FINANCING ICT AND DIGITALISATION IN URBAN AFRICA

CURRENT TRENDS AND KEY SUSTAINABILITY ISSUES

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AFRICAN CENTRE FOR CITIES
urbanism from an african perspective

Alfred Herrhausen Gesellschaft

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EXECUTIVE SUMMARY

Increasingly recognised as a pivotal infrastructure for inclusive economic development and social justice in Africa, information and communication technology is a fundamental component of the continent's infrastructure budget. DFIs, such as the World Bank and the African Development Bank, have long included digital infrastructure and connectivity projects as one of the portfolios that receive financial support. Nevertheless, the investment landscape for sustainable information and communication technologies in Africa remains poorly understood. The availability of data is inconsistent, mirroring a broader knowledge problem across the entire infrastructure finance sector (see Cirolia, Pieterse & Pollio, 2022). Moreover, issues of sustainable investment are by nature of digital infrastructure much less visible and debated than in related sectors of mobility or energy.

This paper is, therefore, aimed at i) highlighting the different components of infrastructure investment in information and communication technologies, ii) showing that the value chain is complex and that different investment patterns and bottlenecks need to be recognised across the sector, and iii) identifying key sustainability issues that deserve attention for digital infrastructure as much as for other types of technical systems. To do so, in this paper, four sections and a tentative list of policy implications linking sustainability concerns to the financial design of information and communication technology infrastructure are featured.

In Section 2, a framework has been developed to understand key components of the digital infrastructure and information and communication technology value chain. Unlike other overviews of information and communication technology investment, this paper considers the hardware and software components of digital infrastructure, identifying hardwired broadband, mobile broadband and data centres for the hardware component, and digital ecosystems for the software component. The rationale for including capital investment in digital ecosystems reflects the fact that not only are venture capital investments in digital services more and more significant across Africa, DFIs and African governments are increasingly involved in supporting and de-risking these initiatives. For each of these four components, this section charters the status quo of current levels of information and communication technology infrastructure availability, with particular attention being paid to how these patterns interface with African cities. This review provides a broad-stroke map for understanding contemporary digital service delivery configurations and levels. Information is provided on unequal distribution and availability patterns, on the permanence of digital divides in light of these patterns, while also including an overview of current agendas aimed at addressing gaps related to access, legislation, skills development and other issues concerning information and communication technology justice. Concerning digital infrastructure from the supply side, the most visible divides appear in terms of broadband penetration and data hosting capacity, which is geographically unequal between countries and within countries, for example, between major urban centres and rural regions. Regarding digital ecosystems, major cities receive the lion's share of investment in business development programmes and digital start-ups; a trend that is not unique to Africa, but to the continent, which has manifested in the emergence of a handful of cities absorbing the majority of high-risk capital directed towards digital innovation.

Having established a shared framework to understand the components and the status quo of digital infrastructure in Africa, Section 3 is focused on financial patterns, identifying the main actors and drivers for investment in each of the value chain parts. Drawing on secondary data and original research by the authors, this section charters key trends in the investment landscape, not the least some specificities that set digital infrastructure apart from other sectors. These trends include –

- a clear focus on supply-side investments by the public and private sectors often to the exclusion of demand-enhancing investments, such as digital literacy.

- a decisive private sector-led edge in certain hardware components, such as mobile broadband dominated by telecom providers and tower companies, and the data centre industry.
- the increasing involvement of city-scale actors in creating tech hubs, with select cities having bypassed the involvement of DFIs to attract international investment in information and communication technology.
- very diverse risk and profitability profiles across the value chain, resulting in the perpetuation of digital divides through profit-driven financial patterns.

Section 4 is dedicated to the sustainability issues that are emerging in relation to digital infrastructure. While the latter is often celebrated as an enabler of sustainable transitions, the hidden environmental and social costs of its components need to be better understood and eventually factored in. Of the many sustainability concerns relating to current investment patterns, this section highlights the following four key issues:

- The need to address digital divides. It is better for them to be understood in their geographic and social complexity. These divides work intersectionally but can be summarised by gross domestic product per capita, urban/rural and gender and age gaps.
- The need to implicate the systemic environmental footprint of digital infrastructure when factoring in the hidden costs of these kinds of investments, for example, sustainable energy, mining and e-waste.
- The need to consider personal data protection and data sovereignty as part of the design of these systems.
- The need to evaluate the impact of artificial intelligence and digital services more broadly on the future of work and employment in Africa.

Drawing on this overview, Section 5 provides key policy directions, namely shifting away from supply-driven investment to other forms of more holistic financing, in particular, those that address uneven demand, factoring in all the environmental costs of digital infrastructure and the extractive nature of many of its components; reframing the narrow yet significant role currently played by cities and local governments to ensure that subnational governments can shape and benefit from digital transitions; learning from the successes of the venture capital model of de-risking investment to apply it in other infrastructure sectors; and building social, environmental and data sustainability into the design of information and communication technology projects and programmes, rather than as an afterthought of digital infrastructure.

CONTENTS

ABBREVIATIONS AND ACRONYMS

2G:	Second generation
4IR:	4th Industrial Revolution
5G:	Fifth generation
ACC:	African Centre for Cities
ADCA:	African Data Centre Association
ADIE:	Agence De l'Informatique de l'Etat (Senegal)
AFD:	Agence Française de Développement
AfDB:	African Development Bank Group
AfDF:	African Development Fund
AHG:	Alfred Herrhausen Gesellschaft
AI:	Artificial intelligence
AIDI:	Africa Infrastructure Development Index
ARPU:	Average revenue per unit
ASN:	Alcatel submarine networks
AU:	African Union
AUDA-NEPAD:	African Union Development Agency and New Partnership for Africa's Development
BBS:	Burundi Backbone System
BC:	Broadband Commission
CFA:	Coopération financière en Afrique centrale
CiTi:	The Cape Innovation and Technology Initiative
DE4A:	Digital Economy for Africa
DFI:	Development finance institution
DSM:	Digital Single Market for Africa
DTS:	Digital Transformation Strategy
DTV:	Digital television
EASSy:	Eastern Africa Submarine System
ECOWAS-CEDEAO:	Economic Community of West African States
EIB:	European Investment Bank
EPSA:	Enhanced Private Sector Assistance
EU:	European Union
EU–AU DETF:	European Union–African Union Digital Economy Task Force
G7:	Group of Seven
GDP:	Gross domestic product
GHG:	Greenhouse gas
GSMA:	Global System for Mobile Communications Association
ICA:	Infrastructure Consortium for Africa
ICT:	Information and communication technology
ICT4D:	Information Communication Technology for Development
IFC:	International Finance Corporation
ISP:	Internet service provider
ITU:	International Telecommunication Union
IXP:	Internet exchange point
KIC:	Kigali Innovation City
MEC:	Multi-access edge computing
mLabs:	Mobile solutions laboratory
MOU:	Memorandum of Understanding
NICI:	National Information Communications Infrastructure
NOFBI:	National Optic Fibre Backbone Infrastructure
OECD:	Organisation for Economic Cooperation and Development
PEACE:	Pakistan and East Africa Connecting Europe

PIC:	Public Investment Corporation
PIDA:	Programme for Infrastructure Development in Africa
PPP:	Public–private partnership
PRIDA:	Policy and Regulatory Initiative for Digital Africa
ROI:	Return on investment
SA:	South Africa
SABR:	South Africa to Brazil
SACS:	South Atlantic Cable System
SAIL:	South Atlantic Inter Link
SDG:	Sustainable Development Goal
SDIP:	Sustainable Development Investment Partnership
SME:	Small and medium enterprise
SOE:	State-owned enterprise
SRMP:	Smart Rwanda Master Plan
UN:	United Nations
US:	United States
USAID:	United States Agency for International Development
VC:	Venture Capital
WARCIP:	West Africa Regional Communication Infrastructure Projects
WB:	World Bank
WBG:	World Bank Group
WEF:	World Economic Forum

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1 INTRODUCTION

In recent years, ICT has been championed as essential for the development of African economies. According to the ITU, expanding mobile broadband penetration by 10% in Africa would yield an increase of 2.5% in GDP per capita (BC, 2016). Leading voices in the infrastructure debates argue that ICT investment has the potential of leapfrogging African economies into rapidly reconfiguring global and regional economic circuits (AfDB–African Infrastructure Development Index, 2018; ICA, 2017a). ICT infrastructure and programmes are not only framed as part of national and regional economic growth prospects, but are increasingly positioned as essential in ensuring just, sustainable and inclusive development. As an example, in Goal 9c of the UN's SDGs, a specific call is made for "significantly increas[ing] access to information and communications technology and strive to provide universal and affordable access to the Internet in least developed countries by 2020". Commitment to using ICT to drive development not only features in global agendas but also in Africa's own programmes. As an example, the AU's Agenda 2063 – The Africa We Want includes several flagship projects related to ICT and regional broadband connectivity.

These global and regional agendas dovetail with important concepts that form part of developmental discourses globally and locally. These include but are not limited to concepts such as the 4IR, ICT4D, the Fintech Revolution, and Digital Rights. While these concepts land in Africa in uneven ways, they emphasise the important role that digital and ICT investment will have in societal transformation. In the context of cities, discourses such as the Smart City have created significant fanfare and excitement, leading many donors, lenders, national governments and city administrations to pursue investments aimed at improving service delivery systems using ICT. Examples such as Akon City outside Dakar and Konza City outside Nairobi promise the development of new towns that rely on new and digitally-enabled technology to deliver more sustainable infrastructure systems.

While ICT is being celebrated as a tool for growth and shared development, Africa is far from achieving equitable access to digital infrastructures and services for people across the continent. Huge gaps remain in ICT infrastructure and services, which may amplify in response to global and local investment patterns. Simultaneously, with many issues related to the sustainability of ICT and digital infrastructure, unlike with many other infrastructures, there is still time to get ahead of the curve and ensure more sustainable investments. As stated by the ICA (2017a), which is a colloquium of governments and institutions aimed at developing the continent's infrastructure, including the WB, the AfDB, and the G7 countries, "[t]he broadband infrastructure gap, the related costs of services and devices, the lack of local content and low proficiency in digital skills are among the critical barriers" to ensuring more just and sustainable development in Africa (ICA, 2017a:14).

This paper provides a high-level overview of the ICT infrastructure investment context in Africa. To do this, a framework has been developed in Section 2 to understand the components of ICT and digital infrastructure. This framework is used to unpack the current penetration levels and status quo in terms of delivery. The financial patterns underpinning the status quo are identified in Section 3. Finally, key sustainability issues in the sector are identified in Section 4, and avenues to encourage more sustainable investment are suggested in Section 5.

2 STATUS QUO OF ICT INFRASTRUCTURE IN AFRICA

In this paper, the entire supply chain/system for ICT is divided into four parts[1]. The first two include hardwired broadband and mobile broadband. Notably, the term 'broadband' can be defined as any Internet access that is faster than a dial-up connection (EU, 2018). From an infrastructural perspective, broadband access to the Internet relies on different types of connective technologies, from fibre-optic cables to radio networks, and other hardware such as network switches, satellites, routers and mobile phones[2]. However, broadband is only one part of the ICT value chain. The third important component of digital infrastructure is data centres. Broadband networks and data centres are further complemented by various software ecosystems allowing end-users to use the Internet and Internet companies to sell their digital services. To capture this additional layer, a fourth component of the ICT landscape is identified in this paper in what is defined as digital ecosystems. While often neglected in existing reports on Africa's infrastructure spend (for example, the ICA report does not include VC investment in digital companies), this component is included here as many government-driven funding programmes and other multilateral initiatives include support for technology start-ups and for local digital ecosystems as part of broader ICT investment strategies, and as digital ecosystems create the software services that, at once, rely on and make other ICT infrastructure necessary. For each of these four components, in this section, the current patterns of ICT and digital infrastructure availability are presented, with particular attention being paid to how these interface with African cities. In this overview, a framework is provided for understanding contemporary service delivery configurations and levels, as well as the gaps in these delivery systems. The last paragraph of this section provides a snapshot of current programmes that have been initiated to address these gaps.

2.1 Hardwired broadband

Hardwire broadband is made of fibre-optic cables laying underground or underwater. These infrastructures can be government-owned, fully private or owned by public–private consortiums, which is the case for a number of important submarine cables and regional backbones (see Box 1). Cables are rented out to service providers, such as ISPs and mobile communication companies, through different types of fee-based structures.

While hardwired broadband has grown exponentially in the last few years, low-latency and high-capacity access remains limited to very few countries. The challenge is particularly acute for landlocked countries, where the cost of connectivity is higher[3]. The backbone of Africa's connectivity to the global Internet is constituted by submarine cables, which is a cheaper option than terrestrial cables. As of 2020, the majority of African states with coastlines access at least one undersea cable. Only Eritrea and West Sahara are currently not served by any submarine cable, which brings the total number of states with undersea cable access to 37. However, of these 37 countries, only 10 have access to more than three cables, and even fewer have access to cables with high capacity. A total of 17 countries only have access to a single cable, which makes them prone to Internet outages, given that if something happens to that specific cable, there is no redundancy.

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[1] Based on this framework, other existing areas of ICT investment on the continent have not been considered, such as satellite broadband, which developmental organisations pursued as a strategy for many years in the 2000s (see IDRC, 2004), DTV, or wireless ISPs. All these are additional and important components of the ICT landscape, but they are smaller in terms of their investment footprint.

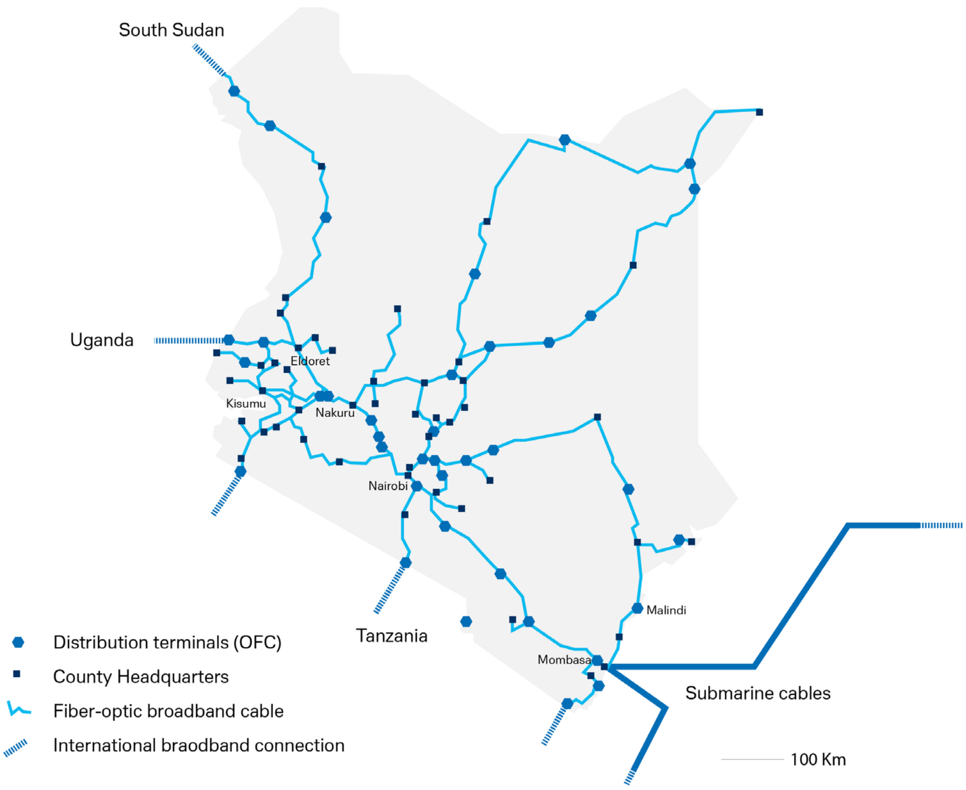
[2] For this reason, government policies usually separate connective technology into three different layers, namely the core layer, the middle mile and the last mile, or, alternatively, core layer, distribution layer and access layer. While important in commercial and investment parlance, a different taxonomy has been chosen for this paper.

[3] Research shows that the cost of Internet connectivity in landlocked countries is higher than in bordering countries with similar socio-economic characteristics (Dahir, 2017).

BOX 1: HARDWIRED BROADBAND NETWORK IN KENYA

In Kenya, the terrestrial network connects to the global Internet at various landing stations in Mombasa, where several international cables shore. Cross-country underground cables with neighbouring countries such as Uganda and South Sudan allow these landlocked nations to access the submarine network, while also creating regional corridors. Furthermore, in the current plan, a regional distribution network will be connecting each of the 47 counties to the national backbone. Finally, a last-mile access to the fibre-optic network reaches each county's headquarters.

FIGURE 1: KENYA'S NATIONAL OPTIC FIBRE BACKBONE INFRASTRUCTURE DISTRIBUTION NETWORK (REALISED AND PLANNED) (ADAPTED FROM: ICT AUTHORITY, 2022)

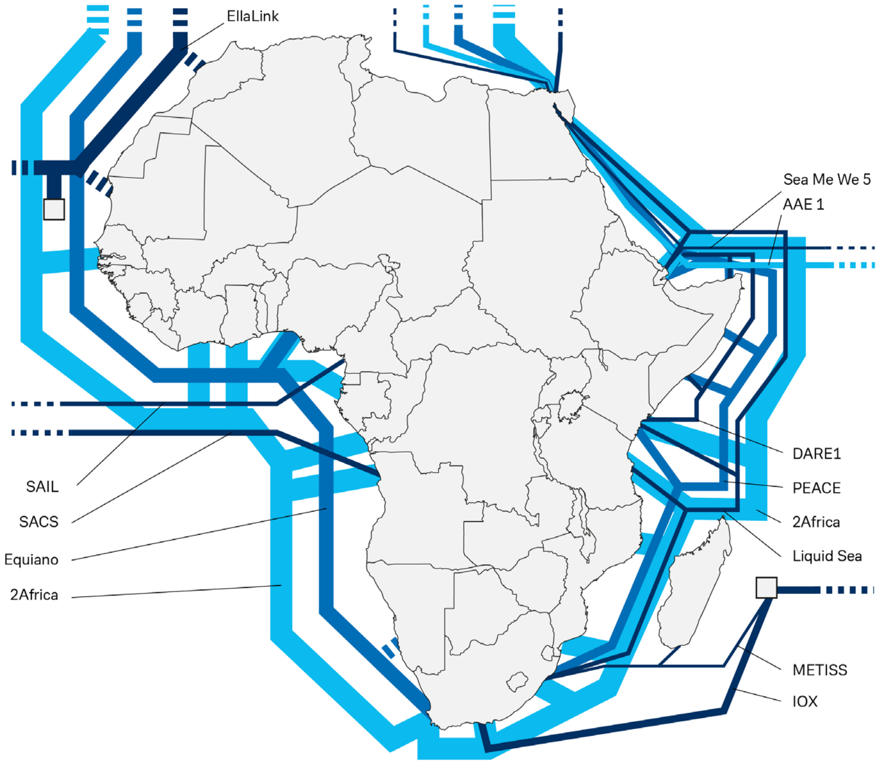


** Note that the infrastructure is built and operated by different players.*

Recent game-changers in increasing Africa's bandwidth access to the global Internet have been SAIL and SACS on Africa's West Coast and PEACE on the East Coast, all of which are operated by Chinese consortiums. Before SAIL and SACS became active, the link between Africa and the Americas, including the US, was mediated by Europe. This also gave regional advantage in terms of latency to Cameroon and Angola. Another Africa–America cable is being designed to connect SA (Cape Town) to the US via Brazil, with the SABR undersea cable being operated by a private company called Seaborn. Figure 2 shows the current biggest cables under construction are Google's Equiano at 100 Tbps and Facebook's 2Africa at 180 Tbps. With regards to 2Africa, the entire continent will be wrapped by a cable with very high capacity; a prospected 180 Tbps. However, not all countries will have immediate access.

Only a handful, namely Djibouti, Egypt, Kenya, Nigeria and SA, have landing stations planned at the current stage as these infrastructures are costly and have a more immediate return in countries where there is a high number of users in terms of penetration or population, for example, in SA and Nigeria[4].

FIGURE 2: AFRICA CURRENT AND UNDER-CONSTRUCTION UNDERSEA CABLES AS AT AUGUST 2021 WITH CAPACITY HIGHER THAN 20TBPS[5]



** The relative thickness of the cable represents their capacity.[6]*

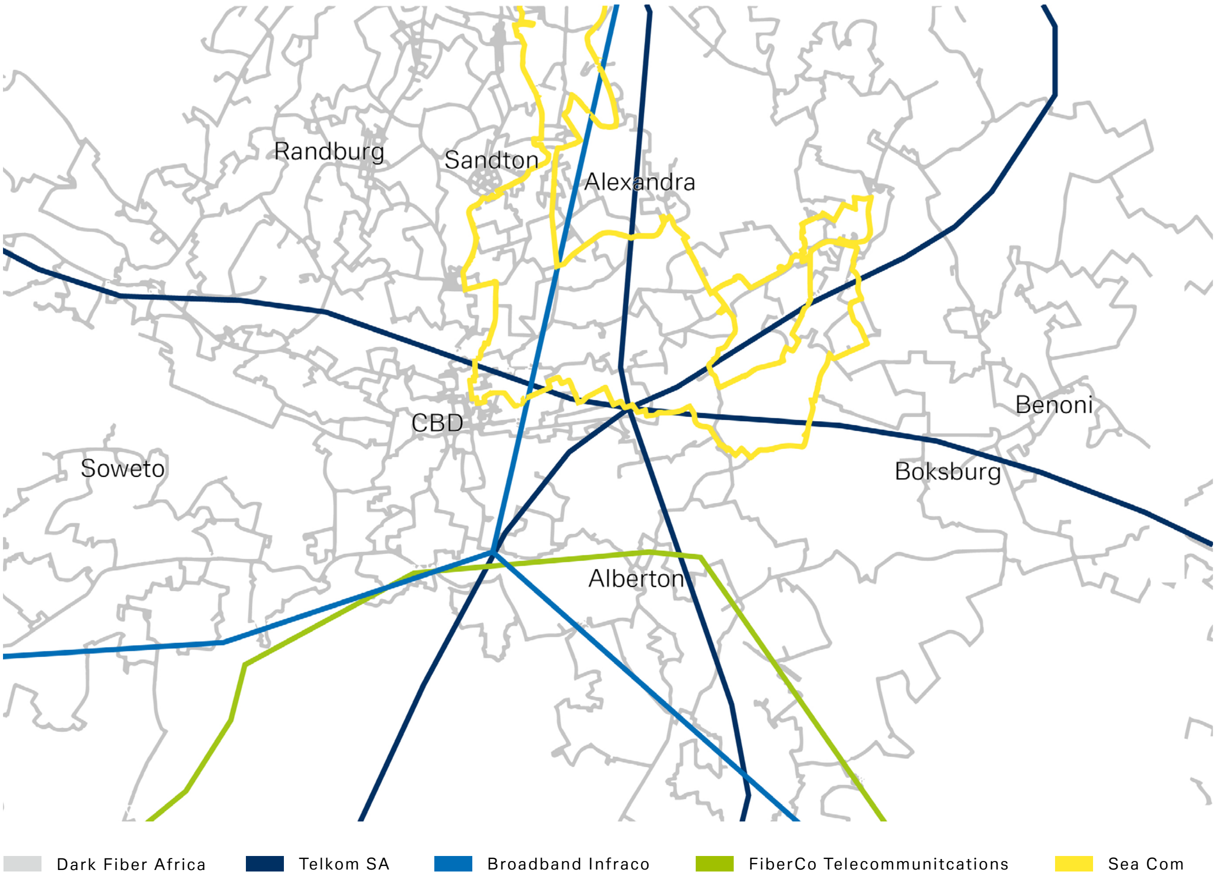
As far as landlocked countries and internal regions are concerned, terrestrial or underground cables are the backbone infrastructure of wired broadband. This is also true for large inland cities, such as Johannesburg or Nairobi. A few cities have also developed their own fibre-optic infrastructure, for example, connecting key sites of commercial activity, key government buildings and colocation facilities with Internet switches to ensure low-latency access to the core network. This is the case in Cape Town, which has its city-owned fibre network under development. Telecommunication companies operate other city-based networks (either private, mixed or SOEs) serving final customers with last-mile solutions. However, in global cities with large Internet economies, there is a third type of network, namely dark fibres. This is almost exclusively an urban phenomenon taking place in large dense cities. Dark networks usually connect several data centres within a single city or metro area, thereby realising additional unused bandwidth with respect to existing infrastructure. Figure 3 shows how a large metropolitan centre such as Johannesburg, SA, relies on multiple fibre-optic networks run by different operators. A number of these networks focus on regional connections, while others have a more localised footprint, targeting the last mile distribution.

[4] Djibouti is a unique case in this sense. It hosts several landing points for a number of different cables. The reason is that Djibouti is a relatively stable country in a relatively unstable region and it provides Internet access to Ethiopia, which is Africa's second largest by population with more than 110 million people. It is, therefore, evident that a few countries work as bottlenecks. In the proximity of a few cities, namely Alexandria, Cape Town, Durban, Lagos and Mombasa, most Internet traffic is channelled to the continent.

[5] Some under-construction or planned cables are missing as not enough specifications were found. These cables are Africa-1 (connecting Europe, ME and Africa east coast); the SABR undersea cable (connecting South Africa to Brazil and the US) SAEX 1 and SAEX 2, which will connect SA to the Americas and South Asia, respectively.

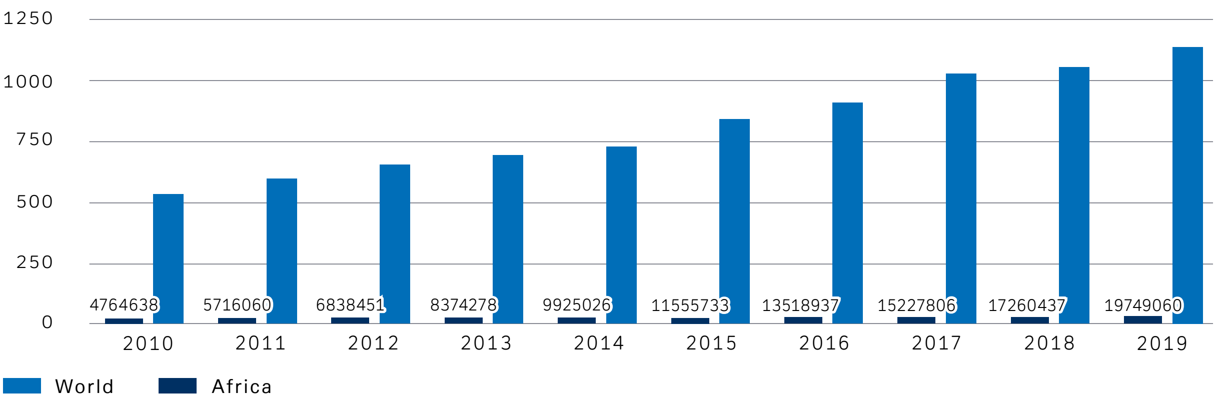
[6] https://www.submarinenetworks.com/en/systems/brazil-africa/sabr/africa-to-us-subsea-cable-coming-soon

FIGURE 3: FIBRE-OPTIC INFRASTRUCTURE OF THE JOHANNESBURG METRO AREA (ADAPTED FROM: INFRAPEDIA, 2018)



Hardwired broadband access is unequally distributed between different countries. There are notable differences between urban and denser areas, and more rural regions in each country. According to data from the WB and the ITU from 2019 (ITU, 2020), fixed broadband subscriptions in Africa totalled less than 20 million units or 1.7% of the world's total, which translates to more than 1.1 billion subscriptions. Although the average year-on-year growth of subscriptions has been 17% compared with that of the world at 9%, the gap remains incredibly significant. Only a handful of countries in Africa have more than one fixed broadband subscription per 100 people, with the average for Africa being 1.5 subscriptions per 100 people, and Africa only accounting for a very small part of the global bandwidth (Chart 1).

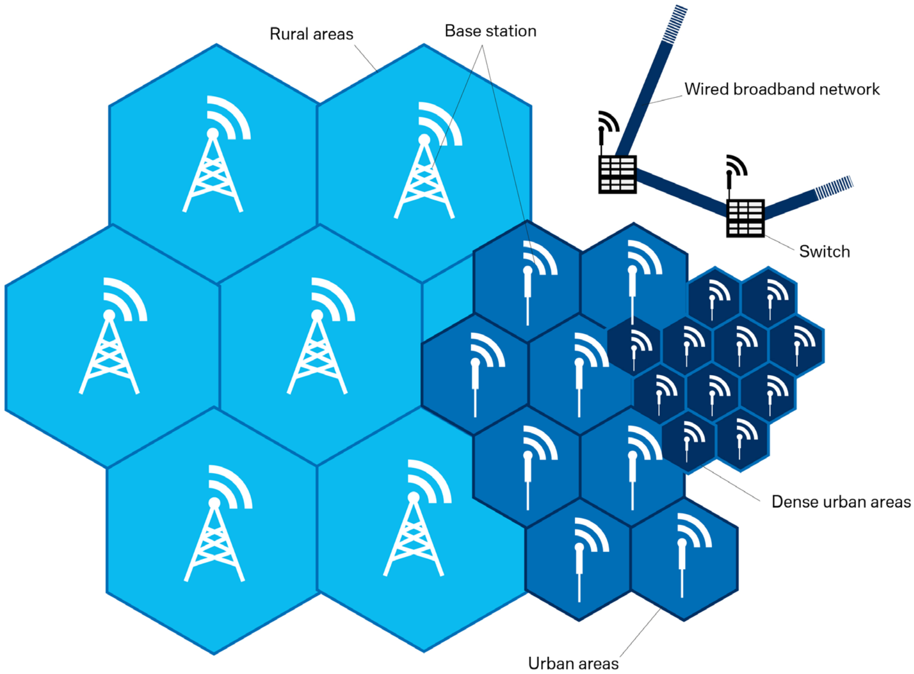
CHART 1: FIXED BROADBAND SUBSCRIPTIONS, AFRICA AND WORLD, 2019 (ADAPTED FROM: WORLD BANK GROUP, 2022)



2.2 Mobile broadband

Mobile broadband includes wireless networks that provide Internet access via mobile telephony infrastructure. Access to the network can happen through a portable modem, a handset such as a smartphone, or any other enabled device such as a car or a smart meter. The first wireless Internet access dates back to 1991 as part of the 2G of mobile phone technology[7]. The most recent standard for Internet access via mobile telephony is 5G.

FIGURE 4: A TYPICAL CELLULAR NETWORK (AUTHORS' REPRESENTATION)



Mobile broadband is the main source of access to the Internet in Africa. In the most recent data published by GSMA (2020), it is shown that 45% of the population in Africa subscribed to mobile services, with more 272 million mobile Internet users (GSMA, 2020). This puts the current mobile Internet penetration at 26% with a growth forecast of 475 million users by 2025, which translates to a 39% penetration. There is significant variation between rural and urban areas, with large coverage gaps in a number of countries and regions. Notably, in addition to coverage gaps, there are also usage gaps, which refers to people living in areas with mobile broadband availability who still do not have the capacity, either financial or otherwise, to access the Internet. The usage gap stood at 49% of adult users in 2019 (GSMA, 2020).

The usage gap highlights the important role of mobile phones in connecting people to available network services (Chart 2). The fast growth rate of mobile Internet is not only driven by investment in network infrastructure by mobile operators, but also by the availability of affordable smartphones (GSMA, 2020). The cheapest available device with Internet connection capabilities cost an average of 57% of GDP per capita in 2015 and 30% in 2019 (GSMA, 2020). However, while smartphones are still a minority of the type of phones owned by adults, many feature phones now include access to basic Internet and social media services, such as WhatsApp and Opera Mini, which is a browser designed for low data consumption (these phones are sometimes called smart-feature phones). Smartphone adoption is also forecasted to double in the next five years, reaching an adoption rate of 65% (GSMA, 2020; Pew, 2018).

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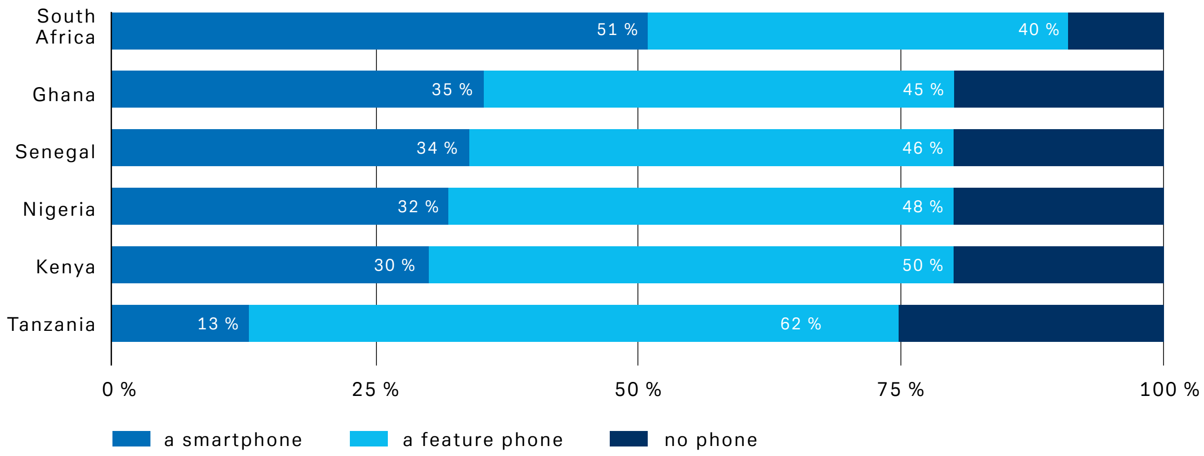
[7] The basic infrastructure of any mobile broadband is a cellular network, for which the service area is divided into small geographical cells varying in size depending on the population density. Each cell contains a local antenna/base station, which in turn links back to switching centres in the telephone network and routers for Internet access to the wired broadband network. One of the main features of 5G networks is that, because of the frequencies at which they operate, they need smaller cells than older generations of mobile broadband (Figure 4).

CHART 2: SMARTPHONE OWNERSHIP IN TOP AFRICAN COUNTRIES, 2017 (JOHNSON, 2018)

Adults report owning …



2.3 Data centres

Whether connectivity is wireless or hardwired, current ICT systems rely heavily on physical facilities hosting servers and switches. These physical facilities are generically referred to as data centres. They are rooms, buildings, or even groups of buildings that house computer systems and connecting/switching technologies. Data centres host one or more of the following functions, namely networking, cloud computing services, colocation and on-ramp clouds. Data centres are fundamental for Internet services for a variety of reasons, including that they contain routers and switches that transport traffic between the servers and the outside world; they allow switching from one network to another; they reduce latency for local access to content and services through MEC; and they enable large computing tasks or data storage through cloud services. In addition, colocation data centres allow different operators to peer with each other, reducing the need to use other parts of the infrastructure to connect different services, thereby reducing pressure on the available bandwidth.

Data centres can be classified in different ways. Given the infrastructure financing focus of this paper, it is interesting to identify three types of data centres, namely government-owned data centres, which are, for example, the facilities where government data are stored; private data centres, which are data centres owned by a certain carrier or ISPs; and carrier-neutral or network-neutral data centres, which allow interconnection between multiple telecommunication carriers and other companies. These are generally operated by a third party who acts as a landlord of the data centre space and rents it out to network carriers, content distributors, cloud providers and other users for colocation.

FIGURE 5: MAP OF DATA CENTRES HOSTED IN AFRICAN CITIES (AUTHORS' REPRESENTATION USING THE CLOUDSCENE DATABASE)

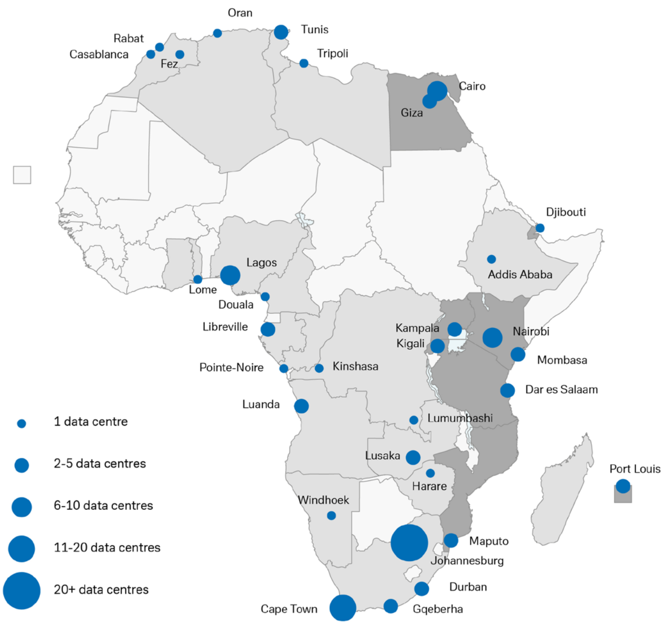
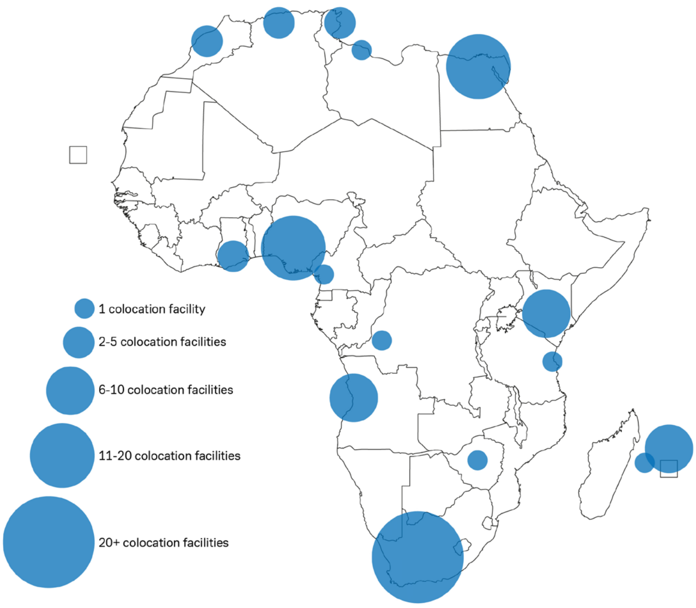


FIGURE 6: MAP OF COLOCATION FACILITIES BY COUNTRY (ADAPTED FROM: COLOCATION AFRICA – DATA CENTER MAP)



Without data centres, it would be impossible to meet the content and service demands on the continent. As elsewhere in the world, the number and computing capacity of data and colocation centres in Africa is increasing quickly, albeit unevenly. Figure 6 captures some of these unequal patterns of data hosting capacity. An uneven distribution across the continent can be seen, for example, with SA dominating in terms of capacity and Mauritius having an outsized number of colocation facilities compared to its size and population. In a few countries, namely in Egypt, Nigeria, Kenya and Morocco, there are larger concentrations of facilities compared to most of the countries on the continent. The concentration in cities where networked infrastructures are better developed can be seen in Figure 5. In fact, data centres depend on networked infrastructure, most importantly on the availability of reliable electric and fibre-optic grids.

2.4 Digital ecosystems

Digital ecosystems capture the software component of ICT investment in Africa. For the sake of this paper, the authors' loose definition of digital ecosystem reflects and expands the WB's definition of tech hubs (Kelly & Firestone, 2016). It includes government-driven smart city projects and services; digitisation projects in sectors such as public services and health; accelerators, incubators and similar digital business development programmes; seed capital, VC and other forms of early- and later-stage investment programmes in digital companies; digital companies and technology start-ups, working in fields such as Fintech, logistics, health-tech, ecommerce, civic tech, digital mobility, ed-tech and enterprise software; and sector organisations. Holistically, digital ecosystems are a socio-technical assemblage which captures a wide and diverse range of initiatives and organisations that produce the software of a particular ICT landscape (Nachira et al., 2007; Pollio, 2020; WEF, 2014).

In their latest mapping in collaboration with Briter Bridges, GSMA identified 618 tech hubs[8] in Africa, a notable growth to 442 in 2018 (GSMA, 2019). Of these tech hubs, the majority (52%) were either incubators or accelerators, with 25% being co-working spaces and 6% maker spaces. One of the features of this phenomenon is the emergence of tech cities (Table 1). According to the data, the top 10 cities account for more than 40% of the total number of tech hubs (GSMA, 2019). It should be noted that the concentration of tech start-ups and capital investments directed to them in cities is not an exclusively African phenomenon on the continent; however, only a handful of cities are producing start-ups that are capable of attracting significant international investment (Florida et al., 2017; StartupBlink, 2021).

TABLE 1: TECH CITIES RANKING ACCORDING TO GSMA, 2019 (GIULIANI & AJADI, 2019)

Tier 1 cities (more than 20 tech hubs)
Lagos, Cairo, Cape Town, Nairobi, Johannesburg
Tier 2 cities (more than 15 tech hubs)
Casablanca, Accra, Abidjan, Tunis, Abuja
Emerging cities (more than 10 tech hubs)
Dakar, Bamako, Kampala, Dar es Salaam, Lomé

[8] For Treisman (2017), for example, a tech hub specially creates structured programmes to foster digital start-ups. The GSMA mapping has a more encompassing definition, which includes co-working spaces, accelerators, incubators and maker spaces.

2.5 Programmes for expanding ICT access and convergence

Many development programmes include an ICT component. Some of these are global in nature, while others are regional. The following is a basic list of programmes that are aimed at addressing ICT backlogs in Africa. Refer to Annexure A for information on the institutional-led ICT content/objectives, programme finance and investment focus of the various programmes.

- SDGs: The UN's SDGs have several goals related to Internet access and tech-related skills development, of which the most important is Goal 9c.
- Agenda 2063: The AU's agenda includes three ICT programmes, including the Pan African e-Network, the Pan African Virtual and e-University and Cyber Security.
- PIDA: PIDA provides a common framework for African stakeholders to build infrastructure. A total of 144 ICT projects are listed on the PIDA dashboard. Notably, the PIDA IXP programme is aimed at improving the Internet exchange network in Africa by ensuring that there are adequate Internet exchanges on the continent.
- Broadband Commission for Sustainable Development: The UN advocacy group has seven targets, namely policy, affordability, connectivity, digital skills, digital financial services, connect MSMEs and gender equality.
- Smart Africa Alliance: Smart Africa Alliance is an agreement involving multiple African countries. Active projects include, but are not limited to a submarine cable system that connects countries across the continent alongside single country-led flagship projects.
- DTS: The DTS is aimed at driving digital transformation on the continent. This strategy includes various policy initiatives that support other AU programmes, including PIDA and Smart Africa.
- European Union–African Union Digital Economy Task Force (EU–AU DETF): The taskforce is focussed on digital ecosystems, but also supports universal access to broadband, upskilling citizens with a digital skillset, fostering a conducive business environment for digital entrepreneurship, and promoting e-Services and the development of the digital economy to achieve the SDGs. This is part of the broader Africa–EU partnership, with specific investment programmes for ICT.
- e-Africa programme: A programme of NEPAD, e-Africa has two programmes, namely the e-Schools initiative, which is aimed at enhancing learning via improved ICT and Internet access in schools, and ICT skills development; and the ICT Broadband Infrastructure Network programme, which is aimed at connecting all member nations via broadband.
- PRIDA: PRIDA encourages universal access to affordable broadband services in Africa through a robust set of policy interventions.
- African Internet Exchange System: The African Internet Exchange System is aimed at ensuring that local Internet traffic remains on the continent by facilitating the establishment of IXPs across the continent, as well as regional Internet hubs, and supporting regional Internet carriers.
- InfoDev: InfoDev is a multisectoral initiative focussed on entrepreneurship and innovation.
- DE4A: The DE4Africa initiative is aimed at boosting the digital capabilities of citizens, businesses and governments. The programme is an extension of the DTS for Africa.
- DSM for Africa: The DSM is an initiative supported by the DTS, which also aligns with Smart Africa Alliance's strategic vision.
- Digital Africa: Digital Africa is focussed on fostering digital technology entrepreneurs on the continent through a range of programmes.
- XL Africa: XL Africa is a WB commissioned project aimed at assisting start-ups in securing between 250 000 and US$1.5 million.
- mLabs: mLabs is a global initiative that is aimed at fostering digital entrepreneurship.

TABLE 2: EXAMPLES OF PROGRAMMES ACROSS THE VALUE CHAIN

	Multilateral	Government/ Bilateral	PPP	Private Sector
Hardwire broadband (cables)	EASSy is a system of submarine cables that run along the Eastern Coast of Africa from Sudan to SA. The submarine system is owned by African (92%) and international (8%) telecommunication companies, with the largest shareholder being the West Indian Ocean Cable Company (29%). However, this project relied on investments from a plethora of sources, including an estimated 30% of financing being from transnational DFIs, including the WB/IFC, EIB, AfDB, AFD, and KfW. Another 30% was financed by SA telecommunication companies, namely Telkom, Vodacom, MTN and Neotel.[1]	The Kenyan National Government entered into a bilateral agreement with the China's Exim Bank to finance NOFBI. The implementing arrangements include the Chinese Government (funding); the Ministry of ICT (oversight); ICT Authority (implementing agency); Huawei (building a national fibre-optic infrastructure) and Telkom Kenya (operations and maintenance). The investment extends fibre-optic cable connections across the 47 counties of Kenya. Phase 2 of the project has a budget of 7.91 billion Kenyan Shillings. [2]	SACS links Luanda, Angola, to Fortaleza, Brazil. The system is owned by Angola cables and is a consortium of five telecommunications companies, namely the State-owned Angola Telecom (51%), MSTelcom (9%), and private companies called Unitel (31%), Movicel (6%) and Startel (3%). The construction of the project is estimated to have cost US$278 million.[3]	Referred to as "Africa's largest subsea project", 2Africa connects 19 countries across the continent, five countries in Europe and two countries in the Middle East. It is funded by the partnership between several private companies, including China Mobile International, Facebook, MTN Global Connect, Orange, STC, Telecom Egypt, Vodafone and the West Indian Ocean Cable Company. Each partner will "own a share of the capacity delivered by the 2Africa system" with the construction of the infrastructure by Telecom Egypt and ASN. The project is estimated to cost just under US$1 billion.[4]
Mobile broadband (4G and 5G)	The EIB has partnered with Cabo Verde Telecom to expand 4G network coverage across the 10 islands of Cabo Verde. A US$25 million loan from the EIB will be used alongside the US$60 million investment by Cabo Verde Telecom.[5]	A Zambian project to improve the country's telecommunication infrastructure and mobile phone usage is funded via a loan of US$280 million from the Chinese government. The Chinese company, Huawei, are contracted to construct the necessary infrastructure.[6]	The Ethiopian government owned monopoly mobile operator, Ethio Telecom, in partnership with the company called Ericsson, a Swedish multinational networking and telecommunications company, which will expand 4G network coverage across the South West region of the country.[7] The financing arrangements of this PPP are not clear as they also involve Chinese private firms.	Kenya's largest telecoms operator, Safaricom, has introduced 5G network coverage to the country, beginning with four trial cities and towns, followed by an expansion across the country. Nokia and Huawei have been chosen as the two technology partners to implement the roll-out of Safaricom's 5G network.[8] Safaricom has not disclosed the value of this investment; however, it comes on the back of a skyrocketing revenue increase from the 2015 investments in 4G in Kenya.[9]
Data centre/ Internet exchanges	The PIDA IXP programme is aimed at improving the Internet exchange network in Africa by ensuring that there are adequate Internet exchanges on the continent to "[k]eep local traffic local". This includes implementing an Internet exchange in all countries, alongside regional Internet exchanges to deal with network traffic. This programme is based on the ongoing AXIS project funded by EU–Africa Infrastructure Trust Fund [10].	In an aim to strengthen its digital sovereignty, the Senegalese Government constructed its first national data centre powered by technology from Chinese company, Huawei. The government relied on a loan of 46 million CFA francs from the Chinese Government to finance the project [11].	The Konza National Data Centre and Smart City Facilities Project is a joint Kenyan Ministry of ICT and Huawei project. It includes the construction of the Tier III Konza National and Disaster Recovery data centres. The 17,5 billion Kenyan Shillings ($172.7 million) project is funded by Chinese concessional loans which are State-backed and is constructed by Chinese company, Huawei.[12] This example shows that PPP are often also part of bilateral programmes such as China's Belt & Road initiative.	SA company, Teraco, will construct their fourth data centre (and the seventh in the country), namely the JB4 facility in Johannesburg. They secured R2.5 billion in loan financing for the vendor-neutral data centre which is being referred to as Africa's largest single-site data centre. The project is funded by a combination of equity and debt-financing and relies on the companies' existing partnership with the SA banking institution, ABSA. The total cost of the project is R4 billion.[13]

	Multilateral	Government/ Bilateral	PPP	Private Sector
Digital ecosystems	XL Africa is a WB commissioned project to amplify "high-growth digital start-ups" with aims to assist start-ups in securing between 250 000 and US$1.5 million. The model of the programme is a "five-month post-accelerator programme" in which a chosen few businesses (20 out of 900 applicants) participate in mentoring and support before they pitch their business in front of a set of investors. [14].	The South African Commission on the Fourth Industrial Revolution produced a report that outlines and includes recommendations on various ICT-related strategies. These include fostering investment in technology start-ups by creating a conducive regulatory environment to encourage investment. It also encourages the deployment of technologies, digitisation being one such technology, which can increase efficiency in various sectors including the energy, water and health sectors.[15]	CiTi is a non-profit company and Africa's oldest tech incubator. The company is described as working "at the intersection of business, government, academia and society" and its partners include public institutions, namely the City of Cape Town, Wesgro, the Western Cape Government, the National Department of Trade and Industry, the National Treasury initiative - The Jobs Fund, MICTSETA, and private institutions, namely African Bank, The Innovator Trust, and McNulty Foundation. They have recently launched a project as part of the Women in Business project of the multinational corporation, CSG.[16]	Working across the African continent, Africarena is a tech accelerator that uses open innovation challenges to cultivate collaboration across the fields of "tech start-ups, corporations and investors". They rely on the support of a number of companies, including Amazon Web Services and BPI France. [17] Note: Some of the actors involved are State-owned, but act as private actors when operating in the African context.

** See Appendix 1 for all sources*

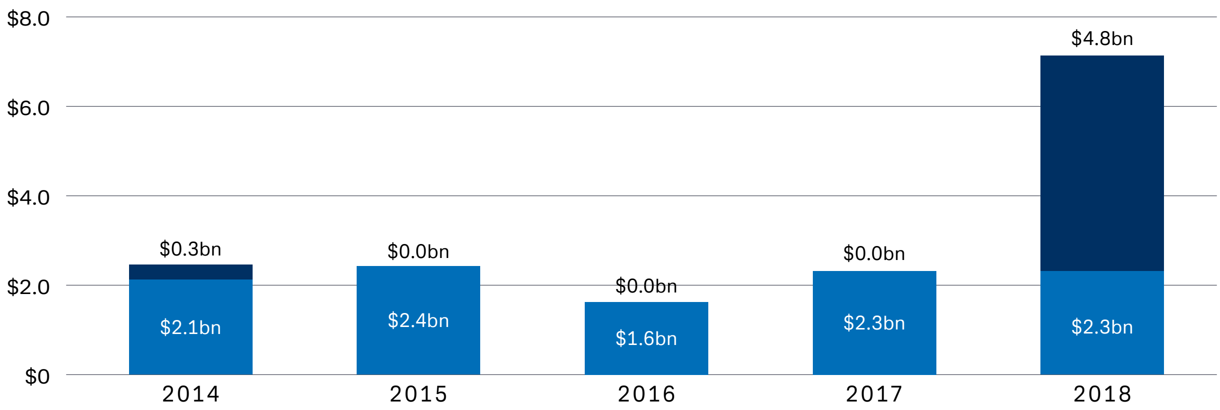
BOX 2: RWANDA'S ICT INFRASTRUCTURE

Whether referring to the SDGs or PIDA, the overarching assumption is that African states will take on these agendas and tailor, co-finance and implement them at country scale. Rwanda has been a champion for Internet connectivity in Africa. Starting in the early 2000s, the country began to invest rapidly in their ICT infrastructure, adopting the first of four rolling NICI policies and the 2020 Vision in 2020. Under NICI-I (2001-2005), the groundwork for the sector was established, developing legal and institutional structures to support investment. This included reducing the barriers for entry for telecommunication companies to improve competition and establishing the Rwanda Utilities Regulatory Agency, with the mandate for ICT. Led by the second plan, NICI-II (2005-2010), Rwanda developed national data centres. Under NICI-III (2010-2015), Rwanda completed the construction of more than 2 000 km of fibre-optic network linked to the undersea cables running along the East African Coast. As the country is landlocked, access to the coast is negotiated through agreements with Kenya, Uganda and Tanzania, allowing for access to cable links at Mombasa and Dar es Salaam. The project cost almost US$100 million. The fourth and the last five years, the NICI plan was evolved into the 2020 SRMP, developed with the support of UN Habitat (Rwanda Ministry of Information Technology and Communications, 2015). While the plan is national in scope and is aimed at supporting secondary city growth, the capital city of Kigali is by far the largest city, experiencing the most rapid technological change and investment. At the Transform Africa 2017 event in Kigali, Inmarsat, which is a leading global satellite organisation, signed an MOU with the Rwanda National Government and the Smart City Alliance in a pledge to transform Kigali into a smart city. To do this, Inmarsat, in partnership with Actility, created a Low Power Wide Area Network (using the LoRaWAN protocol) covering the entire city. They have also launched the Smart Cities Education Programme, which is aimed at developing skills in coding and digital literacy.

3 FINANCING AND INVESTMENT IN ICT AND DIGITAL INFRASTRUCTURE

In this section, the question of who is investing, how much and why is explored. Overall, the investment landscape of ICT projects in Africa has historically seen the involvement of national governments and DFIs across all stages of planning and implementation, with a tendency to fund large-scale infrastructure for broadband access and only more recently an involvement in smaller initiatives (AU, 2020). However, with the transformation of the ICT industry brought about by mobile phones, the number of actors involved has drastically increased, with the lion share played by telecom companies and other service providers. As evident in Chart 3, the investment trend for ICT infrastructure emanating from public sources, which does not include investment in the fourth component identified in this paper, has mostly been stable in recent years. However, regarding disaggregate data, while the overall amount has remained stable, the commitments of different players have oscillated. For example, African national governments' spending went from US$ 570 million in 2015, to almost 900 million in 2016, to 600 million again in 2017, and up to more than 1 billion in 2018. Similarly, the contribution of Chinese investment had oscillated between US$ 300 million to US$ 1 billion in the same years (ICA, 2018; 2019).

CHART 3: INVESTMENT IN ICT (BILLION, US$) (ICA, 2017B, 2018, 2019)



** Note that prior to 2018, private investments were not counted (calculated differently).*

The limit of this data point is that it does not include investment in the software ecosystem, which is a significant part of the picture. As an example, the footprint of Chinese investment is not limited to hardware infrastructure, but extends to mobile phones and other connected gadgets, with Transsion and Xiaomi being best-selling brands in Africa; and to software, with Transsnet's music and video platforms and Opera's browsing and news platforms being among the most downloaded applications on the continent. It is hard to quantify the footprint of initiatives in support of digital ecosystems, such as accelerators and SME funds. However, information is available on VC investment across the continent. Contrary to data on investment in hard infrastructure (ICA, 2018), VC equity investment in digital start-ups has grown almost exponentially in the last few years. Even 2020 saw a growth in the number of deals, despite a plunge in the total sum invested, in other words, more, but smaller deals on average (Partech Partners, 2021)[9].

[9] This might be for a number of reasons, namely that the authors did not have more recent data after 2018 from ICA, whereas secondly, VC data is more updated by industry associations, and thirdly, hard infra has a longer investment cycles and is, therefore, more difficult to quantify year on year.

Unlike other sectors, a large part of the investment in ICT is in the form of equity. However, debt and grants also feature, but to a lesser extent. As an example, in 2017, which is the last available data, investments emanating from DFIs and bilateral partners equity represented more than 52% of overall and loans 47.7%, compared to other sectors in which loans are the great majority, for example, with 94% in transport, 99% in water and sanitation, and 98% in energy (ICA, 2018). Table 3 provides a list of examples, showing how different actors, namely government, bilaterals, DFIs and private, are involved in all four components of the ICT chain, while Table 4 offers an overview of the main blended finance mechanism utilised in the delivery of ICT infrastructure.

TABLE 3: MAIN ACTORS INVOLVED IN THE FINANCING OF ICT INFRASTRUCTURE (ADAPTED FROM: WEF, 2018)

Actors	Types	Who do they invest?	Risk appetite
Private sector	Industry operators such as telecommunication companies and data centre companies.	Provide ICT services for a profit	Low
	Investment and commercial banks	Provide financing for ROI	Low
	Investment funds (VC, etc.)	Provide financing for ROI and grow capital	Variable
	Technology companies (Amazon, Alphabet, Meta, etc.)	Develop their own infrastructure, expand user base	Low-medium
	Philanthropic organisations	Address digital divide and other inequalities in access to ICT	Medium-high
PPP	Can take several different forms	Combine the goal of expanding access to ICT infrastructure and provide ICT services for a profit	Varies
Government/ Bilateral	National and subnational communication authorities, institutions	Economic development goals such as providing access to connectivity, and specific political goals such as developing sovereign ICT infrastructure, etc.	High
	Sovereign funds	Create economic development	Medium-high
	National development banks	Combine financing for ROI and economic development goals such as basic access to digital services for lower-income citizens	High
	Foreign development agencies and export credit agencies providing aid and other forms of development finance	Economic development goals and specific foreign policy goals	High
Multilateral	DFIs (AfDB, WB)	Economic development goals	High

TABLE 4: BLENDED FINANCE MODELS (ADAPTED FROM: WEF, 2018)

Blended finance mechanism	Description
Project bundling	ICT infrastructure projects can be bundled into dedicated investment vehicles or funds that reduce exposure to individual risks of geography or technology and enable smaller projects to attract capital from larger investors. The use of dedicated infrastructure funds has been increasing since their creation in the 1990s when they were often listed publicly. However, their use in ICT has been limited. As an example, only 3% of all deals undertaken by infrastructure funds in Asia from 2010 through 2015 involved telecommunications, compared with 44% involving energy, 22% utilities and 16% transportation.
Securitisation mechanisms	Securitisation mechanisms, such as social bonds, have a similar risk mitigation effect as bundling mechanisms and are often given advantageous tax treatment by governments because of their positive social impact. The Social Bond Programme of the IFC is one such example. The IFC, part of the WBG, collects money from investors through the bond issue and invests in eligible projects through financial intermediaries. Over its fiscal years 2015 and 2016, the IFC invested US$255 million in the telecommunications, media and technology sectors, accounting for 12% of programme commitments.
Multistakeholder funds	Infrastructure investment can also emanate from financing vehicles involving multiple parties across sectors. The European Commission, together with the EIB, has launched a project bond initiative to raise capital for large infrastructure projects in the ICT, transportation and energy sectors. The goal is to help infrastructure projects attract institutional investors, such as insurance companies and pension funds, by providing the projects with credit enhancement in the form of senior debt. Other examples include the Global Fund, an international financing organisation started with seed capital from the Bill & Melinda Gates Foundation and originally targeting global health needs, which is being considered as a model for addressing other SDGs.
Co-investment vehicles	These mechanisms allow network operators to solicit funds from other players when expanding and upgrading infrastructure, which attracts financing and diversifies risk. For instance, the Mobile Solutions Technical Assistance and Research project, funded by the U.S. Agency for International Development (USAID), offers a service that helps network operators attract project-based co-investment from other entities without regard for the sector but specifically favouring private sector investment.
Risk guarantees	These contracts can be either on their own or part of broader blended finance arrangements. Risk guarantees have been shown to address major risk elements that inhibit private investors, enabling capital to flow more directly to underserved regions and populations. The use of risk guarantees in blended financing arrangements can be facilitated by making benchmarks on costs associated with infrastructure projects publicly available, thereby demystifying the process for capital providers, and sharing success stories to promote best practices and models for cooperation.
Infrastructure marketplaces	Infrastructure marketplaces, such as the SDIP run by the WEF and the OECD, bring together infrastructure project owners, investors, public sector actors and other stakeholders to share information, discuss potential investments and arrive at blended financing arrangements for projects that have a demonstrated impact. Though such marketplaces have gained traction for transportation and energy infrastructure projects, they have yet to expand into ICY.

3.1 Hardwired broadband

As explained earlier, hardwired broadband can further be divided into access to international bandwidth (in other words, submarine cables) and local/national optic cable infrastructure, which delivers Internet services to the last mile user. Focussing on submarine cables, the investment landscape is dominated by international consortia, which are often conglomerates of tech companies, ISPs, telecom operators, content providers, a few large telecommunication companies that own their own Internet infrastructure (so-called Tier 1 ISPs), and, less frequently, national governments. In practice, two models coexist, namely 1) large operators owning their own infrastructure, and wholesale operators allowing others to use the infrastructure in exchange for a transit fee. These contracts are usually undisclosed. The vendor landscape is also dominated by a small number of companies that sell the infrastructure components and a few contractors that have the capacity to build such undersea connections. It is evident in Table 5 that most cables that have a 20Tbps+ capacity in Africa have been built by a handful of companies. In terms of growth, the undersea cable market is accelerating quickly despite the huge upfront capex necessary for these infrastructures (Telegeography, 2021). Demand growth is driven by major content and cloud service providers, namely Alphabet, Meta, Amazon and Microsoft.

TABLE 5: CABLES WITH CAPACITY OF MORE THAN 20 TBPS (ACTIVE AND PLANNED)

Name	Tbps	Year	African countries served	Investors
SAIL	32	2018	Cameroon	The SAIL cable system is invested by CAMTEL of Cameroon, and China Unicom as the landing party in Brazil, Huawei Marine is the turn-key solutions provider for the SAIL cable system.
SACS	40	2018	Angola	Funded by Angola Cables, a consortium of major Angolan telecoms companies, namely Angola Telecom with 51% of the capital, Unitel with 31%, MSTelcom with 9%, Movicel with 6%, and Startel with 3%
EllaLink	100	2021	Cabo Verde (in the future, Mauritania, Morocco)	The majority shareholder is an infrastructure fund called Marguerite. The supply contract was awarded to ASN.
Equiano	100	2021	Nigeria, SA, Namibia	Funded by Google, built by ASN. It has several other branching units to potentially connect other countries on the West Coast of Africa.
SEA-ME-WE 5 – South East Asia–Middle East–Western Europe 5	24	2016	Djibouti, Egypt	The 19 SEA-ME-WE 5 member companies include Bangladesh Submarine Cable Company Limited (BSCCL), China Mobile International (CMI), China Telecom Global (CTG), China United Network Communications Group Company Limited (CU), Djibouti Telecom, Emirates Integrated Telecommunications Company (du), Myanmar Post and Telecom (MPT), Ooredoo, Orange, PT Telekomunikasi Indonesia International (Telin), Saudi Telecom Company (STC), Singapore Telecommunications Ltd (Singtel), Sparkle, Sri Lanka Telecom PLC (SLT), Telecom Egypt (TE), Telekom Malaysia Berhad (TM), TeleYemen, Turk Telekom International (TTI) and Trans World Associates (Pvt) Limited Pakistan (TWA).
AAE-1 -Asia-Africa–Europe 1	40	2017	Djibouti, Egypt	China Unicom initiated the AAE-1 cable project in 2011 with the support and partnership from Telecom Egypt. The AAE-1 consortium, which obtained the construction and maintenance contract in 2014, comprises more than 17 carriers, including British Telecom, China Unicom, Djibouti Telecom, Etisalat, Global Transit, HyalRoute, Jio, Metfone, Mobily, Omantel, Ooredoo, Oteglobe, PCCW Global, PTCL, Retelit, Telecom Egypt, TeleYemen, TOT, VNPT and Viettel.
METISS-MEltingpoT Indianoceanic Submarine System	24	2021	Madagascar, Mauritius, SA	The METISS consortium comprises Canal+ Télécom, CEB Fibernet, Emtel, Zeop, and SRR (SFR) Telma. The METISS consortium has contracted Liquid Telecom to act as the Landing Party in SA, responsible for the installation of the terrestrial component of the METISS cable system and the operational aspects of the system in SA.
DARE1 – Djibouti Africa Regional Express	36	2021	Djibouti, Kenya, Somalia	A new submarine cable that connects Djibouti, Somalia and Kenya is now active after more than five years of work. A total of 4 900 km long, it is equipped with the latest generation of optical fibre. The consortium behind the project brings together Djibouti Telecom, Somtel, Hormuud Telecom and Telkom Kenya. They have invested more than US$81 million.
PEACE - Pakistan & East Africa Connecting Europe	60	2021	Djibouti, Egypt, Kenya, Somalia, the Seychelles, SA	PEACE is privately owned and invested by PEACE Cable International Network Co. Limited, a subsidiary of China-based HENGTONG Group and supplied by Huawei Marine.

2Africa	180	2023	Angola, Cabo Verde, Comoros, Congo, Djibouti, the Congo, Egypt, Gabon, Ghana, the Ivory Coast, Kenya, Madagascar, Mozambique, Nigeria, Senegal, SA, Somalia, Sudan, Tanzania	China Mobile International, Facebook, MTN GlobalConnect, Orange, STC, Telecom Egypt, Vodafone and WIOCC announced today that they will partner to build 2Africa, which will be the most comprehensive subsea cable to serve the African continent and Middle East region. The parties have appointed ASN to build the cable in a fully funded project, which will greatly enhance connectivity across Africa and the Middle East.v
LiquidSea	30	2018	Djibouti, Egypt, Kenya, Mozambique, SA, Tanzania	Liquid Telecom. Not much information is available about this cable.
IOX – Indian Ocean Xchange	54	2019	Mauritius, SA	Indian Ocean Xchange Ltd. The 8 890 km IOX cable system, being built by ASN, will provide customers and partners with a new open-access alternative path for connecting Africa, Asia and onwards to Europe and the USA.
SAEX-1 – South Atlantic Express	108	2021	SA, St. Helena	According to the website, SAEX is a Mauritius-based company owned by a South African subsidiary. Listed partners include Italy's Sparkle, US's ACA International LLC, and Nokia's ASN.
SAEX-2 – South Asia Express	108	2021	Mauritius, SA	According to the website, SAEX is a Mauritius-based company owned by a South African subsidiary. Listed partners include Italy's Sparkle, US's ACA International LLC, and Nokia's ASN.

Regarding local/national optic cable infrastructure, according to the Internet Society (2018)[10], at least four different financing models can be identified in terms of stakeholders involved. These are outlined in Table 6 below.

TABLE 6: UNDERGROUND FIBRE-OPTIC CABLES FINANCING MODEL TAXONOMY BASED ON ACTORS INVOLVED (ADAPTED FROM: INTERNET SOCIETY, 2018)

Model	Example
Operator-driven model: Each telecommunication operator develops its own fibre-optic network	In SA, telecommunication operators with sufficient financial capacity have developed their own fibre networks. Some operate at a national scale, while others only have urban networks so far.
Cooperative model: Operators agree to share the cost of deploying fibre backbone	The BBS is a partnership between different operators in the country to share a national backbone on an open-access basis. BBS is a joint venture between the Government of Burundi and five ISPs. The project involved the creation of a 1 250 km fibre-optic backbone connecting all 17 provinces and cross-border connections for access to the landing points of international submarine cables in Mombasa and Dar es Salaam.
Government-led model: Government institution that funds the implementation of fibre-optic infrastructure	In Rwanda, the government built a national fibre-optic backbone financed in part, from the sale of the incumbent operator. It later created a PPP to manage the asset (see case study above).
Wholesale model: Carrier-neutral operator that bears the cost of developing the fibre network and then leases to other operators	Liquid Telecom, a Pan-Africa telecommunication group, has one of the continent's largest fibre backbones stretching from SA to Uganda. They also have capacity on five submarine cables. Their network connects LLDCs in Botswana, Lesotho, Rwanda, Uganda, Zambia and Zimbabwe.
Regional approach: Fibre networks can also be developed as an international partnership between different nations, with financing often coming from DFIs, as is the case of the terrestrial fibre corridors funded in the PIDA programme	The Bissau–Conakry Fibre-Optic Link is an under-construction terrestrial cable connecting the capitals of Guinea and Guinea-Bissau with a 10 Mbps capacity. Funded under PIDA, partners include the ECOWAS–CEDEAO, the WARCIP, and Guinea's Ministry of Telecommunication and Digital Economy.

[10] This taxonomy has specifically been developed by the Internet Society (2018) for landlocked countries, but it can also apply to landlocked areas of countries with sea access.

3.2 Mobile broadband

Mobile broadband investment in Africa, as elsewhere, is dominated by telecom operators, either private or government owned, and other private sector companies, namely network operators, ISPs, tower builders and equipment vendors. Governments and DFIs have played a relatively smaller role compared to investment in other infrastructure sectors (WEF, 2018). One of the reasons for the heavier involvement of the private sector has, at least initially, been a good ARPU, which is the revenue generated by adding a single user to the grid. This has produced uneven patterns of access, with rural and urban areas experiencing different levels of mobile broadband penetration, as discussed earlier. Today, with Africa having one of the lowest ARPUs in the world, further investment in network expansion and upgrading driven by commercial goals has significantly slowed down (WEF, 2018).

This, in turn, means that sovereign funds, national development banks and multilateral DFIs will have a bigger role to play in the financing of developmental mobile broadband for projects, upgrades and expansions that do not meet bankability criteria exclusively based on ROIs. To date, for most investments carried out by telecom operators and for network operators, access to capital is provided by commercial banks through loans and other credit services, or by other institutional investors. Unlike hardwired broadband where government and DFIs are more involved in the financing itself, regarding mobile broadband national governments have mostly played a regulatory role, limiting their intervention to managing and leasing network frequencies to operators with obvious exceptions in planned economies such as Angola and Ethiopia. Table 7 offers a broad perspective on the main actors involved in the realisation of mobile infrastructure, with the caveat that other actors exist and are not listed, such as international regulatory and standardisation authorities, for example, the ITU.

TABLE 7: MAIN ACTORS INVOLVED IN MOBILE BROADBAND INVESTMENT (AUTHORS' REPRESENTATION)

Actor	Actors	Role
Private	Telecom operators	They build the infrastructure and use it to provide connectivity services. They might lease part of the infrastructure to other operators.
	Network operators	They build the infrastructure and lease it to third-party operators, such as telecom operators, etc.
	Equipment vendors	Sell necessary hardware and related services for the deployment or update of mobile broadband infrastructure. In trials, these companies might provide in-kind capital.
	Banks	Provide loans and other credit services for the deployment of mobile broadband
	Investors	Provide capital investment for the deployment of mobile broadband
Government	State-owned telecom operators	They build the infrastructure and use it to provide connectivity services. They might lease part of the infrastructure to other operators.
	State regulators	They regulate and make frequencies available to operators upon payment of a fee
	Sovereign funds and development banks	They provide loans and other credit services to deploy connectivity services in remote and rural areas where mobile broadband would not be a bankable project. They might provide catalytic finance to support private operators.

Multilateral/ Bilateral	Development institutions and credit export agencies	They provide loans and other credit services to deploy connectivity services in remote and rural areas where mobile broadband would not be a bankable project. They might provide catalytic finance to support private operators.

There are three important factors to note about the investment picture for mobile broadband. First, part of the current infrastructure is becoming obsolete (the 2G network). Nonetheless, mass adoption of mobile 5G is not imminent. In many parts of Africa, the focus in the near term for operators and other stakeholders will be to increase 4G uptake, which remains relatively low or unused (GSMA, 2020). However, 5G trials have been conducted in various countries, with 5G networks having been deployed in a few of them. Secondly, demand for increased mobile broadband depends on a few external factors, for example, the presence of hardwired broadband, which is a bottleneck for the deployment of 5G, but also, importantly, the data demand generated by mobile phone users. With the majority of affordable phones only functioning with relatively small data needs, the market demand for increased mobile broadband is low. Moreover, the current price for 5G-enabled phones is much higher than for earlier generation handsets. Therefore, what is likely to happen in terms of the investment landscape is innovation in the Fintech sector for subscription and financing solutions, for example, pay-as-you-go, for users to upgrade their handsets in a market that is currently dominated by the prepaid model (GSMA, 2020). Lastly, and given this combination of low demand and supply-driven investment, new models of network sharing and ownership are emerging, for example, tower companies leasing their network to telecom operators, as well as innovative financing models, in which the equipment vendors become shareholders of the infrastructure and enter a revenue-sharing arrangement with the operators (GSMA, 2020).

3.3 Data centre-enabled cloud and colocation services

The investment landscape for data centre construction in Africa can be broken down into the three types identified in Section 2, namely government or national data centres; data centres owned by telecom operators and ISPs, in other words, non-carrier neutral; and data centres with neutral colocation. These three types of data centres involve different types of investment, given that the actors involved and the needs they address are different.

Government-owned data centres are sites designed to host national data ecosystems, from biometric and health data to smart city solutions, and to create back-ups of important digitised information. Given the public mandate of these data centres, they are usually funded through public finance, which means that they might be supported by multilateral and bilateral lenders. A case in point of this type of data centre is Senegal's National Data Centre where funding came through a Chinese loan linked to the facility being built by and equipped with Huawei hardware. Currently under construction, the facility will be managed by Senegal's State ICT firm called the State Informatics Agency (ADIE). Funding for these government facilities, however, might not directly go to the construction, but serve some specific aspect of data management, such as security. Another example is Tanzania's Electronic Single Window System (TESWs), for which a bid from the AfDB has been published to complete the data centre for the first stage of the project. Furthermore, the other two types of data centres, namely telecom data centres (in other words, facilities owned and operated by a telecommunications or service provider company); and colocation data centres (in other words, carrier-neutral multi-tenant facilities, can be funded by development finance). One example is the US$300 million loan provided by the US through the International Development Finance Corporation (IFC) to Zimbabwe's Liquid Telecom's Africa Data Centres to fund infrastructure expansion in SA and Kenya. However, most data centres are privately funded either through self-raised funds or through financing from commercial banks. One example is the R2.5 billion loan transaction led by ABSA, along with several other partners, and earmarked for the construction of a 38 MW hyperscale data centre in Ekurhuleni, east of Johannesburg, by colocation company Teraco. In general terms, the investment picture shows a very dynamic growth, given that Africa's hosting capacity is still small, with less than 1% of the colocation data capacity being available globally (ADCA, 2020). Especially with new data needs brought about by the Covid-19 pandemic, the pace of new facility construction has accelerated, with statistics showing that available supply doubled in 2020 from 2019 levels (ADCA, 2020). This demand is sustained by the expansion of global content providers into Africa (for example Facebook and Netflix); global cloud providers (for example, Microsoft Azure and Amazon AWS); and content delivery networks (for example, Cloudfare), showing that large private corporations currently catalyse the growth. In more general terms, the financing landscape is dominated by specialised colocation companies (private) or by telecom operators (private or public, for example, Safaricom, Ethiotelecon, etc.), and by equipment vendors, of which the most important are Chinese technology companies such as Huawei and ZTE.

Despite the growth, important issues of financing remain, especially if one considers the uneven distribution of data capacity. One of the bottlenecks, for example, is the availability of hardwired broadband, upon which remote data storage and computing depend. Therefore, for countries lagging behind in terms of broadband, the financing of data centre hosting is difficult. Another bottleneck is the demand for streaming and cloud computing, so access to affordable connections and a mature digital ecosystem is necessary to make data centres financially sustainable. In countries where this is not the case, for whatever reason, data centre construction does not provide a sufficient investment rationale and, therefore, this uneven distribution in hosting capacity can be seen between nations and within nations, and between larger cities and smaller towns (see paragraph 3.1). The feasibility of a data centre is also dependent on the availability and reliability of energy supply. Lastly, neutral colocation is also only possible in countries that have a liberalised approach to the management of Internet access. If this is not the case, data centre companies have notable barriers to access the market.

3.4 Digital ecosystems

Investment in digital ecosystems can be broken down in different ways. First, a distinction should be made between investments directed to national/local ecosystems as a whole; investments directed to specific initiatives, which can be local or continent-wide and investments directed to single tech start-ups or tech companies (Table 8). In the examples provided in the table, it is evident that the rationale for investing can be profit-driven (as in the case of venture funds), developmental (as in the case of national and local government supporting digital entrepreneurial ecosystems), innovation-driven (as in the case of university-based incubators and national science programmes) and philanthropic (as in the case of accelerator programmes dedicated to social enterprises and digital NGOs) (ITC, 2020).

TABLE 8: EXAMPLES OF INVESTMENT IN DIGITAL ECOSYSTEMS

Scale	Types	Examples	Who is "investing"?
National/Local ecosystems as a whole	Nation-wide SMEs and digital start-up support programmes	SA SME fund for digital start-ups 2019, Start-up Uganda, etc.	National governments, national ICT authorities, industry associations
	City-based initiatives	Silicon Cape initiative in Cape Town, Lagos Angel Network, etc.	Local governments, industry associations
Single initiatives	Local accelerator programmes, incubators, etc.	iHub Nairobi, Naspers Foundry in Cape Town, MEST Incubator Lagos, LaunchLab at Stellenbosch University in SA	Investment funds, philanthropic donors, corporations, DFIs, universities, etc.
	Continent-wide accelerators, regional start-up competitions	Africa's Business Heroes, Africarena, Starupbootcamp Afritech, Africa XL, etc.	Investment funds, philanthropic donors, corporations, DFIs
Single companies/ Start-ups	Company-specific seed investments, VC investments, grants, growth-stage investments, etc.	Future Africa (venture fund based in Nigeria), Algebra Ventures (Egypt)	Investment funds, philanthropic funds, universities, corporate investors, etc.

Digital ecosystems receive financial and in-kind support through a number of different investment mechanisms, the first of which is SME funds. These funds usually operate at the scale of a single country and are directed to a variety of companies, not only digital ones. However, many SME funds play an important role in financing digital ecosystems, given that the majority of companies that are part of these ecosystems are SMEs. SME funds can either be funded by public finance or by private funds. In SA, for example, the SA SME Fund is participated by more than 50 listed companies and by PIC, an asset management firm wholly owned by the government. Other national SME funds instead receive loans from DFI, such as the AfDB, for example through its EPSA for Africa initiative. SME funds, therefore, have a variety of different structures and use different investment vehicles, from grants to equity.

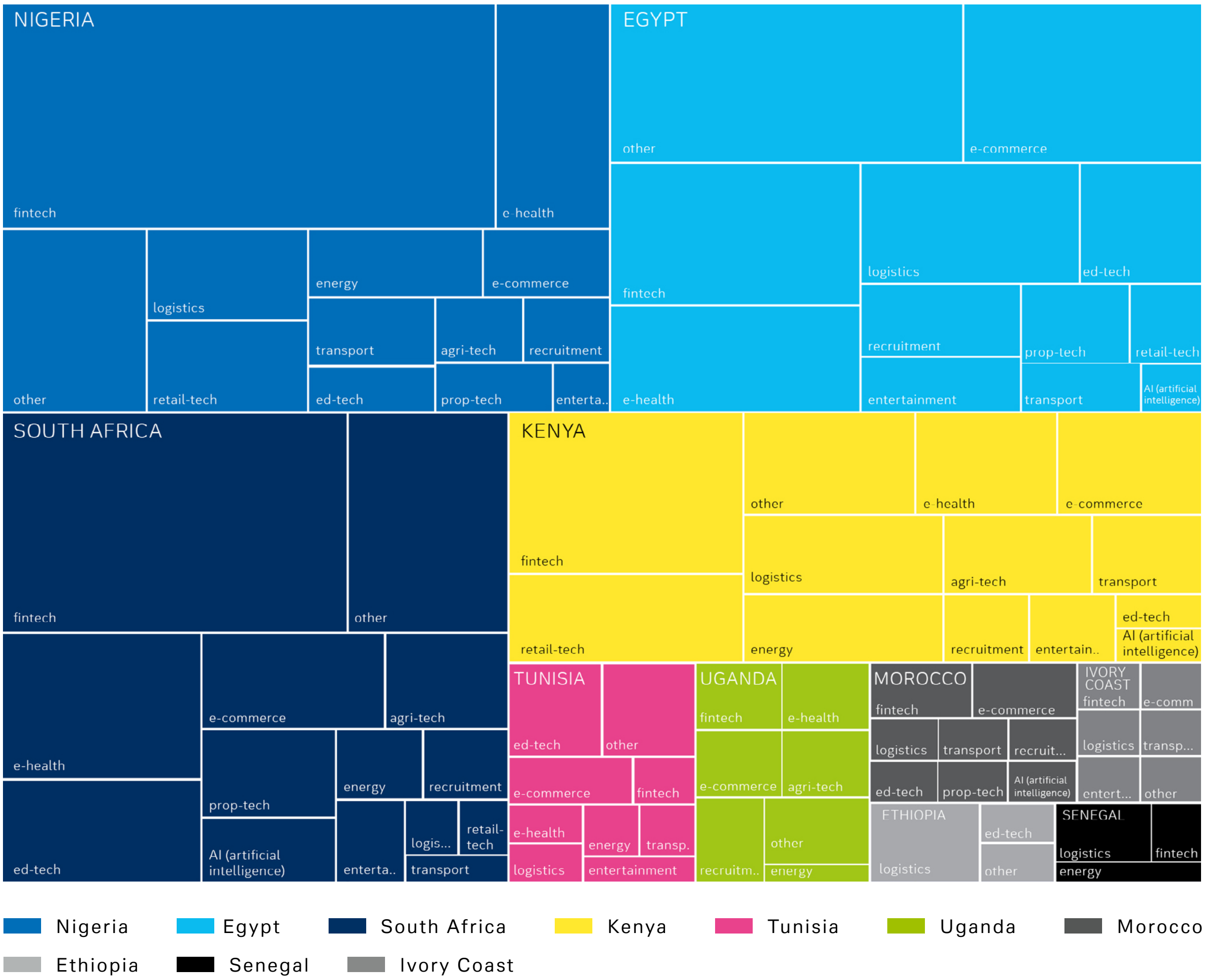
Another model is the start-up accelerator. An accelerator is an entrepreneurial programme for high-growth start-ups that receive training and mentorship to achieve investment readiness. At the end of an acceleration programme, start-ups may receive funding from investors, especially venture capitalists and other high-risk funds. Different typologies of accelerators exist across the continent. First, there are local accelerators and Africa-wide ones. Then there are horizontal and vertical programmes, in other words, programmes that accept any kind of digital start-up and programmes dedicated to specific sectors, such as Fintech and Agritech. This is the case for corporate-sponsored accelerators, which usually select companies aligned to the strategic priorities of the sponsor. Innovation-driven accelerators are usually hosted in universities or other research institutions. Finally, there are philanthropic and non-profit acceleration programmes for ICT social enterprises and other non-profit entities. A recent report by Afrilabs (2019), which is an Africa-wide network of incubators and accelerators, for example, shows that start-up hubs, in other words, accelerators, incubators, coworking spaces and maker spaces, are funded by a very diverse array of donors, DFIs, governments, NGOs and corporations, among others.

Linked to the accelerators model is the VC financing model. VCs are investment vehicles that are usually private and directed to the early-stage funding of digital start-ups with high-growth potential. In this sense, VC is one form of many different early-stage investment alternatives, from angel investing, crowdfunding, to other seed funding options for companies that are too small or too young to raise capital in the public markets, for example, bonds, or through commercial debt, for example, a bank loan. Many forms of early-stage investment and seed funding are not technically VCs. They are often grants provided by SME funds, philanthropic institutions or other private investors, for example, through a corporate-backed accelerator. In 2018, data from Afrilabs show that only 30% of funding in their Africa-wide start-up cohort was channelled through equity investment, with the majority being in-kind, non-equity and grants (Afrilabs, 2019). However, the high visibility of VC has made it a litmus test to understand investment patterns in start-up ecosystems in Africa.

Although the seed investment picture is much broader than VC, only continent-wide VC data exists. Not much is known about other forms of investment. In terms of VC, a few patterns arise. First, the growth of this investment vehicle, with 46% over the last five years vs 8% globally even though the African share of global VC remains very small overall. Secondly, the concentration in a handful of countries (BCG, 2021). Thirdly, the preference for a few sectors, namely Fintech, e-commerce, private health, Agritech, energy and logistics (Chart 4).

One last trend is the combination of investment in digital ecosystem and hard infrastructure, for example, through tech parks and greenfield smart city projects. A few examples are the Rwanda KIC, which is aimed at creating synergies between multinational technology firms, higher education institutions and local start-ups, the Ethiopia EthioICT-Village, featuring a data centre and an incubator for digital start-ups, as well as high-speed fibre-optic connectivity and reliable electricity, and the under-construction Konza Technopolis, a key flagship project of Kenya's Vision 2030 combining investment in digital infrastructure and a number of research and start-up facilities.

CHART 4: NUMBER OF FUNDED START-UPS BY COUNTRY, SECTOR AND NUMBER OF START-UPS IN 2019-2020 (TOP 10 COUNTRIES) (ADAPTED FROM DISRUPT AFRICA 2020)



4 DEBATES ABOUT SUSTAINABILITY ISSUES AND TRADE-OFFS

This section outlines several key areas where debates in the ICT and digital infrastructure sector have identified issues related to sustainability. These areas provide a scaffold onto which more sustainable investments might be measured and begs critical questions to be asked about the relationship between the financing of ICT infrastructure and the address of key sustainability issues. As an example, the following question must be asked: Does the current financing arrangements exacerbate or enable the address of any of the below sustainability issues?

4.1 Development potential and the digital divide

The developmental potential of ICT is not only related to the accessibility of these services, but also to the use of ICT for innovative service delivery models that can extend the reach and efficacy of other important services. Innovations in urban utilities such as water or energy, for example, can be linked to improved accountability in elections and other democratic processes. The possibility of innovation that is meaningful and responsive to social needs, however, rests on specific conditions, for example, according to ICA (2017a:29), "high-data rate connectivity (for example, between the "things" or users and cloud computing servers), ultra-low latency (for example, for robotics control applications in next-generation factories) and data security and privacy (for example, user profiling or industrial data) are critical to the development of innovative services".

The digital divide, as discussed in previous sections, engages with the issues of access and its uneven geographic distribution. Access, in this context, reflects a combination of factors, such as the affordability of mobile phones or data, and the speed and consistency of these affordable connections, and the restrictions placed on content, for example, by governments (BC, 2016). Many proposals are on the table regarding how to ensure that broadband is more affordable, consistent, fast and 'free'. Within this, there is considerable debate regarding the regulation/privatisation of the ICT sector, which has proven to reduce costs and the tendency to 'block' content in comparison to large government-owned monopolies; however, there are still many debates about the extent to which this privatisation will attend to other pressing issues related to sustainability in the sector (for example, the extent to which local technologies and supply chains can be encouraged or the negative effects of e-waste) and the issue that rural and poorer areas will continue to lag behind if investment is entirely driven by profit considerations.

> *Unfortunately, COVID-19 has further exacerbated the price gap between advanced and basic mobile devices, also increasing the complexity of the digital divide issue in Africa. Costs for 4G devices have skyrocketed as the demand for electronic components rapidly rose. Logistics issues caused by the pandemic (scarcity of flights and rising logistics costs) also contributed to the rising costs of 4G devices, making those products less accessible for the mass market in Africa (Vodafone, 2021:8).*

While the backlog in investment to bridge the financing gap requires significant investment (for example, calculated at US$139 billion by 2030), addressing the digital divide requires more than supply-driven solutions, as digital literacy, in other words, the capacity to use digital tools to their full opportunities, is fundamental (Global Infrastructure Hub, 2022). With uneven literacy patterns, there are gender-based and class-based divides that are also important questions of the social sustainability of ICT investment (GSMA, 2018). As an example, the gender gap in ownership and use of digital technologies is regarded as one of the crucial bottlenecks for more just and sustainable ICT infrastructure delivery.

4.2 Ecological costs and risks

It has been well established that sustainable digitisation requires sustainable energy production. Access to electricity is essential for all aspects of the digital/ICT value chain (BC, 2016). According to ICA (2017a:65), "[d]igitalization can contribute to GHG [greenhouse gases] emissions, through the energy consumption involved in the lifecycle of digital infrastructure as well as the production, use and disposal of digital products and services". For this reason, the nature and distribution of electricity are important for the long-term sustainability of these infrastructure systems.

Regarding the ICT sector, a paradoxical relationship exists between the energy supply needed to enable digital communication and services. Beyond the fact that the ICT industry is energy-intensive and that power supply is one of the obstacles to investment in upgrading the connectivity capacity of African nations, the presence of intermittent black-outs is one of the investment rationales to have more data centres that host content locally, so that interruptions in power supply do not correspond to interruption in the availability of Internet content. It has been calculated that running the Internet globally currently requires a similar carbon footprint than the entire pre-Covid-19 air travel industry (The Shift Project, 2019). Investment in energy start-ups that provide alternative solutions to grid-based energy supply is also driven by the continent's patchy power infrastructure.

Linked to the energy issue, the materials used for handsets, batteries and other key technologies associated with digitisation, ICT and renewable energy generation form part of long, environmentally costly and extractive supply chains. In a 2021 policy brief produced by the WB on transforming extractive industries, the authors point out that "[t]he production of minerals such as cobalt, graphite and lithium could increase by nearly 500 per cent by 2050" in response to the demands of ICT sectors (WB 2020:12). Lithium and cobalt are most often associated with batteries, copper and platinum which are used in most digital devices. SA produces almost 70% of the world's platinum. SA, Zambia and the DRC lead in copper mining. Cobalt, another key component of small batteries, remains linked to child labour, despite efforts of the international community to have a more just supply chain. While many countries in Africa rely on extractive industries for economic development, the environmental and social costs are many, including heavy metal contamination of water and soil, and human rights abuses in mines.

Ecological issues feature along all parts of the supply chain. Not only is it important to think about how the technologies that support digitalisation are produced, but also how they are disposed of. "ICT drives e-waste … By 2021 the annual total volume of e-waste is expected to surpass 52 million tonnes … electronics end up in landfills in countries in the global south" (EEB, 2020:3). Electronic waste (e-waste) refers to obsolete electric and electronic equipment, which may be toxic and requires careful disposal. As the digital sector is iterating rapidly, rate of growth of e-waste is particularly high as technologies become obsolete quickly and are updated regularly. Notably, a higher proportion of e-waste is traded and disposed of informally or illegally in African countries owing to a range of structural, economic and regulatory factors (ICA, 2017a).

Finally, there are also critical climate risks. As ICT is a rapidly evolving sector, some of the climate risks associated to this infrastructure have been poorly assessed or documented. This is particularly true because of the rapid technological transformation in the sector, impacting the ability of actuarial scientists to track and document the frequency and severity of climate hazards and vulnerabilities across the full value chain (BC, 2016). Notably, the shorter lifecycle of ICT infrastructure allows for rapid iteration with fewer sunk costs. As with all infrastructure, acute and longer-term climate-related risks require redundancy and the ability to respond rapidly (BC, 2016). To address climate risks and ensure services that are affordable and of high quality, emergent cost-saving and resilience-enhancing innovations and technologies should be incorporated incrementally.

4.3 Data sovereignty and personal data protection

ICT infrastructure and ecosystems are ultimately systems that produce and allow the mobility of digital data. This raises issues of data sovereignty and personal data protection, as well as of cybersecurity. While these are very complicated matters of national security and geopolitical relations between African states and their partners, they are also key sustainability questions as it is more and more evident that it is very difficult to retrofit digital infrastructure to make sure that it embeds the right kinds of protection. These kinds of protection, therefore, need to be considered at the very first stage of the design and the investment cycle, and not as afterthoughts.

Data sovereignty is the idea that data should be subject to the laws of the country in which the data are collected (ADCA, 2020). This is particularly important as data are produced and often owned by international content providers who might not be based in the same country where data are produced, and because international technology companies are active at all levels of the supply chain, from undersea cables to data centres and investments in Fintech start-ups. Linked to the notion of data sovereignty is the idea of personal data protection or data privacy, which concerns the access, use and transfer of personal data, be it biometric, financial or otherwise. It is not a secret that global technology companies provide their services free of charge in exchange for access to personal data for advertising purposes. Neither is it a secret that governments across the world have used their sovereign power to access personal data. However, while there is a general consensus that a rights-based approach to digital data is needed, the way to achieve this is very much debated, with very different approaches exemplified by the US, namely multistakeholderism, and China, multilateralism (Gagliardone, 2019).

An African Union Convention on Cyber Security and Personal Data Protection was drafted in 2011 and adopted in June 2014. In the Convention, not only is personal data protection addressed, but also Africa-based electronic transactions and cybersecurity. However, as of 2020, the Convention is only ratified by 8 out of 55 AU members, while 14 more countries have signed it, but have not ratified it (AU, 2020b). Given this vacuum and the fact that, as of today, at the national level only 28 countries (approximately 50% of the total in Africa) have personal data protection legislation in force, the AU launched the Internet Security Infrastructure Guidelines for Africa, in partnership with the Internet Society, to facilitate the implementation of the Convention (UNCTAD, 2021). These guidelines provide guidance for actions to be taken by the AU (in other words, the creation of an Africa-wide Cybersecurity Committee), by national governments, and by private companies and operators. The implementation of these guidelines, as well as the broader Convention, will, therefore, require additional investment of significant financial resources by all actors identified in this paper.

4.4 The future of employment and work

There are several important sustainability concerns related to work and the ICT/digitisation growth in Africa. The first relates to the question of automation and the many worrisome losses associated with low-skilled labour. There is considerable concern that the digital sector will reduce the need for labour-intensive work, without replacing these losses with new opportunities. Vulnerability to automation is now based on whether jobs or tasks are codifiable and whether or not they are routine. The opportunities that will be created will likely be much higher-skilled, requiring the retooling of some of the workforce. This is echoed on many platforms where it has been acknowledged that “[t]he greatest long-term benefits of ICT intensive jobs in the region are likely to be not in the lower-skilled delivery of digital products or services but in digital design, creation and engineering” (Samans & Zahidi, 2017:3). Some reports are more optimistic, pointing to useful job creation opportunities. According to ICA (2017a:65), as an example,

> *[b]eyond the leapfrogging to mobile phones that has entailed enormous economic and social benefits to millions of people; a similar leapfrogging could happen with distributed manufacturers, at least at the urban scale, allowing start-ups or small businesses with little capital to begin manufacturing on a small scale, then using the earnings to finance expansion into mass manufacturing.*

However, most sources suspect that the digital boom and automation of key sectors will have a negative impact on jobs and the workforce (see, for example, the large amount of work on SA work forces).

5 POLICY DIRECTIONS

As with all infrastructure, most investment attention in the ICT sector has focussed on the supply side, despite the growth of digital ecosystems that also nurture the demand for digital innovation in a few countries and cities. Not only has this resulted in uneven and, at times, underutilised supply of bulk capacity, but this focus has also left the demand-side of the equation less attended to. Useful demand-side investments include investment in digital literacy, subsidising access to last-mile connectivity, and support for the creation of African digital content and services beyond the current focus on few profitable sectors. As argued in this paper, a supply-driven investment does not fully address digital divides, either geographic or gender based, etc., and sometimes even exacerbates them. Imagining ways in which investments in backbone connectivity may be married to demand-side capacitation is, therefore, paramount.

Another important consideration is the environmental costs of investment in digital infrastructure. While African users arguably have a much smaller environmental footprint than users in the rest of the world, understanding the extractive nature, the energy-intensive maintenance and the after-life environmental costs of hardware and consumer products is paramount. Finding ways of costing, calculating and evaluating the environmental implications of investment in digital infrastructure and innovation is a challenge that needs to be treated not as an externality of digitalisation, but as a crucial component of more sustainable investment. This may be the effect of enabling a circular economy approach to the digitisation projects, and, more broadly, to the delivery of ICT infrastructure.

Given the complex landscape of stakeholders involved at various levels, digital infrastructure and innovation need to become a priority of local and regional governance. At present, city governments are mostly involved in supporting smart city programmes. This can involve supporting digital ecosystems through business development programmes such as city incubators, and with fiscal benefits. However, a much broader view of the sustainability of digital ecosystems is necessary as digital infrastructure has important planning implications in terms of its land uses, energy requirements and waste management. The current focus on smart city policies and solutions is too narrow to address the sustainability challenge in ICT investments faced at the local level.

Relatedly, evidence has been presented in this paper that local governments have arguably been more successful in fostering positive investment cycles in the digital ecosystem through SME funds, business development programmes and accelerators. This is because, with all its limits and semi-exclusive focus on profit-driven innovation, the accelerator model has two benefits, namely training start-ups to become investment ready, thereby matching them with the specific needs of a specific subset of investment capital (in other words, VC); and secondly, work through cycles of learning and experimentation in which more established companies or investors mentor younger companies and digital entrepreneurs. The question that arises is whether this accelerator model can be extended and adapted to other infrastructure sectors, to de-risk investment in sustainable infrastructure by creating these kinds of protocols. As noted in other papers in this series, cities face difficulties in matching their investment needs and the capital provided by DFIs and multilateral banks, whereby cities and metropolitan governments lack the technical and political capacity to interface with international lenders to improve their sustainable infrastructure delivery. Can this model serve the purpose of better matching the infrastructure needs with the current capital investment landscape for the energy, water and mobility sectors?

Lastly, while it is difficult to take a position on which kind of geopolitical internet governance would work best for a more sustainable digital landscape in Africa, it is clear that critical trade-offs, for example, between public- and private-driven approaches, or between data protection and service affordability, need to become part of the investment conversation. This is because, even though digital infrastructure seems to have a much shorter lifespan than other infrastructures, it is still prone to lock-ins. Choices made now, not only over how these critical systems are built, but also how they are governed, will shape the digital future for decades to come. Retrofitting these systems will be much more difficult than building sustainability from the ground up.

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APPENDIX 1: SOURCES FOR TABLE 2

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[2] https://icta.go.ke/national-optic-fibre-backbone-nofbi/; https://www.standardmedia.co.ke/news/article/2000226520/waiting-game-for-counties-after-fibre-optic-plan-budget-trimmed; https://icta.go.ke/national-optic-fibre-backbone-nofbi/. Note: the total loan amount is documented as different amounts in different places. The exact amount of finance is thus unclear.

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[4] https://www.2africacable.com/; https://www.2africacable.com/faq-s; https://www.businesstoday.in/latest/world/story/facebook-set-to-expand-undersea-cable-project-in-africa-304291-2021-08-16#:~:text=2Africa%20is%20expected%20to%20be,the%20Middle%20East%20and%20Europe. Note: https://www.socialmediatoday.com/news/facebook-invests-1-billion-into-new-sea-cable-to-improve-internet-access-i/578004/ > this website seems to indicate that Facebook is paying the full 1 billion dollars, however, it is hard to confirm.

[5] https://www.eib.org/en/press/all/2019-171-eib-backs-high-speed-cabo-verde-internet-and-telecom-connection

[6] https://www.reuters.com/article/zambia-telecoms-idUSL5N1KQ44X

[7] https://www.ericsson.com/en/press-releases/1/2021/ethio-telecom-and-ericsson-launch-4g-network-for-south-west-ethiopia-at-major-event-in-jimma; https://www.reuters.com/article/ethiopia-telecomunications-idUSL6N0TV2KO20141211; Note, this investment includes investment in Ethio Telecom's regional data centres and the data centres in Addis Ababa.

[8] https://www.safaricom.co.ke/about/media-center/publications/press-releases/release/1039

[9] https://www.reuters.com/article/us-kenya-safaricom-idUSKBN2BI1H7; https://www.businessdailyafrica.com/corporate/companies/Safaricom-set-for-5G-network-launch/4003102-5453976-84hqeqz/index.html

[10] https://www.au-pida.org/view-programme/51/