# Ethiopia 2050

## ICT Infrastructure Grand Challenges and Proposed Solutions

Prepared by:

**David Nicholson**
Chief Technology Officer
Consensus Solutions LLC

**Mekonnen Kassa**
Global Infrastructure Service Director
Microsoft Corporation

# Ethiopia 2050: ICT Infrastructure Grand Challenges and Proposed Solutions

The fourth industrial revolution has been in place for a few decades now. Information technology-based inventions and innovation have been the primary drivers of this revolution. Though a few countries have been leading the innovation, the products and services offered by this revolution have benefited billions of people from many countries around the world.

Ethiopia is one of the beneficiaries, but the benefits realized by Ethiopia are very limited because of some challenges faced in Ethiopia. In this paper, we will briefly summarize the upcoming societal grand challenges Ethiopia will face for the next 30 years, describe specific challenges around Information and Communication Technology (ICT) infrastructure, propose solutions to address infrastructure challenges and discuss how these solutions to ICT challenges can be leveraged to address Ethiopia's societal grand challenges.

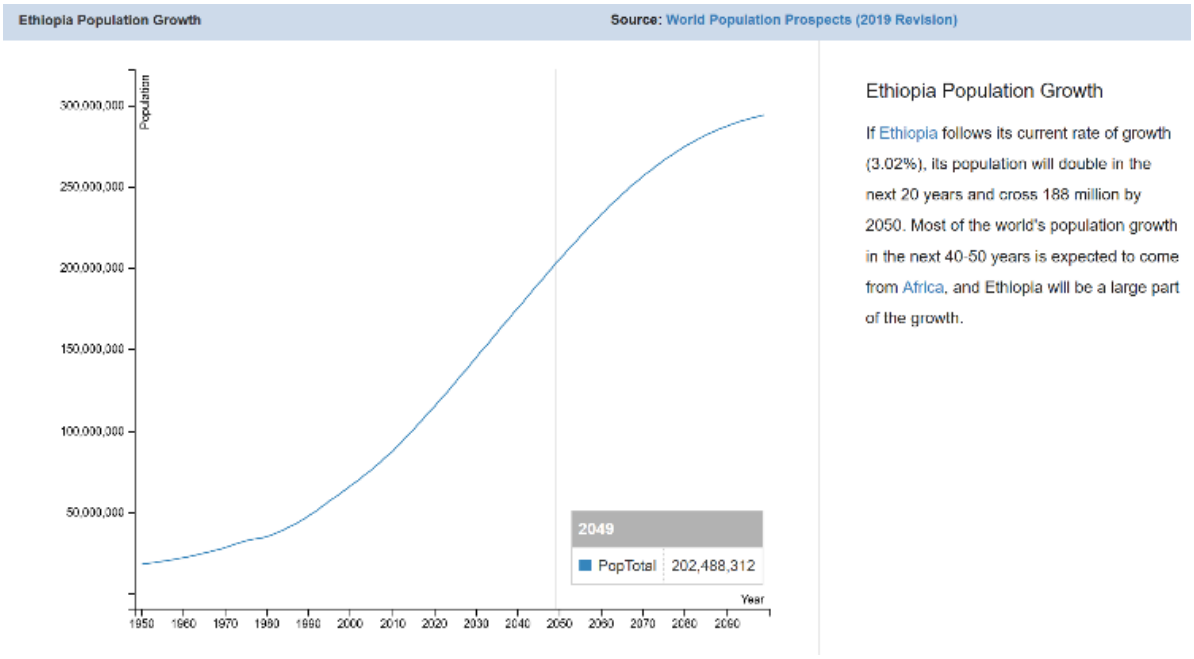
We are delighted at the opportunity to describe information technology infrastructure challenges and propose solutions to help address the identified societal grand challenge. We hope our contributions in this paper will be considered by academics, technocrats, Ethiopian government officials, and private sector leaders to proactively address the upcoming grand challenges that Ethiopia will face over the next 30 years. We welcome feedback and additional input from ICT professionals and the grand challenge sector specific experts.

## 1 Upcoming Societal Grand Challenges

Ethiopia currently has a population of a little over 110 million, equally split between males and females. About 70 million are under 29 years old and about 45 million under 24 years old. The challenges with having such a young demographic would have devastated the country had it not been for 80% of the population currently residing in rural areas.

Looking ahead, given a 3.8 percent per year population growth rate, the total Ethiopian population is projected to reach 202.5 million by the year 2050. The current—less than 20%—urban population is projected to more than triple to 60 million by 2050[1]. Skyrocketing population growth, a very young demographic and large migration to cities will be the main causes for upcoming grand societal challenges.

[1] World Bank and The Government of Ethiopia (2015) Ethiopia Urbanization Review, Urban Institutions for a Middle-Income Ethiopia – October 18, 2015
http://documents.worldbank.org/curated/en/543201468000586809/Ethiopia-Urbanization-review-urban-institutions-for-a-middle-income-Ethiopia (accessed on September 30, 2019)




Ethiopia will be challenged to produce food, afford shelter and ensure the safety of her growing population. Affordable healthcare services must be available for all, and health related risks must be monitored and mitigated in near real-time. The citizenry will demand access to high quality education, middle class income opportunities and ubiquitous access to entertainment services. The globally connected, conscious and aware citizens will mandate fast, easy, integrated and transparent services from public institutions.

Information and Communication Technology will play a critical role in addressing the impending challenges and meeting the upcoming demands, but information technology has its own challenges, specifically around the provision of foundational infrastructure services—networking, compute and storage—on top of which information technology services can be built. Addressing the foundational ICT infrastructure challenges will facilitate subsequent development of software applications relevant to address each of the grand societal challenges.

Solving any of Ethiopia's grand challenges (clean water, large-scale urbanization, food security, sustainability, energy, safety and security, health care and education) by 2050 will simply not be possible without a reliable and highly available, secure, scalable and neutral IT infrastructure.

# 2 ICT Infrastructure Challenges and Proposed Solutions

The components of ICT infrastructure include networking connectivity, computing resources and data storage capacity that together host software applications and services used by individual users, public institutions and private business. A high-functioning reliable ICT infrastructure is the lifeblood of a thriving modern economy and this is a precedent set to stay onto and after 2050. Almost the entire population in Ethiopia, Ethiopian government, Ethiopian businesses, Ethiopians abroad, foreign government, foreign businesses and tourists will require reliable and available infrastructure to access a variety of digital services both inside and outside of Ethiopia.

As of the end of 2019, Ethiopia has a single government owned ICT service provider—Ethiotelecom[2]—exclusively delivering networking and offering very few compute and storage services. The network backbone[3] of the PSTN/2G/3G/4G network is fiber optic, providing connectivity of up to 155Mbps to 85 towns along four separate routes extending from Addis Ababa. The fiber optic network was upgraded in 2008: 7,906 Km of new cable was installed, increasing the network capacity to 400 Gbps and the total installed cable length to 10,256 Km. Satellite connectivity is depended upon for international data connectivity with two separate dishes communicating with satellites operated by two different private corporations; the fastest of which provides 400 Mbps downstream and 100 Mbps upstream connectivity. Ethiotelecom's actual network statistics such as latency, effective last-mile download and upload speeds and throughput information are not publicly available, but there are fixed 256 Kbps - 4 Mbps broadband and 80 Kbps Wireless CDMA offerings.

Like networking, limited compute and storage infrastructure services are offered by the government owned provider. Ethiotelecom has a web hosting, virtual private sever (VPS), and dedicated hosting services. The webhosting service offers four options ranging from 5GB to 100TGB storage. VPS offers three server options from 2GB to 8GB RAM with 30GB to 100GB storage. Similarly, dedicated hosting has a 16GB or 32 GB RAM choices with 8 core and 2 TB storage. Offerings based on higher level abstractions popularized by recent trends in cloud computing—for example, platform-as-a-service—are not available. Further, besides Ethiotelecom, there are no other compute and storage services providers within Ethiopia. Institutions, businesses, and individuals use their own dedicated on-premise infrastructure. All customers depend on this single network provider and deal with major challenges to procure, import, deploy and operate their own compute and storage services.

Ethiotelecom has about 43 million customers; 42 million mobile phone connections (with 22 million data and internet subscribers) and 1 million landline customers. Mobile phone services are prepaid, with domestic calls costing 0.5 Br (0.017 USD) per minute and international calls costing up to 23 Br (USD 0.77) per minute. Internet charges are around 700 Br (25 USD) per month for up to 10 GB of data transfer and 5000 Br (165 USD) for unlimited data transfer.

The cost of these services is ill-afforded by Ethiopians—whose average income is less than 2 USD per day—and the service often suffers from poor quality. It's challenging to get information about the coverage area, throughput, and latency statistics; we can only rely on the experience of its customers. The availability of services is primarily in urban areas, but the service is highly unreliable, suffering from high latency and low bandwidth. This is not sustainable in the future.

Ethiopia must have a technology infrastructure that will stay useful and remain relevant in the future. Building reliable, available, scalable and secure infrastructure is capital intensive and requires highly skilled engineers. In order for Ethiopia to address this major challenge of building such an infrastructure, Ethiopia has to incentivize technologically capable private corporations. Private companies have traditionally been better placed to innovate at speed and high quality than state run organizations. For example, the computer system built and used by Google to search content on the world-wide web is probably far superior to any computer system run by any public organization in any country. Telecom companies like Verizon, AT&T, T-Mobile and multinational corporations, such as Microsoft, Amazon, Google and Alibaba afford to build this infrastructure because they are typically incentivized to maximize the extraction of revenue from the systems they create and to divert that revenue to shareholders; as a result, they raise large capital and employ highly skilled resources towards building their infrastructure.

[2] https://www.ethiotelecom.et/ (accessed on December 6, 2019)

[3] https://www.ethiotelecom.et/about-us/ (accessed on December 6, 2019)

ICT infrastructure build-out will involve design and operational tasks. Design of networks with low latency and high bandwidth, elastic computing resources with modern platforms, and high capacity data storage services will be needed. For example[4], Verizon (a USA network operator) has built a network that covers 98% of the USA with minimum 25Mbps to a maximum 1Gbps last-mile connectivity, sub 40ms coast-to-coast latency, sub 70ms trans-Atlantic latency using backbone links exceeding 1Tbps. Operationally, these systems must be built and then maintained to a standard that ensures the infrastructure is highly reliable, resilient, available, scalable, and secure.

It will be essential for Ethiopia to have a reliable, available and scalable network backbone that has good connectivity with networks outside of the country. Ethiopian citizens, businesses and institutions don't currently benefit from consistent reliable network access: As recently as June 2019 there were a number of country-wide Internet outages[5].

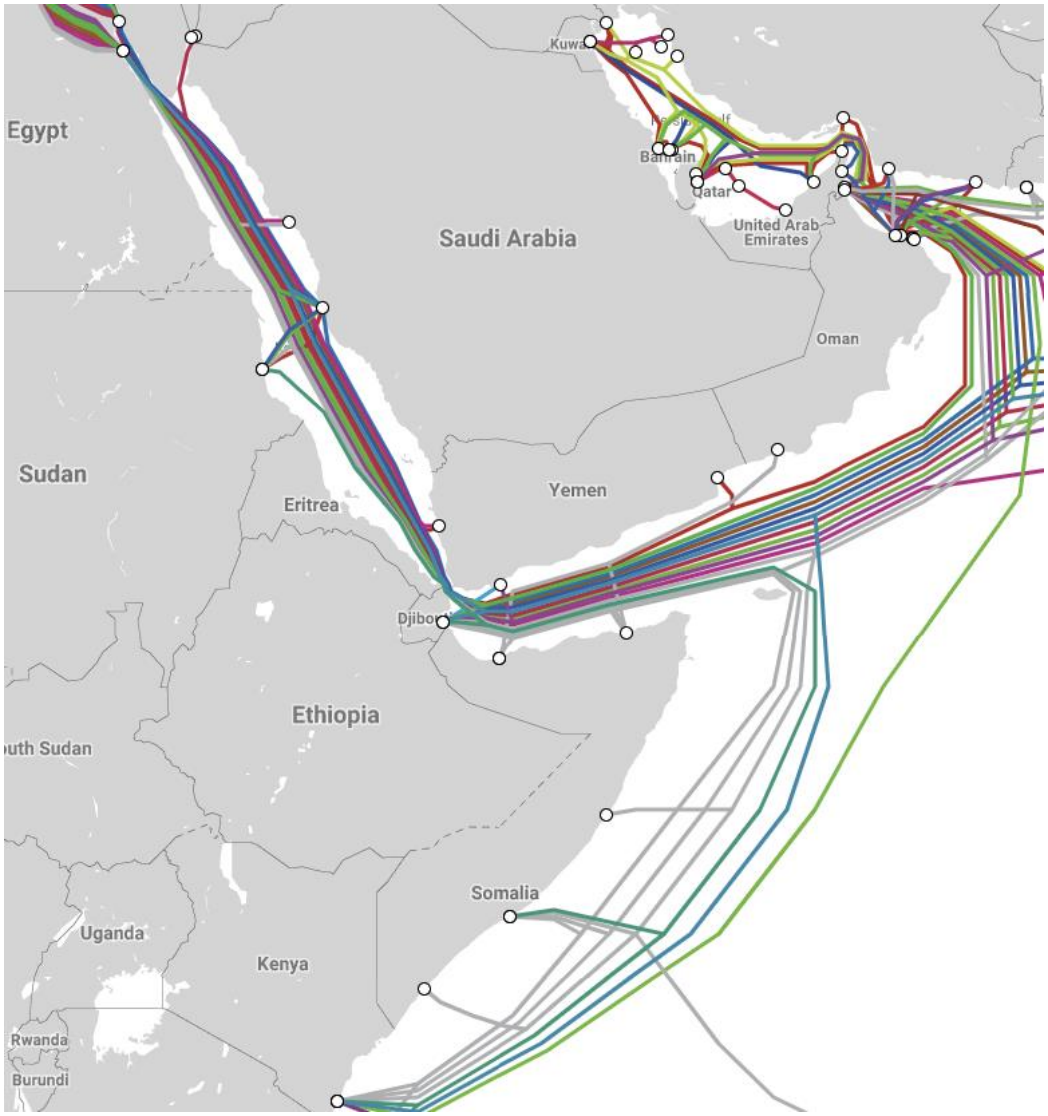
### 2.1 Proposed Networking Solutions

It is essential that network connectivity to the outside world be reliable, censorship resistant and able to withstand any potential political changes in international relations that may take place between 2019 and 2050.

Ethiopia does already benefit from international data connectivity via redundant satellites operated by distinct providers. However, it should be assumed that these satellites introduce high latency and provisioning additional bandwidth is prohibitive. Thus, we recommend establishing reliable, high-bandwidth fiber optical connections to multiple neighboring countries and designing the network such that it can transparently route around service degradation/disconnection in any one of the fiber or satellite connections. Four of Ethiopia's neighboring countries have known submarine fiber optic connectivity to the wider Internet: Djibouti, Somalia, Kenya and Sudan.

[4] https://www.verizon.com/about/our-company/network-performance (accessed on December 6, 2019)

[5] Total internet outage identified in Ethiopia – June 11, 2019
https://netblocks.org/reports/total-internet-outage-identified-in-ethiopia-gBLkVoA4 (accessed on September 30, 2019)




Existing neighboring countries with submarine fiber connectivity[6]

We recommend that peering relationships be established with network operators in as many of these neighboring countries as possible. Connectivity can then be built out from each of these neighboring countries to a set of "peering points" (smaller data centers that merely facilitate interchange of data between different networks) within Ethiopia. These peering points should be a combination of existing Ethiotelecom operated facilities and new privately owned and operated facilities (providing redundant connectivity in the face of an outage only impacting a single operator). This will allow build out of a network within Ethiopia that ensures any person or business within Ethiopia can reliably communicate with the wider Internet, even in the face of any individual degradation or disconnection of service (ranging from small technical outages at a single network operator through to a disruptive policy decisions made by other countries).

[6] TeleGeography Submarine Cable Map – September 25, 2019
https://www.submarinecablemap.com/ (accessed on September 30, 2019)

Due to there currently being limited compute and storage infrastructure hosted within Ethiopia, initially we anticipate there will be heavy network ingress/egress over connections facilitating connectivity to the wider Internet. There will likely be high utilization of cloud computing services from data centers in nearby regions. Provision of reliable network connectivity will allow Ethiopian applications developers access to existing cloud computing resources already provisioned in other countries (for example, the Microsoft Azure data centers in UAE and South Africa[7] or the Amazon AWS data center in Bahrain[8]); longer term, the improved international connectivity can be used to entice private companies to build out cloud computing data centers within Ethiopia (doing this would better serve their Ethiopian customers by supplying them with lower latency, higher bandwidth connectivity to compute applications and storage).

Building out a solid Internet backbone inside Ethiopia with reliable external connectivity to the wider Internet provides a foundation that can be built on to provide local network connectivity to ordinary Ethiopian citizens, government agencies and private businesses. The new peering points within Ethiopia can provide connectivity to a variety of privately-owned domestic networks that can operate using a variety of technologies:

- Modern cabled networks
  Dedicated cable networks are ideal for high density population areas such as large cities (the expense of building out new infrastructure can be justified as the benefits are spread over such a large population base). Many developed countries have existing networks that could be replicated using similar technology within Ethiopia (for example the cable network operators in the USA such as Comcast).

- Retrofitted telephone networks (DSL)
  For the more sparsely populated areas of the country where there already exists analog telephone connectivity, the telephone network can be retrofitted to facilitate relatively high bandwidth Internet connectivity. For example, upgraded DSL technology can be used. An example of where DSL has been effective in providing high bandwidth access to citizens in rural areas is in the United Kingdom: Initially DSL was enabled over existing copper telephone cables between homes and telephone exchanges (sometimes over distances of multiple miles) giving the majority of the population connectivity of around 1Mbps (much like the current Ethiotelecom network). Over time segments of the network have been upgraded to fiber (with DSL still being used for the last few hundred feet to terminate the connection into the customer premises); most of the population now have access to last-mile DSL connectivity of around 50Mbps.

- Wireless networks
  It is also essential that a wireless network exist, capable of providing connectivity to population in the remotest, most sparsely populated regions, as well as providing additional "on-the-move" connectivity to those in the cities. Population residing in remote areas can access highspeed networking using TV Whites spaces - gaps left between TV broadcasting

[7] Azure regions - 2019
https://azure.microsoft.com/en-us/global-infrastructure/regions/ (accessed on September 30, 2019)

[8] AWS Global Infrastructure - 2019
https://aws.amazon.com/about-aws/global-infrastructure/ (accessed on September 30, 2019)

VHF and UHF channels – that will deliver broadband access over wider areas than Wi-Fi spectrum[9]. For large urban residents, using existing 4G technology, wireless "last-mile" connectivity of around 20Mbps can be achieved. The technology landscape here is continually improving with countries such as the USA and China starting to roll out next generation 5G (and in about a decade, 6G) wireless technology.

In each of these categories of network, existing technology can be leveraged. It is also possible that existing private companies who already operate similar networks in other countries could be incentivized to provide a service within Ethiopia. However, when engaging with private companies to build out such critical infrastructure it is important to ensure citizens of Ethiopia are provided with reliable, widely available, competitive, affordable and censorship-resistant Internet connectivity. Learnings can be taken from existing countries that do have pervasive technology infrastructure but are in various ways hindered from achieving one or more of these goals, for example:

- Net neutrality in the USA: In many parts of the USA (particularly its rural areas) there is not a competitive market for Internet Service Providers (with much of the USA population only having one choice of network provider). This has resulted in high prices, unreliable connectivity and arbitrary limitations on access to 3rd party services for some of the population. To an extent, the government mitigates this problem with regulation (the "network neutrality" legislation imposed on carriers) however there are examples of private network operators attempting to subvert this regulation[10].

- Censorship in China: The Government of China has stringent rules around what private citizens can and cannot do using their Internet connectivity and has been quite effective in having these rules enforced by private companies that operate networks[11]. Were Ethiopia's domestic networks operated primarily by Chinese corporations, there would be risk of a foreign state actor censoring use of domestic Ethiopian networks.

### 2.2 Proposed Compute Solutions

Computing, in a general sense, is the provision of information processing machinery—made up primarily of a Central Processing Unit (CPU) and memory—for software applications to run on. Buildouts of compute resources can range in scale from an individual server operating on-premises at a small business through to a massive network connecting many servers all housed within a purpose-built data center and accessed remotely over a network.

Software programmers use these compute resources to build and run business-specific software applications. Whilst programmers may often directly target the underlying CPU and memory, it is also common for higher level abstractions to be provided that ease the

[9] https://www.microsoft.com/en-us/corporate-responsibility/airband (accessed December 6, 2019)

[10] Net Neutrality Violations: A Brief History – January 24, 2018
https://www.freepress.net/our-response/expert-analysis/explainers/net-neutrality-violations-brief-history (accessed on September 30, 2019)

[11] China Internet Freedom Score – May 31, 2018
https://freedomhouse.org/report/freedom-net/2018/china (accessed on September 30, 2019)

development of computer software for certain industry applications (Internet of Things, Blockchain, Artificial Intelligence, etc.)

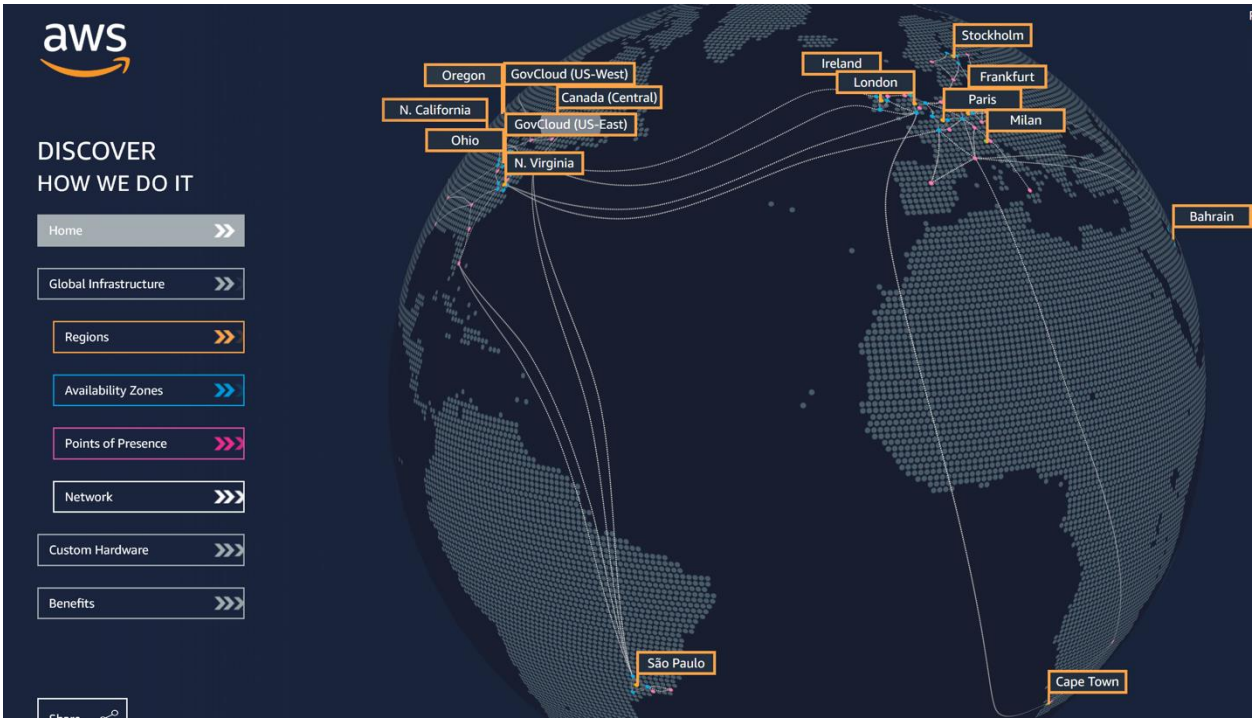
Due to economies of scale that can be achieved by large multinational technology companies (such as Amazon, Microsoft, Alibaba and Oracle) we see an increased trend of "cloud computing". This is where compute resources are typically provided by a selection of large multinational technology providers who operate large data centers, each containing many tens of thousands of computer servers; these servers host applications and workloads from a wide base of business customers; the application/service owners pay according to their compute utilization. Securing and protecting the infrastructure from malicious individual and state actors is the responsibility of the cloud providers who can bring to bear their skilled cyber security professionals and their economics of scale. This model relieves application/service developers from the capital expenditure of building a data center, importing equipment, maintaining and operating the data center, staffing with skilled IT professionals and from developing their own higher-level compute abstractions (databases, IoT, Blockchain, AI, etc.)

As of the end of 2019, Microsoft Azure has 54 data centers servicing 140 countries including data centers in South Africa, in the UAE and in multiple European countries[12]. Amazon Web Services (AWS) has 22 data centers worldwide including one in the UAE and a planned data center in South Africa[13]. Though Microsoft and Amazon have a larger share of the market and extensive global presence, other providers like Alibaba (with 20 data centers including one in the UAE[14]) are gaining market share and planning to expand their presence. These providers are also innovating to quickly deploy cost-effective, reliable and environmentally friendly data centers close to where consumers live. An undersea immersed data center is one such innovation. Microsoft recently deployed a 40ft shipping container sized data center in Scotland that uses renewable energy to power 864 servers with over 27 PB of storage[15]. These data centers will be close to where half of the world population lives: Within 200 km of the ocean shore. All that is required to consume cloud services by countries like Ethiopia is reliable network connectivity as described above.

Our recommendation is for Ethiopia to provide reliable network access to data centers owned and operated by private Cloud Computing service providers. As an option, Ethiopia can entice one or more of these cloud service providers to build data centers within Ethiopia. This could be a long-term plan for Ethiopia to create jobs, produce skilled resources and to have more control to enforce country specific policy and regulation.

[12] Azure regions - 2019
https://azure.microsoft.com/en-us/global-infrastructure/regions/ (accessed on September 30, 2019)
[13] AWS Global Infrastructure - 2019
https://aws.amazon.com/about-aws/global-infrastructure/ (accessed on September 30, 2019)
[14] Alibaba Cloud's Global Infrastructure – 2019
https://www.alibabacloud.com/global-locations (accessed on September 30, 2019)
[15] https://news.microsoft.com/en-au/features/under-the-sea-microsoft-tests-a-datacenter-thats-quick-to-deploy-could-provide-internet-connectivity-for-years/ (accessed on December 6, 2019)


2019 Global Microsoft Azure Footprint




2019 Global Amazon Web Services Footprint - https://infrastructure.aws/


2019 Global Alibaba Could Service Footprint

### 2.3 Proposed Storage Solutions

Storage, in a general sense, is the provision of resources that allow data generated by software applications to be persisted and later retrieved in an efficient and reliable way. Storage requirements for modern compute applications are often massive. The advent of new technologies—such as machine learning upon big datasets, virtual reality and high resolution photography—leads to continually increasing storage demand. A high capacity, reliable and scalable storage service facilitating fast read and write performance is essential for a reliable ecosystem of modern compute applications.

Like compute resources, storage is also provisioned as a cloud service by the same large multinational companies. Various abstractions are offered by these providers for consumption by the individual engineers who write software applications (for example: databases for efficient storage and retrieval of structured data, blob storage for reliable storage of massive unstructured data, geographic replication and backup for sensitive data that cannot be lost in a disaster). Beneath these abstractions live a massive amount of storage medium (e.g. memory chips, magnetic disk drives and magnetic tape) hosted within the aforementioned data centers operated by the large cloud providers.

Ethiopia would be best served by providing reliable network access to the large data centers operated by existing private cloud computing companies. These companies have the best economies of scale to provision the underlying storage devices at the best possible price, and also have a large amount of accumulated expertise in providing abstractions on top of the raw

storage medium (such as database interfaces, replicated storage, etc.) ready for consumption by regular software application programmers in specific business domains.

# 3 Addressing Upcoming Societal Grand Challenges with Technology

Information Communication Technology driven software solutions can play a critical role to help address the societal grand challenges that Ethiopia will face over the next 30 years. These software applications need to be developed on modern platforms, be compatible with a variety of devices, and be hosted on a highly reliable infrastructure. Computer systems, made up of a combination of software programs, will play critical role to address many of the upcoming societal grand challenges.

## 3.1 Food Production

As Ethiopia ramps up food production for a rapidly growing population, software applications and computer systems will be essential. There will be a need for automation in farming, supply chain management and inventory control to ensure efficient production of a large enough supply of food. With the right infrastructure in place, Ethiopia can take advantage of advanced emerging techniques, for example: big-data mining to understand weather conditions, soil makeup, seed selection, and determine optimal fertilizer usage or monitoring and operation of large food production facilities by networks of Internet of Things (IoT) devices.

## 3.2 Public Safety and Security

A large population and growing urbanization accentuate the need for efficient and effective policing. Technology will enable public safety institutions to accomplish more, faster with less personnel by utilizing technologies such as IoT, AI, high resolution image capturing, big data analytics, electronic record keeping, automated dispatch systems, etc. For example, IoT can be used to manage traffic signals during events and incidents, monitoring and alerting when weapons are fired, and gathering real time actionable intelligence using cost effective connected devices and integrated systems[16].

## 3.3 Healthcare Services

Technology plays a decisive role to deliver healthcare services to a large population and to manage public health risks. Improving quality and speed of care, administering medication, and cutting costs can be facilitated with electronic medical record keeping, telemedicine, telemonitoring, and IoT technologies. Enabling healthcare professionals and their patients to communicate regularly and to seamlessly exchange information (wearable devices to predict and treat health issues) from diagnosis to treatment to management without regard for location and facilities, would be enabled by technology. Any disease that has the potential to develop

[16] 5 Major Public Safety Technology Trends for 2019 – December 21, 2018 https://insights.samsung.com/2018/12/21/5-major-public-safety-technology-trends-for-2019/ (accessed on September 30, 2019)

into an epidemic can be tracked and mitigated as well. Large amounts of data collected by healthcare systems can be stored in high capacity, expandable, and cost-effective cloud storage[17].

### 3.4 Education and Employment

Advances in technology can enable a better education of Ethiopia's population. It will become possible to educate people remotely using technologies such as video conferencing and online courseware software. This will be of great benefit to the remote, rural population of Ethiopia who will have access to education that they may not have otherwise had and at a much lower cost (with minimal—if any—student debt accrual). The benefits will be more pronounced for higher level (e.g. university) education where there will be less availability of appropriately specialized instructors.

### 3.5 Governance and Public Service

In 2019 much existing government function (e.g. property records, birth/death records, taxation) in Ethiopia operates around paper record-keeping. Once institutions across Ethiopia have reliable access to cloud computing a transition to digitized processes can begin. Initially, existing document types can be digitized (scanned) and stored in document databases in the cloud. This system can then gradually be further transformed to make documents searchable and then eventually have application-specific relational databases operated on by custom-built software.

Having government systems operate digitally can facilitate improved transparency as well as better tracking and tracing (e.g. using blockchain technology). This in-turn can reduce corruption (e.g. in functions such as licensing) and improve fairness (e.g. in functions such as elections).

### 3.6 Access to Financing

Financing is an essential ingredient of a thriving and growing economy. The large, entrepreneurial Ethiopian population will need access to financing in order for the economy to grow. The role technology is already playing in financial services will continue to grow and be driven by changing market conditions; financial institutions will need to reduce costs and risk. Innovation such as artificial intelligence and distributed ledger (blockchain) technology will be catalysts to make small and large financial products and services, credits and loans and investment, accessible to all Ethiopians.

### 3.7 Risks and Regulations

There will be risk introduced to governments, population, and businesses as a result of increased penetration of ICT in Ethiopian society. These risks will come from both malicious state and individual actors who attack critical infrastructure (e.g. power stations, healthcare facilities, drinking water reservoirs, telecommunications, financial institution and data centers). This infrastructure gains more of a cyber-attack surface as it becomes more networked and as

[17] The Impact of Technology in Healthcare – June 2, 2019 https://www.aimseducation.edu/blog/the-impact-of-technology-on-healthcare/ (accessed on September 30, 2019)

data is more often stored electronically in computerized information systems. The frequency of attacks, the complexity of sophistication the methods, and impact severity of attacks is increasing. Ensuring the security of these systems and preventing inappropriate use of data is crucial. Government regulatory institutions and private sector expertise will have to work together to develop and use security technology and to develop regulatory, compliance and legal policies.

## 4.0 Conclusion

Ethiopia currently has a population of a little over 110 million people, and looking ahead, the total population is projected to reach 202.5 million by the year 2050. Ethiopia must begin to proactively work to deal with grand societal challenges it will face in the next 30 years. An ICT infrastructure will play a critical role to meet grand challenges, but it is also a grand challenge to build an infrastructure with reliable network connectivity, scalable computing power, and high capacity data storage. Ethiopia initially may need to incentivize private companies to build reliable networking and leverage cloud computing services provided by multinational corporations. Doing so will be vital to address the many societal grand challenges Ethiopia faces on the road to 2050.