a centre for those suffering from the virus (see below), which can also be used for other purposes relevant to healthcare delivery.

The contribution of engineers to tackling the crisis

Engineers in Zimbabwe have taken a proactive stance to tackling COVID-19 in the past few months. In April 2020, various PEIs and other engineering stakeholders received an invitation from the President of Zimbabwe to present on how to best tackle COVID-19 at national level. The meeting was part of the development of an agreement to take forward key actions to curb the spread of transmission and address immediate public health needs. The result was that ZIE developed a concept paper in collaboration with key stakeholders and potential donors for the development of a COVID-19 community isolation centre in Harare.

The centre itself will host various essential facilities that protect the public by preventing exposure to people who have, or may have, COVID-19, including 390 beds in 10 general wards (male, female, children's, maternity and post-natal wards), a 10-bed observation unit (for people

awaiting evacuation to hospital); sluice rooms; a diagnosis and treatment centre; an administration wing and store rooms; a kitchen; a staff canteen; a central sterile services department; boiler and laundry rooms; ablution blocks; and an incinerator. A full risk assessment has also been undertaken to identify and propose mitigation for issues related to project design, inflation, funding, weather, and political economy.

The estimated overall cost, including project design, project management and operations, construction materials, labour and equipment/machinery, medical equipment, and furnishings is approximately £13 million (ZWL 6.6 billion). There were 4 meetings as of September 2020: so far, a location for the main innovation centre has been agreed, and the design team have already started working with architects, project managers, and other construction experts. The architects have developed a blueprint in order to be able to replicate these centres across multiple cities in Zimbabwe.

Separately, universities in various provinces around the country are supporting government institutions and supplying hand sanitiser, masks, gloves, and other PPE to clinics, hospitals, and security personnel to combat the spread of the virus. Chinhoyi University of Technology, for example, produces more than 2,000 masks per day and has provided approximately 5,000 masks to various health facilities and businesses. Similarly, alongside mask production, Great Zimbabwe University has innovatively procured glycerol, hydroperoxide, and ethanol from Tongaat Hullet, Zimbabwe's largest sugar producer, to manufacture hand sanitiser.

How engineers have collaborated during the crisis

The COVID-19 community isolation centre is led by the representative body of the Zimbabwe built environment professionals (ZBE), which is advocating to individuals, corporates, NGOs, international finance institutions, development banks, and other donors to support the development of the facility, in order to ease pressure on existing isolation facilities in the country. It is recognised that for this effort to be effective and sustainable, it will require policy, regulatory, management and health-related technical expertise.

The project seeks to work collaboratively with stakeholders in crisis management to achieve the following objectives:

- increase the number of COVID-19 isolation beds in Zimbabwe by 400 before the end of 2020.
- provide a safe environment and a facility, in line with WHO standards, for professional monitoring of COVID-19 patients before the end of 2020.
- add to the existing health infrastructure in the country and help to achieve Sustainable Development Goal 3 of the United Nations.
- relieve pressure on other hospitals by releasing 400 beds in other Harare hospitals for treatment of non-COVID-19 patients before the end of 2020.
- provide a template for other COVID-19 isolation facilities in the country.
- minimise project costs by offering pro-bono services by ZBE professionals in collaboration with other similar-minded professional organisations.

A full overview of the relevant stakeholders in the centre are listed below.

Table 2: Overview of stakeholders in the COVID-19 community isolation centre

Stakeholder	Interested in
ZBE Professional Bodies	Delivering the project
Ministry of Health and Child Care	Customer and health standards approvals
City of Harare Health Department	Building approvals
Environmental Management Agency	Environmental approvals
Engineering Council of Zimbabwe	Regulation of engineering aspects
Project Management Institute Zimbabwe Chapter	Project management
WHO	Infection prevention and control compliance
Residents' Association of the proposed area	Implications of an infectious disease facility for the local community
Donors	Financial management and project governance

The facility, if the proposal is approved, will be driven by the private sector (in Harare's surrounding provinces of Mashonaland East, Mashonaland West, Mashonaland Central, and the dormitory town of Chitungwiza) to mobilise professionals and other service providers in the construction industry to offer their services pro-bono. Other service providers and stakeholders will be approached on an ad hoc basis, depending on the needs that evolve in the early implementation of the centre.

3. Impact of the COVID-19 crisis on young engineers, education and skills

It is possible that the pandemic has helped to highlight and showcase the importance of engineering skills in society at large and, in particular, how essential they are in responding to a national emergency. This belief is reflected in the promptness with which the government has consulted engineering stakeholders for support to mobilise a rapid response to the pandemic. PEIs also think that the reputation of engineering as a profession has potentially increased as a result of engineers' response to the pandemic.

From a capacity-building perspective, the increased tendency for meetings and services to be digitised or conducted virtually is considered by some PEIs to be potentially transformative for engineering in the future. This is because increased reliance on technology and remote learning may result in more wide-reaching platforms that help students and newly qualified engineers to learn from home. This has highlighted the fact that engineers are engaging and must continue to engage with IT and software to explore theoretical aspects of the profession remotely.

In terms of the impact of the COVID-19 crisis on young engineers so far, it is expected that students may increasingly struggle to find employment after their studies, as there are currently very few opportunities for paid or voluntary work.

4. Post-crisis outlook

The engineering industry in Zimbabwe has clearly mobilised in support of the government's response plan and started to bring to together plans and blueprints targeting the most pressing needs in the community. It is apparent that the crisis has helped to shed light on the importance of the engineering industry, and some PEI representatives see this as an opportunity to increase the visibility of engineering in society at large, and as an inevitable step towards digitisation of the industry and virtual practice.

The increased reliance on IT, which has resulted from the lockdown, is likely to be beneficial in terms of opening up opportunities for conducting business, PEI member training, capacity building, peer learning, and mentorship online.

Engineers are already planning for greater resilience and cross-sectoral collaboration to tackle future crises, and a good example of this is the COVID-19 isolation facility proposal and early planning efforts, as detailed above. This isolation facility serves as an example of how opportunities for true collaboration between the government, the private sector, and professional engineering bodies can be mobilised fast and sustainably. There is clear interest in PEI leadership on the part of the government. It will be important to build on this momentum, to ensure engineering solutions are increasingly multisectoral and developed with longer-term outcomes in mind.

ZIE's president, Dr Diarra, stated that "engineering is life, life is engineering". However, not all of society has, in the past, appreciated how essential this industry is. COVID-19 could therefore help advance PEIs' longer-term vision to promote the character and status of the profession and promote public awareness and confidence in it. ZIE, for example, is looking at ways to 'revamp' the curriculum with help from universities that offer specialised engineering programmes.

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Interviews

- Dr Sanzan Diarra, CEO, ZIE

Annex: List of interviewees

- Engr. Dr Alex Okopi Momoh, NSE Executive Secretary
- Dr Ann Kingiri, Senior Research Fellow, Science, Technology & Innovation (STI) at the African Centre for Technology Studies (ACTS)
- Brian Turyabagye, Founder of SkyApps Technologies Ltd. and Project CARE entrepreneur
- Catherine Wanjoya, Slimlak Agencies – Kenya and Project CARE Entrepreneur
- Chiara Kunnie, Business Development Manager, Praekelt.org
- Eng. Chinenye Justin Nwaogwugwu, MNSE, Managing Director and Founder, MACJAMES Global Resources Ltd. and MACJAMES Ikiomoye Technologies Ltd.
- Chris Campbell, CEO, CESA
- Colin Little, Engineer, B4SA
- David Thomlinson, Chair of GCRF Africa Catalyst Steering Committee
- Eng. Felicia Nonene Agubata, FNSE, member of APWEN, COREN and NSE SheEngineer, Invent it, Built it Project Director
- Frederica Yawson, African Center for Economic Transformation (ACET) and entrepreneur
- Gussai Sheikheldin, Science, Technology and Innovation Policy Research Organization
- Rev. Eng. Happy Musumali, Deputy Registrar & Director of Operations, Engineering Institution of Zambia (EIZ)
- Ian Jandrell, Dean of the Faculty of Engineering, and Tanya Schonwald, Development Professional and Specialist, University of the Witwatersrand
- Dr Makhamisa Senekane, Lecturer at the Department of Physics and Electronics, National University of Lesotho, and founding member of LesYAS
- Eng. Martin Manuhwa, President of the Federation of African Engineering Organizations
- Eng. Naadiya Moosajee, WomEng
- Oagile Kanyeto Past President, Botswana Institute of Engineers, currently Managing Director of Mattra International)
- Eng. Oduwa Agboneni, member of NIMechE
- Paul Kennedy, Community and Communication Manager, Zindi
- Eng. Paul Kioko, Dean at the School of Engineering and Technology in SEKU
- Richard Seun Lawal, member of TheReformers and former President of NIMechE – National Students Forum
- SAAE members
- Dr Sanzan Diarra, CEO, ZIE
- Seriti L. Phate, President of Lesotho Association of Engineers and Managing Director of Tsoelopele Consultants & Contractors (pty) Ltd.
- Steve Gray, Founder, The MakerSpace Durban
- Teresa Hattingh, Lecturer, North-West University
- Zoe Pacciani, Country Director at Engineers Without Borders-USA for Uganda

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