African Open Source Digital Infrastructures: Evaluating the Landscape

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Abstract

This study analyses the progress, challenges and opportunities of open-source digital infrastructure in Africa. The African continent has seen some rapid progress over the past two decades in areas such as mobile connectivity, electrification and availability of internet-capable devices such as smartphones. However, despite this progress, many African countries remain poor, are vulnerable to shocks such as natural disasters and pandemics, and face various development challenges. As the world becomes more digital, Africa's development is increasingly determined by its digital capability. Open-source digital infrastructure is a key component of the required digital capability. The optimal application of digital infrastructure to development in Africa requires active participation in the creation and maintenance of open-source digital infrastructure contribution, in a manner similar to which research and development enables adoption of technology produced elsewhere through increased absorptive capacity.

The extent of African participation in the creation, contribution and maintenance of the global open-source digital infrastructure has not been well studied. To our knowledge this is the first extensive report on the level of contribution from various African countries to open-source digital infrastructure. The report uses a mix of quantitative data, policy and open-source case studies on the African continent to understand what led to successes or failures of this infrastructure.

Our quantitative analysis using data from GitHub (which currently represents 95% of global open-source contributions), shows that although the share of African GitHub users is still small (only 2.79%), there are signs of recent growth in open-source digital infrastructure across the continent. In Nigeria and Kenya, the share of open-source users in Africa has grown dramatically from approximately 5% in both countries in 2010 to 22 % and 12% respectively in 2020. Significantly South Africa was the leading contributor to open-source a decade ago (with over 50% of the users), but was overtaken by Nigeria in 2019. It then began to stagnate, in terms of open-source users, in 2016, but has shown some recovery from 2019. What caused South Africa's relative contribution to decline? This question is explored further in a case study of the South African government's attempt to adopt and promote open-source in the early 2000s.

With regards to Internet standards development, Africa has the least number of active participants in working groups and document authors of drafts and RFCs in the Internet Engineering Task Force (IETF). There are currently 15 RFCs and nine drafts (both active and expired). As of this date[1], there are 9,170 RFCs that have been published, which means African contribution to the IETF is almost negligible (0.26 %). Our qualitative studies highlighted a number of challenges faced by African engineers including lack of support from home organisations, lack of funding to participate in onsite meetings and a significant language barrier.

Our qualitative case studies are drawn from open-source projects on the African continent. While most of the organisations we interviewed were based in South Africa, their work and impact covers many countries on the continent. These case studies ranged from new open-source projects to mature ones (over 10 years old). We conducted interviews with at least one representative from nine organisations to learn about their objectives, projects, contributions to open-source infrastructure, community involvement, stakeholders, funding structures, successes and challenges. Our interviews reveal that funding is a big challenge for open-source projects. As a result, organisations rely on volunteers (many

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[1] 04 January 2021

times students) to continue deploying projects. For most of the organisations, there was buy-in from the community once they understood the benefits of the projects and what their role would be.

Our case study on efforts to encourage the widespread adoption of open-source, especially by the government in South Africa in the early to mid-2000s, traces the efforts by a relatively small number of people who worked for the adoption of open-source by government for its processes. Those working in government saw an opportunity to use open-source in the transformation of the South African state, replacing moribund systems from the apartheid era with customisable technologies interoperable across the entire state. Internal political jockeying provided some resistance, but it was the global war on open-source led by Microsoft's Steve Ballmer that raised the barriers to a wider spread open-source adoption. While Microsoft has pivoted to supporting open-source, the conflict seems to have left a legacy of wariness in South Africa about open-source. The failure to support the development of local IT capacity, including capacity in open-source technology, through government procurement seems to be a significant cause of unmet demand for information and communication technology (ICT) skills, as well as the levelling off of South Africa's contribution to open-source.

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[2] https://datatracker.ietf.org/stats/document/author/continent/?type=rfc

[3] https://datatracker.ietf.org/stats/document/author/continent/?type=rfc

1. Introduction and Research Question(s)

This report presents the findings of Open Source African Digital Infrastructures: Evaluating the Landscape, a research project funded by the Ford Foundation and the Sloan Foundation. The project investigates "how African participation in the development, maintenance and application of global open-source digital infrastructure can be enhanced". To answer this overall question, the project investigated the following sub-questions:

1. What is the extent of African contributions to the code-base of critical open-source digital infrastructures?
2. What are the challenges, constraints, and obstacles to the development of open-source digital infrastructures on the African continent?
3. What lessons can be learned from successful African-led open-source projects?
4. How, if at all, are open-source digital infrastructures different in the African context?

To answer these questions, a research study was conducted consisting of four components:

1. A literature review;
2. A qualitative study focusing on African-led open-source projects;
3. A quantitative study of African participation in open-source digital infrastructure development; and
4. An open-source policy case study.

The research adopts the description of infrastructure proposed by Brett Frischmann.

Infrastructural resources satisfy the following criteria:

> (1) The resource may be consumed non-rivalrously for some appreciable range of demand.

> (2) Social demand for the resource is driven primarily by downstream productive activities that require the resource as an input.

> (3) The resource may be used as an input into a wide range of goods and services, which may include private goods, public goods, and social goods. (Frischmann, 2012)

To be considered by the project infrastructure must be digital, that is be constituted by digital communication or information. It need not be information or communication directly intelligible by human beings but can include information held by computers or communication between them. Thus digital infrastructure includes computer programmes, internet protocols (IP), open standards and associated documentation. Open-source explicitly permits the creation of value by downstream users in contrast with proprietary software which attempts to capture all the value from the resources.

We address the questions of African contribution, challenges and lessons from participation in open-source digital infrastructure through literature reviews, qualitative, and quantitative analysis. The qualitative analysis was carried out using case studies to help us better understand African contributions to open-source digital infrastructure. The case studies were identified through a snowball approach to sampling. The literature review, our quantitative GitHub content analysis, and interviews with open-source contributors and experts helped reveal to us case studies to study in depth. The snowball approach helped select relevant cases, rather than using a statistically relevant sample. Case studies were selected if they are open-source infrastructures, applications, platforms, frameworks or protocols that were primarily developed in Africa, domiciled in Africa, or had a significant amount of African

contributors or capital. Case studies were also relevant if they highlighted successes or obstacles, lessons learned, or best practices.

The quantitative content analysis was conducted to identify location-based data about contributions to open-source repositories in the hope of measuring the extent of the African contribution to open-source projects in general and code-based digital infrastructures in particular. Here, GitHub API queries as well as third party repositories such as GHTorrent were used as techniques to collect data to measure African contributions to open-source projects. The frequency of categories of attributes of GitHub entries such as geographic location of author or project, or inferred geographic location, in cases where a country is not captured, were used to measure African participation. In addition to measuring the frequency of African contribution we also collected specific quantitative data on case study projects to check the level of African contributions on projects domiciled on the African continent.

The case study on the open-source movement and policy development and adoption process in South Africa in the 2000s aimed to provide an additional perspective on African participation in the creation of open-source digital infrastructure. We developed the policy case study using the multi-level perspective (MLP) as a theoretical framework. MLP is frequently used to study socio-technical transitions and we applied the framework to investigate South Africa's attempt to transition to a new information technology paradigm in which open-source software was expected to play a much stronger role. Given the vibrancy of the open-source movement in South Africa in the early part of this decade and the adoption of a formal government policy it could have been expected that South Africa's participation in and contribution to building digital infrastructure would have been very much greater. However, our analysis shows that this did not happen.

Finally, the policy case study included a systematic literature review through which a small number of key scholarly articles were identified, followed by semi-structured interviews with key players in the open-source movement. The data from the literature and interviews was supplemented with inputs from team members who were themselves involved in the open-source movement in the 2000s.

2. Literature Review

In this section we review literature on the African contribution to the open-source digital infrastructure.

2.1.   Quantitative Component

The extent of African participation in the creation, contribution and maintenance of the global code-based digital infrastructure is not known to a high degree of certainty. There have however been a number of attempts to map regional contributions to open-source projects using quantitative methods , and although the methodology for finding geographic associations has its limitations, studies of the landscape seem to indicate low levels of contributions from African authors.

GitHub is by far the most dominant public open-source repository available by two orders of magnitude. There were 200 million projects in the GitHub database as of July 2021. The next nearest open-source repository, Gitlab, had 546,000 projects. ('Comparison of Source-Code-Hosting Facilities', 2022) This makes GitHub the most critical repository to analyse when studying the geographic location of open-source contributions around the world. GitHub carried out their own country analysis in their "State of the Octoverse report".(GitHub, 2021) The 2020 report shows that while growth in African contributors is significant, this growth is disproportional when compared to the absolute growth of open-source contributors at the global level. For example, African GitHub contributors grew by 10,000 in 2019 compared to global GitHub contributors which grew by 10 million in the same period.

These conclusions are based on authors that share their country location under their user profiles. However, 33% of authors do not share their country of origin or do not have any location identifiers such as the top-level-domain of their email address, making some of these conclusions possibly premature. This gap in knowledge about the location of 33% of GitHub authors will be explored in this research.

In 2010, Takhteyev et al. did an empirical study of the geography of open-source software development in GitHub. (Takhteyev & Hilts, 2010) The study showed that developers are highly concentrated in North America and Western and Northern Europe. They also discovered that code contributions, interest and attention show strong local bias. In addition, North American projects receive more contributions than those made elsewhere and receive much more attention. To extract data for the study they used the GitHub public API. They followed a recursive process to discover accounts, beginning at GitHub founder and looking for accounts connected to this user and then recursively continuing to look for accounts connected to those. Through this process, they found 70,414 accounts out of the total 250,000 GitHub accounts at the time. The balance of accounts were isolated. They then studied geocoding in accounts (46% of accounts had location) and looked at relationships between pairs – following repository watchers and code contributors. The results showed that the 38.6% of the GitHub users were in the United States (US) and they had 38.7% of the contributors and received 43.1% of the contributions globally. This was followed by the United Kingdom (UK) with 7.3% of the users, a 7.7% share of contributors and receiving 6.5% of contributions from around the world. Africa only had 0.6% of the users and 0.6% and 0.5% of the contributors and contributions, respectively.

Mombach et al did a comparative study of open-source development around the world in 2018. (Mombach et al., 2018) They selected the top 10,000 open-source projects on GitHub using the number of stars and attempted to identify the location of these projects. GitHub does not directly provide the country associated with a project, however, location is available for some GitHub accounts. Of the 10,000 top projects, 3,311 projects (33%) were owned by accounts with an empty location field and were removed. 645 projects were not software systems, e.g., projects referring to programming books, tutorials, and lists. For the remaining 6,044 projects, they implemented and used a script that attempts to match a project location to a list of country names in English (Note that GitHub has a free form entry for the location field).

With their script, they successfully matched the location for 2,870 projects (47%). The location of some of the remaining 2,518 projects (42%) was made possible by manually associating them to countries. For example, the location of a project could mention a company or building name, which could then be matched to a country. 656 projects (11%) were eliminated because they included locations which are not countries (e.g., The Earth) or locations mentioning more than one country (e.g., Canada & France). After following these steps, they were able to identify the country of 5,388 projects – these were distributed over 77 countries. The US had the largest number of projects (2,302 projects, 42%); three times greater than the second country, China. The US numbers for projects were similar in scale to the dominance of US users found by Takhteyev eight years prior, however, China had risen quickly to a second place major contributor. Africa is not mentioned in the report, but the map shows South Africa, Kenya and Nigeria having between 1 and 10 projects.

Some work was done by Frederickson in 2018 using a mix of GHTorrent (a database that monitors the GitHub public event timeline, and retrieves extra information from the GitHub API for each event seen) and the GitHub archive to understand where software developer's live. (Frederickson, 2018) Using GHTorrent and GitHub he retrieved a list of all GitHub users that have had any public activity in the last seven years. This includes actions like forking or starring a repository, opening or commenting on an issue, and pushing commits. In total, there were slightly over 15 million GitHub accounts that met this

criteria. Over the course of several months, he fetched the profile information for each of these users using the GitHub API. Google maps Geocoding API was used to transform the free from location strings into normalised location information. After fetching the profiles, about 2.3 million of these users had a location listed. While most of these accounts did not have a profile listed, it was still a large enough dataset to establish trends.

An online interactive system allows you to explore the number of GitHub accounts in each country for top developers (ranked by number of followers). The top country is the US with 651,017 GitHub accounts, followed by China and India with 183,805 and 168,328 respectively. Three accounts were identified in South Africa, five in Nigeria, two in Cameroon and one in Kenya. Most of the Nigerian accounts were repositories that were information-related such as lists of useful software. One of the South African contributors, Guy Bedford, was a major contributor to two web development tools, SystemJS and Next.js. The Kenyan contributor, Eugene Mutai, built an Mpesa API called project Mulla. Further analysis was done to check how well the population is correlated with GitHub accounts; they were somewhat correlated and had a log regression of 0.5 (half the variance can be explained away by population). GDP was more correlated with GitHub accounts with a much stronger log regression of 0.84. There were a few exceptions like oil rich countries like Saudi Arabia, Iraq and Kuwait that under-invest in human capital.

A study on the per capita level of open-source development in the world was done by Hoffa in 2016. (Hoffa, 2016) The study made exclusive use of GHTorrent. They noted that only approximately 9% of GitHub users have a country code on GHTorrent. For normalisation purposes, they looked at countries with a population larger than 300,000. The study showed that the US was predictably the top country in terms of the number of contributions to GitHub. But when normalised to country size, the US dropped to 6th place. Hungary, Estonia, Switzerland, Norway, and New Zealand had more contributions per capita than the US. In terms of contributions by unique users, New Zealand, Sweden, Switzerland, Norway, Finland, Denmark, Netherlands, Canada, the UK, Australia, Luxembourg, Estonia, and Ireland showed a larger presence of developers per capita than the US.

Geographical bias in GitHub contributions was raised by Takhteyev in 2010 and a focussed study on this aspect was done by Rastogi et al. in 2015. (Rastogi et al., 2015) The work tried to understand the influence of geographical location on the evaluation of pull requests. They used a mix-methods approach and analysed 70,000 pull requests on GitHub and studied 2,500 survey results. They found that geographical location had a significant effect on pull request acceptance decisions. Compared to the US, submitters from the UK (22%), Canada (25%), Japan (40%), Netherlands (43%), and Switzerland (58%) have higher chances of getting their pull requests accepted. However, submitters from Germany (15%), Brazil (17%), China (24%), and Italy (19%) have lower chances of getting their pull requests accepted compared to the US. The probability of pull request acceptance decisions increases by 19% when the submitter and integrator are from the same geographical location. Survey responses from submitters indicated that the perception of bias is strong in Brazil and Italy. In addition eight out of every 10 integrators felt that it was easy to work with submitters from the same geographical location. Africa is not mentioned in this study, but it is highly likely that acceptance of pull requests will be even lower for the African continent.

Open-source projects and the FLOSS ecosystem can also be viewed through the lens of a supply chain system. This was the focus of work by Amreen et al who looked at software ecosystems representing distributed decisions in supply chains of code and author contributions. (Amreen et al., 2019) They sought to measure the relationships among projects, developers, and source code. One of the major obstacles to this analysis was the fact the author names often change or are incomplete as authors commit from different organisations and computers with different stored author details. They sought to

solve this problem by looking at (1) author distance based on string similarity, (2) author distance based on string frequency, (3) author similarity based on fingerprints (files touched, time zone and text similarity of commit messages and gender similarity). Results for all these methods were not presented but they act as a good source of tools to attempt to trace the same author who is posting under different names. This work also studied code flow networks for open-source projects; this can be used to understand how code transfers from one project to another. Knowledge flow networks are also presented and can reveal lead developers on a project and their follower clusters.

On the whole, the current literature on analysis of African participation in global digital infrastructure reveals very low open-source contribution levels from the continent. The most up to date analysis from GitHub's "State of the Octoverse" showed that Africa has only 2.3% of the active users (users making active contributions) on GitHub. GitHub represents the most significant repository — making up approximately 98% of open-source contributions worldwide. However, the quality of location-based metadata is poor; 91% of authors do not have location data from which their country can be determined and 33% of authors linked to the top 10,000 projects on GitHub do not share their location information. Therefore, there may be more African authors that have not been accounted for in the current statistical analysis. There are also many obstacles faced by African open-source contributors. Apart from a lack of good digital infrastructure and skills, authors face geographical bias towards their contributions. None of the literature looked at time-series analysis to understand the movement of authors between countries or check if contributions were from home or work, or from which cities or towns contributions are being made —these are critical questions to understand where successes are being achieved in Africa and what constitutes an "African" contribution to digital infrastructure.

2.2.   Qualitative Component

In this section we present a literature review on ownership, sustainability, inclusivity, business models, of open-source in Africa and the relationship between open-source and international development projects and government policies and programmes. Open-source's greatest advantage is that it has no monolithic controlling legal entity and code is held in a commons, so that there are few leaders, and those without much formal power. Primary contributors often emerge as de facto leaders, and even then there is little hierarchy. Together with the challenge to diversify (in terms of geography, race, gender, social and educational background) the pool of contributors, reliance on non-traditional incentives presents a major obstacle to long term sustainability of open-source digital infrastructure. Open-source code is partially produced by corporations with economic incentives to do so, but also produced by individuals. Individual motivation includes indirect economic motivations such as acquiring skills and demonstrating competence to future clients or employers but also other motivations including problem solving, mastery of technology, status within an expert community and a desire to benefit others. However the additional capacity to engage in social production is dependent on available time, energy and access to a networked computer (Benkler, 2007). These are what Benkler refers to as 'lumpy' goods. If a person has sufficient capital to acquire a PC it can then be used for social production as well as for personal gain. Similarly an uncapped Internet connection can enable social production without additional costs.

While in Africa there are simply fewer technology corporations and fewer individuals with the available capacity to contribute to open-source, the issue is more complex than may at first appear. On the one hand those with Internet access often do not have uncapped high speed access thus limiting their likely open-source contribution. On the other hand there is a large global market for open-source coding that Africans can access without having to immigrate. Due to the nature of the work it can take place asynchronously and remotely, and requires only demonstrated competence rather than formal qualifications.

We performed an initial review of the literature relevant to the topics of ownership, sustainability, inclusivity, business models, as well as the relationship between open-source and international development programmes in Africa. The analysed literature includes academic papers from multiple disciplines including information technology, ICT for development, gender studies, work, and organisational psychology, as well as evaluation reports and commissioned research from international development agencies and philanthropic organisations.

a) Ownership

In this report the term 'ownership' is used to reflect the discourse prevalent in software development discussions to refer to control over software through statutory monopolies such as copyright and patent. It does suggest a claim by the authors that software is the kind of phenomenon that can constitute property in the philosophical, jurisprudential or constitutional sense.

In the open-source software literature, ownership is usually presented as a polarity between proprietary ownership and the commons. The commons is constituted by contributions from multiple authors, and may be used by any person but only in accordance with the rules imposed by that particular licence. The commons of open-source software relies on free software and open-source licences that use copyright (and sometimes patent) but invert the logic of software licensing to prevent enclosing of the code (Boyle, 2010). It is important to note that the commons is not simply free for anyone to appropriate; although it is open for use, the use is conditional on adhering to the rules of the commons which in the case of open-source are required by the open-source licence. While no single entity has control over the commons it is not appropriable.

In addition to these two traditional modes, Fink et al (2020)suggested a third, hybrid model (which they labelled 'big tech') which is a combination of proprietary infrastructure, which allows access only through the owner, and commons infrastructure of digital platforms (such as Android operating system which is almost entirely but not completely open). In their paper the authors examined the ownership of code-based digital infrastructures through the lens of software libraries – i.e., how does the ownership of software libraries affect their deployment – with the hypothesis that deployment is affected by who owns the libraries: communities, proprietary software vendors, or big-tech providers. Their findings suggest that "the emerging landscape is neither the community-based utopia of early open-source research, nor the dystopia of the recent digital dominance literature". One of their insights is dominance of big tech, whose libraries have become foundational infrastructures. Proprietary and community libraries have optional, complementary roles.

b) Sustainability challenges

Sustainability challenges of open-source projects are well known among contributors but not necessarily to users and consumers of those (Eghbal 2016). Since those projects are often distributed among multiple individuals and organisations, common governance models are unlikely to be applied. The movement's tricky relationship to money and compensation of its contributors adds to the challenge – it often relies on voluntary work of its biggest contributors, whose main motivation is to build their portfolio and reputation, as well as the desire to make an impact. The movement also suffers from a 'free rider' problem, especially in the last five years with the increased number of developers who are using the shared code, but not giving back to the community (Eghbal 2016).

Perhaps the biggest challenge to sustainability of open-source digital infrastructure is the fact that there is no central entity to decide what gets developed and used. This decentralised nature of open-source makes it difficult to take authoritative decisions when talking about organisational needs and sustainability.

Open-source projects tend to function well when they are either small enough, so they do not require lots of maintenance, or when they are large enough to find corporate support (Eghbal 2016). Unfortunately, the majority of such projects lie somewhere in the middle. Having in mind the expansion of usage of open-source digital infrastructures, and their transition from voluntary passion projects to critical infrastructures, it is essential to provide them with the support they need.

c) Inclusivity

Expanding the pool of contributors could have a positive impact on the ecosystem at large. However, there are only certain demographics who can afford the time and financial means to make significant contributions (Eghbal 2016). These tend to be white, middle-class, English-speaking men. Bidwell (2020) points out that systemic devaluing of women's contributions to development of community networks essentially stems from the male-dominated culture of open-source communities. The gendered work culture is also discussed in Lin et al (2018), where the authors recommend that the open-source environment would benefit from a more gender-balanced and inclusive workplace.

d) Examples

The African Virtual Open Initiatives and Resources (AVOIR) project supported by the International Development Research Centre (IDRC) of Canada from 2004 to 2007 is a collaborative effort among several African higher education institutions to support capacity building in open-source software engineering (IDRC 2007). The three key boundary partners in this project were AVOIR nodes (eight universities and three additional partners who joined halfway through the project), software developers and software users.

The development programme intended to see all AVOIR nodes taking ownership of the project beyond initial funding, and the feeling of ownership was set to determine the success of the network as a whole: nodes create local communities of developers who actively contribute to software design and development; they market these solutions and build sustainable business opportunities around adaptation, implementation, and support; and they adapt and extend the tools to address local needs and preferences, including localisation into local languages.

However, only one node (UWC) had success in developing a business model, marketing the software and generating income from services and development. While there is no evidence why other nodes were not that successful, project evaluators assume that it is due to a lack of skills with respect to implementing open-source business models, and the fact that AVOIR-produced software has strong competition not only from proprietary alternatives, but also from within the international open-source community.

At the time when this project was implemented (between 2004-2007) open-source developers in Africa were facing significant challenges in terms of infrastructure that is needed to actively participate in FOSS development. In interviews with AVOIR developers during the project evaluation, the interviewees highlighted there was a strong sense of ownership – more than when using proprietary or even other open-source software (barriers of joining these other open-source communities were perceived as too high) (IDRC 2007). The ability to understand how everything works by looking at the source code and active contribution to the project cultivated the sense of ownership. However, there was a clear discrepancy in levels of activity and participation at different nodes.

e) Business models

A stronger focus on business development is required to ensure long-term sustainability of open-source projects. In terms of governance, it is essential to avoid imbalance between partner institutions. In order to have a sustainable community of practice, responsibilities need to be distributed among the entire

network. (UNICEF 2016) acknowledges that open-source businesses play a significant role in today's dynamic innovation environment. The paper presents some strategies that can be used to generate income for open-source software, hardware and content – for example using the SaaS (software as a service) business model – and explores potential revenue streams such as consulting, charging for additional services and sale of additional proprietary products.

Some open-source tools, like servers and databases are easier to monetise than for example libraries and frameworks (Eghbal 2016). Charging for the latter would limit their adoption.

f) Open-source and international development programmes

The preference for free and open-source software in sustainable development emerges primarily from the ability to localise free-of-charge open-source applications, which could help bridge the digital divide. Open-source can potentially play a key role in ICT capacity building. In 2006, the United Nations Development Programme - Asia-Pacific Development Information Programme (UNDP-APDIP) in cooperation with the International Open Source Network, IDRC and the United Nations Educational, Scientific and Cultural Organisation (UNESCO), published a compilation of case studies from across the world (Hoe 2006).

The thirteen case studies (four of which are from Africa) are initiatives that were deployed making use of open-source, with the aim to boost economic development and empower people in the Global South. One of the case studies, the Translate.org.za project, focused on translating several popular open source desktop packages into the 11 official languages of South Africa, and creating tools, documentation and methodologies for localisation.

The important lesson learned is that if efforts are made to localise open-source applications in a local language, in addition to the availability of the localised open-source, competing proprietary software vendors are likely to localise their software as well because they do not want to lose the market advantage to open-source.

g) Public policy support for OSS development

Our analysis of ownership, business model, inclusion and open-sources support by governments and international actors reveals several insights. Governance of open-source projects is directly linked to their decentralised, distributed nature and lack of a central decision-making entity. There are a wide array of possible legal and governance structures for open-source projects, from dedicated foundations to holding the copyright to the code (for example Linux), to contributors sharing their code under the same open-source licence. As a consequence there need not be clear owners or leaders, and where there are they need to retain the confidence of the community in order for the project to be viable.

In the African context – similar to ICT4D projects – the financial sustainability of open-source projects largely depends on sustainable business models, of which there is frequently a lack. In Africa many open-source projects are donor funded, and there is often little vision on sustaining an initiative once the funding runs out. Their existence in the first place is driven by the donor agenda – someone decides to invest in, for example, open-source infrastructure in Africa, and implements a project without sufficient knowledge of what will happen after the funds run out. The ecosystem as a whole should work towards sustainability beyond donor funding. The fact is that many open-source contributions are entirely voluntary, and developers do not get compensated for their work. The most obvious source for funding open-source in Africa is for governments to make using open-source software a priority, and procure support customisation and support in the country. However, other than the case study on efforts to adopt open-source by the government in this report there is a dearth of literature on this possibility.

2.3.   Policy Component

A systematic review of the literature relevant to a case study of open-source government policy in South Africa was performed as part of the policy case study component of the project. The open-source policy case study focuses on South Africa as one of the countries that were prominent in the consideration of open-source at a national policy level during the early part of the 21st century. We conducted a systematic review of relevant literature on the South African government open-source policy and initiatives.

The systematic review was aimed at uncovering useful theoretical as well as empirical contributions that can inform the case study. An exploratory search was used to evaluate various keywords and keyword combinations that would result in a comprehensive but manageable number of records. The results from various searches were combined and resulted in 170 records. This was finally reduced to 144 records after removal of duplicates. The number of publications was further reduced based on quality and relevance and explicit reference to South Africa. This resulted in 12 articles that were reviewed in detail.

Our analysis, detailed in section below, shows that only a small number of publications documented aspects of the historical events that led up to the adoption of the 2006 open-source policy by the South African government. Most of the other publications are concerned with implementation of the policy after 2006. This included documentation of open-source development in four companies in South Africa. One of the publications explored the state of open-source software in South Africa and the supply and demand of OSS professionals.

Three papers in the collection offer different perspectives through diverse theoretical lenses or alternative empirical data. This included an analysis of the 2006 South African open-source policy using critical discourse analysis (CDA) and Habermasian theory of communicative action (TCA), a report on uniquely South African data on open-source software development expenditure collected as part of the National RD survey since 2005/2006, and a field study on the politics of open-source implementation.

2.3.1.   Search Strategy and Keywords

An exploratory search was used to evaluate various keywords and keyword combinations that would result in a comprehensive but manageable number of records. The bibliometric databases selected were: Scopus, Web of Science, and Google Scholar using Publish or Perish (Harzing, A.W., 2007). The searches used are summarised in Table 1. In cases where the keyword searches resulted in irrelevant publications these were manually filtered out.

The results from the various searches were combined which resulted in 170 records which was reduced to 144 after removal of duplicates.

**Table 1: Bibliometric databases and keywords used**

Database	Keywords	Records
Web of Science	ts = ("open-source" AND Africa AND adoption) manually filtered on title	6
Web of Science	WOS TI=("open-source" AND policy) manually filtered on Title and Abstract	25
Scopus	Scopus - TITLE-ABS-KEY (("open-source software" OR "free software" OR foss OR floss) AND ("public policy" OR "national policy" OR "government policy")) manually filtered on title and abstract	44
Google Scholar via Publish or Perish	("open-source" OR "free software" OR foss OR floss) AND ("Africa") manually filtered from 107 references	58
Google Scholar	allintitle:("open-source" OR "free software" OR foss OR floss) AND ("South Africa")) manually filtered	9
Google Scholar	allintitle:("open-source software" OR "free software" OR foss OR floss) AND ("public policy" OR "national policy" OR "government policy"))	17
Google Scholar	(intitle:"open-source" OR intitle:"free software" OR intitle:foss OR intitle:floss) AND (intitle:"South Africa") AND (adoption OR diffusion OR deployment) AND policy	11
SA Government and unpublished work	Snowball sampling	2

2.3.2. Screening and Selection

Figure 1 provides a summary of the literature section and reduction process. Publications in the list of 144 were judged for quality and relevance on scales of 1 to 3. For quality, a 1 was awarded to peer reviewed journal and conference papers and other high quality papers. Articles in the press, keynote addresses and so on were awarded a 3. Other publications falling somewhere between high quality peer reviewed publications and popular articles were awarded a 2.

Relevance was assessed by the author based on the aims of the project. The quality and relevance scores were used in the next filtering step. All articles with relevance 1 were kept, as well as articles with relevance 2 and quality 1 or 2. Articles in English and French were retained whilst articles in Korean were eliminated. The resulting articles are listed in the author matrix in Appendix A.
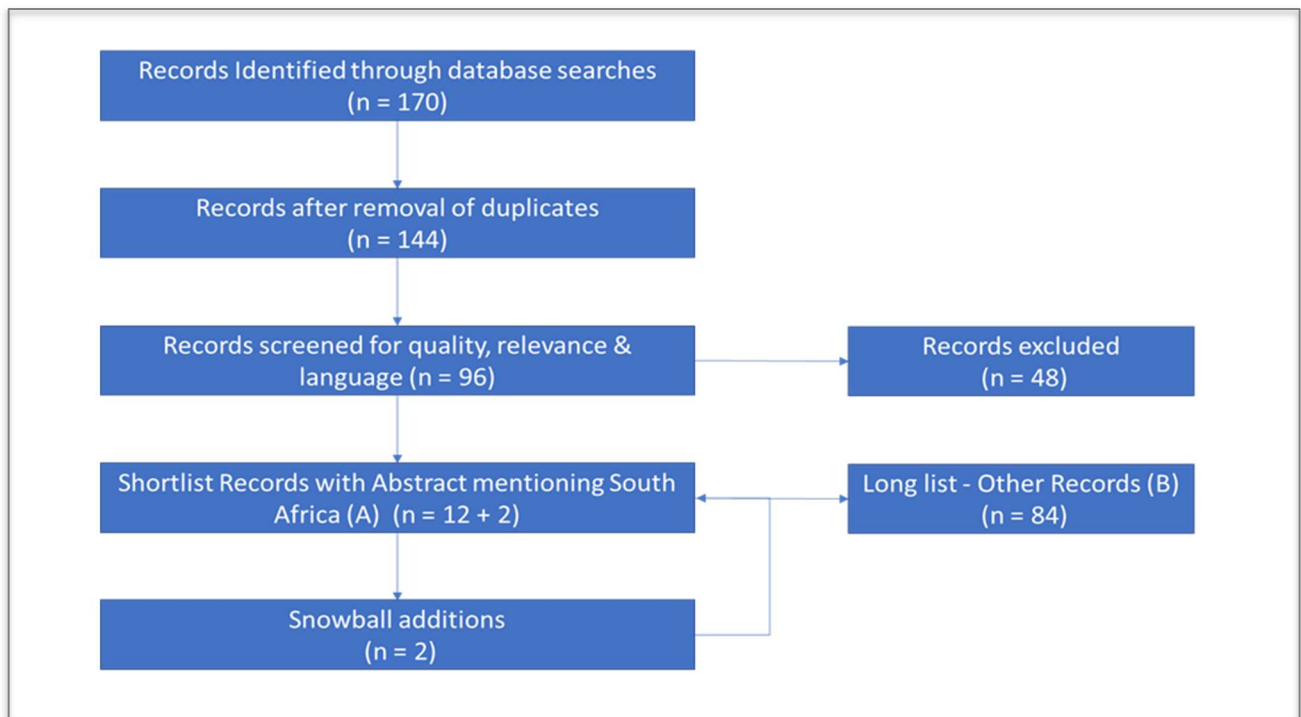
Figure 1: Literature selection and reduction process

These steps resulted in a shortened list of 96 records. Since 96 is still a large number of articles it was decided to separate the remaining articles based on whether they explicitly deal with South Africa or not. Twelve articles mentioned South Africa in their abstracts. Two additional articles were later added to this list as part of a snowball sampling strategy in which relevant articles were identified as the original list was reviewed. These articles were earmarked for detailed reading and summarisation of key points. The rest of the articles were scanned for key concepts documented in the concept matrix only.

Table 1 lists the publications that mention South Africa in their abstracts. Each of the articles are briefly discussed in chronological order before overall conclusions on this collection is made.

Sibisi et al (2002) and Sibisi et al (2004) are two versions of a document that proposes "…recommendations designed to help the country to benefit as much as possible from open software, and to remove the barriers to future open software development projects". The 2002 document is the result of deliberations of a National Advisory Council on Innovation (NACI) Open Software Working Group. The 2002 document, which reads somewhat like a manifesto for open-source, makes arguments for the government to play a leading role in the adoption of open standards and open-source. The benefits of open-source are illustrated through four scenarios that describe its benefits: being able to run on older hardware where users cannot afford operating system and office suite licences; the possibilities that open-source software in learning environments offer for capability development; translation of software interfaces into local language; and the dissemination of scientific software developed through public funding as open-source.

The 2002 document states many of the advantages of open-source as self-evident and does not reference all its claims. However, it is percipient in its identification of key issues such as the need for open standards to resist lock-in to proprietary solutions, and the differing economic circumstances that prevail in rich countries, such as the US, where "where there is an implicit subsidy provided by wealthy institutions, well-funded universities and corporations" for open-source, which does not exist in poorer countries. It also distinguishes between software infrastructure and software applications and highlights

the symbiosis between open standards and open-source in the Internet's digital infrastructure. Regarding the aforementioned, open standards clearly enable open-source adoption through the transparent availability of specifications that open-source must attain to be able to interoperate with propriety software, which in many cases has already established a dominant position. This aspect of the synergy between open standards and open-source is generally well understood, but the document makes the point that by the same token, open standards, such as the Internet standards and protocols, are enabled by open-source software.

Table 2 Publications that explicitly deal with South Africa

Year	Author/s	Title
2002	Sibisi, S; Jensen, M; Machanick, P; Blake, E	Open Software & Open Standards in South Africa - A Critical Issue for Addressing the Digital Divide
2004	Sibisi, S; Jensen, M; Machanick, P; Blake, E, Summers, EB; Bailey D	Free/Libre & Open Source Software and Open Standards in South Africa - A Critical Issue for Addressing the Digital Divide
2006	Mosoval, F; Gardiner, J; Healey, P; Prestedge, A; Johnston, K	The State of Open Source Software (OSS) In South Africa
2006	Gopalakrishnan, J	Lessons in open-source wisdom from South Africa
2008	Mtsweni, J; Biermann, E	An investigation into the implementation of open-source software within the SA government : An emerging expansion model
2009	Ngeleza, B; Mkhize, P; Lubbe, S	The Application of an Organic Model for Strategic Management to FOSS Migration Within the South African Public Sector
2009	Van Beulen, I; Van Belle, Jean-Paul; Madhusudhan, M	Open-source adoption in South Africa by organisations: an exploratory study
2009	Gastrow, M; Parker, S	How much is free?: quantifying open-source software development in South Africa
2010	Mac Lennan, Elizaveta; Chigona, Wallace	A Critical Analysis of the Policy on Free and Open Source Software Use for the South African Government
2010	Mutula, S; Kalaote, T	Open-source software deployment in the public sector: a review of Botswana and South Africa
2011	Weilbach, L; Byrne, E	Implementing open-source software to conform to national policy
2012	Handlykken, AK	Exploring the politics of Free/Libre/Open Source Software (FLOSS) in the context of contemporary South Africa; How are open policies implemented in practice
2015	Ngoepe, M	Deployment of open-source electronic content management software in national government departments in South Africa

Although the authors state that Sibisi et al (2004) is a revision of the original document, Sibisi et al (2002), the 2004 report differs substantially from the original. Not only did it grow in length from 22 pages to 63

pages, the newer document has a different emphasis reflecting developments since the publication of the original report. The title of the report also changed from *Open Software & Open Standards in South Africa* to *Free/Libre & Open Source Software and Open Standards in South Africa*. Two of the scenarios in the original report, Funeka's awakening and Sipho's choice[4], were retained as FLOSS Parables and Language Translation – A True Open Software Story as an example of FLOSS application. Whereas the 2002 report "emphasised public sector in its recommendations regarding use of FLOSS…", the 2004 "…version broadens and extends the recommendations to include public and private sectors, with specific recommendations for the environment, agriculture and education domains".

Sibisi et al (2002) and Sibisi et al (2004) point to the need to study the context in which the South African open-source wave arose and faded. In this regard, both the global context and domestic circumstances are relevant. Globally various countries and regions such as the European Union adopted open-source policies and strategies. The World Summit on the Information Society (WSIS), a two-phase United Nations-sponsored summit on the information society, took place in 2003 in Geneva and in 2005 in Tunis. One of WSIS main aims was to address the global digital divide by increasing access to the Internet and ICTs in the developing world. As reflected in the subtitle of the two reports, "A Critical Issue for Addressing the Digital Divide", the recommendations on FLOSS were to a significant extent influenced by the issue of the digital divide.

In 2002 South Africa had experienced a major devaluation of its currency further increasing the cost of imported software. Despite the devaluation of the currency, by 2002 South Africa was at the beginning stages of one of the longest economic growth periods since the 1960s. ICTs and the information society had high status under the Mbeki administration which had appointed the Presidential Information and Communications Technology (ICT) and the Advisory Council and established the Presidential National Commission (PNC) on Information Society and Development (ISAD).

The open-source policy case and associated developments therefore have to be seen in context of the democratic transition in South Africa and the development of new institutions, other domestic developments, the globalisation phenomenon of the 1990s and 2000s and the emergence of the Internet as a mainstream global infrastructure.

Sibisi et al (2004) provides an update on various open-source related developments after 2002 including:

- January 2003: publication of "Using Open-source software in the South African Government". A document produced by the Government Information Technology Officers Council (GITOC), containing policy recommendations and implementation targets, and representing the current accepted policy of the South African government;
- May 2003: publication of "Designing and managing a framework for assessing results of use to OSS in South Africa: Phase 1". A document produced by the State Information Technology Agency (SITA), that also supports the FLOSS implementation process;
- November 2003: commissioning by the PNC on ISAD of a study on South Africa's OSS policy which was expected to improve on the current OSS policy and provide guidelines for a move to the next phase of its implementation.

In summary, Sibisi et al (2002) and Sibisi et al (2004) are essential reading for any study of open-source policy and associated developments in South Africa in the first decade of the 21st century. The two

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[4] A word play on the title of the novel "Sophie's Choice"?

reports also serve as useful jumping off points for exploring what led up to the phenomenon and how it subsequently developed.

The State of Open Source Software (OSS) In South Africa (Mosoval et al., 2006) is a conference paper presented at The Tenth Pacific Asia Conference on Information Systems (PACIS 2006). The paper explores the state of open-source in South Africa in the business and government environment and investigates the supply and demand of open-source software professionals in South Africa through an online survey of 291 South African organisations, 280 South African schools, 44 training institutes and 70 Computer Science and Information System lecturers throughout South Africa. The authors found that although there were only a small percentage of South African organisations that had significant usage levels of open-source, there was a growing trend in the use of open-source in South Africa and that the majority of open-source users planning on maintaining their current levels of usage. "It was observed that 67% of non-OSS [open-source software] users are considering OSS use in the future, with the majority of these respondents having made preliminary investigations into the viability of OSS use" (Mosoval *et al.*, 2006).

Lessons in open-source wisdom from South Africa (Gopalakrishnan, 2006) was the cover story on the trade publication Linux For You[5] in April 2006. The article describes the author's exploration of the open-source scene in South Africa after being made aware of it upon her brother receiving the Unbuntu Linux distribution on CD. The publication provides information on South African IT billionaire Mark Shuttleworth's company Canonical, the Shuttleworth Foundation, the Council for Scientific and Industrial Research (CSIR) Open Source Centre and the Meraka Institute, as well as various open-source related projects including the Go Open Source Campaign, tuXlabs, HIP2B[2], Learn Linux and the Freedom Toaster. Gopalakrishnan (2006) complements Sibisi et al (2002) and Sibisi et al (2004) by providing high-level information on specific initiatives and people that formed part of the open-source drive in South Africa in the 2000s.

An investigation into the implementation of open-source software within the SA government: An emerging expansion model (Mtsweni & Biermann, 2008) is a paper presented at the SAICSIT '08, the 2008 annual research conference of the South African Institute of Computer Scientists and Information Technologists on IT research in developing countries. By the time the paper was written, South Africa had adopted an open-source policy that mandated open-source usage in government. The paper however argues that little progress had been made on open-source implementation in the South African government. The authors reported on the status of open-source usage within the South African government based on a survey of forty national departments. They found that open-source usage within government was not yet as extensive as required by the open-source policy. The paper identified challenges and obstacles hampering open-source implementation and proposed an open-source expansion model as a possible solution to improve the status of open-source usage within government departments.

The publication provides further information on the South African open-source scene and in particular on implementation of the government's open-source policy as well as brief descriptions of open-source adoption initiatives in Malaysia, Brazil and Germany.

The Application of an Organic Model for Strategic Management to FOSS Migration Within the South African Public Sector (Ngeleza et al., 2009) is a conference paper presented the 5th European Conference on

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[5] Linux For You was launched in February 2003 as a magazine that aims to help 'techies' avail the benefits of open-source software and solutions. The publication, now called Open Source For You, describes itself as Asia's leading IT publication focused on open-source technologies.

Management Leadership and Governance. The paper provides some additional information on the open-source phenomenon in South Africa including a reference to a 2001 parliamentary decision on FOSS migration[6]. The paper mainly argues that open-source migration in government requires a dialectical rather than a linear strategy and proposes an organic model based on Farjoun (2002).

Open Source Adoption in South Africa by Organisations: An Exploratory Study (Van Beulen et al., 2009) was presented at the Euro-India ICT Cooperation 2nd International Event which took place from 10 to11 December 2009 in New Delhi, India. The publication examines open-source adoption trends in South Africa to investigate how South African companies went about "adopting OSS, the factors that influenced adoption and the factors that contribute to sustainability of OSS post adoption". In addition, the publication investigates the usefulness of several theoretical frameworks for such research. Theoretical frameworks examined include: the Technology, Organisational and Environmental (TOE) framework (Lippert & Govindarajulu, 2006), the Open Source Skills and Risk Tolerance model (Woods & Guliani, 2005) and a cost model from the same source.

The publication collected data using questionnaires, documentary analysis and interviews and followed a grounded theory approach for analysis. A purposive sampling approach was used to identify four South African cases: IDS, Outprosys, Fundamo and 3i Solutions. The study of four South African companies that had adopted open-source software as part of their IT stack provides a useful complement to the rest of the publications in this collection. It is noteworthy that all four companies are still in existence and that at least one has been extremely successful namely, Fundomo, a Cape Town-based mobile payment solutions provider, which was bought out by Visa in 2011 for $110 million.

How much is free?: quantifying open-source software development in South Africa (Gastrow & Parker, 2009) is a Human Science Research Council (HSRC) report that uses National Research and Development Survey data for a quantitative analysis of open-source software development in South Africa. Since the 2005/06 annual surveys of research and development (R&D) expenditure, the South African survey has included a question on the proportion of R&D expenditure devoted to the development of open-source software[7]. The inclusion of this question means that South Africa now has data from 2005/06 until the latest published survey of 2017/18 on expenditure on open-source software development. In the publication the authors had access to data indicating the number of entities in each sector (business, government, science councils, higher education and not for profit) that attribute at least some expenditure to open-source development as well as the aggregated and provincial expenditure in each sector.

At the time of publication only two surveys with the question on open-source software development included had been published. The authors report that in 2005/6 and 2006/7 total expenditure on R&D was R14,5 billion and R16,5 billion in the respective years. Of this, 4,5% and 5,1% were devoted to software development of which 16,1% and 23,1% were on open-source development. According to the survey a significant portion of software-related R&D was therefore through open-source development. They also find that it was mostly due to business expenditure on open-source software development. The

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[6] The source (Walker, 2004) could thus far not be located. Walker, M., (2004). What is Open Source Software? IMFO/Winter pp34 – 35, 37

[7] This appears to be unique to South Africa – see Annex Table 2. Main characteristics of BERD surveys in https://one.oecd.org/document/DSTI/EAS/STP/NESTI(2012)3/en/pdf

publication includes a provincial breakdown which indicates that most open-source development happened in Gauteng and the Western Cape.

The qualitative information gathered through interviews mainly shed light on firms' perceptions of government's failures on open-source implementation and support to the ICT sector.

It is noteworthy that firms performing open-source development that meet the necessary criteria of novelty would be eligible for the R&D tax rebate for expenses related to such development.

The publication alerted the present authors to an emerging discourse on quantifying and valuing free and open-source software and digital infrastructure. Important references related to this topic include:

- The Sixth IMF Statistical Forum: Measuring Economic Welfare in the Digital Age: What and How? Session III. What Is the Value of Unpriced Software And Data? Platforms And Markets (IMF, 2018), with presentations by Wendy Li et al (2019), Carol Robbins et al (2018) and Rana Foroohar[8];
- Measuring open-source software (OECD, 2019).

A Critical Analysis of the Policy on Free and Open Source Software Use for the South African Government (Mac Lennan & Chigona, 2010) is a paper presented at the 4th International Development Informatics Association Conference: IDIA 2010 held in Cape Town in 2010. The paper examined the government policy on open-source use and its implications in the South African context. "To uncover distortions, ideologies, and hype present in the policy, critical research perspective, using critical discourse analysis (CDA) and Habermasian theory of communicative action (TCA), was adopted. The main purpose of the research was to identify communicative distortions and evaluate their implications for OSS use in South Africa." The analysis was performed on four sections of the *Policy on Free and Open Source software use for South African Government* (DPSA, 2006) using a methodology proposed in Cukier et al (2004) (Cukier et al., 2004). In terms of the Habermasian methodology a discourse analysis is performed in which four validity claims, which must exist for the ideal speech situation to be realised, are examined. The four types of claims examined are truth, clarity, sincerity, and legitimacy claims.

The authors identify several communicative distortions in the policy on open-source use of which the majority are related to the declared benefits of open-source, legitimation forms, and use of metaphors and connotative language. The authors state that "[m]ost of the distortions show a strong bias towards OSS that can be partially explained by the government unrealistic expectations of the OSS social and economic benefits, such as spin-off development of the local ICT skills base, job creation, raising the profile of South Africa in the global economy, and promoting a culture of openness and transparency in the government". According to this Habermasian analysis, the seeds of failure can be discerned in the text of the 2006 policy.

Open-source software deployment in the public sector: a review of Botswana and South Africa (Mutula & Kalaote, 2010) is an article published in the journal *Library Hi Tech*. The paper consists of a review of the use of open-source software in the public sector in Botswana and South Africa. In the case of Botswana this was done through interviews with of information technology managers from ICT-intensive government ministries. The information on South Africa was gleaned from secondary sources. The paper therefore adds no new empirical data relevant to the present study but does reference a number of open-

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[8] No paper provided but the recording of her input can be viewed at
https://www.imf.org/en/News/Seminars/Conferences/2018/04/06/6th-statistics-forum

source projects in South Africa including CSIR research projects such as the Advanced Fire Information System (AFIS).

Implementing open-source software to conform to national policy (Weilbach & Byrne, 2011) is an article in the *Journal of Systems and Information Technology*. The publication investigated the implementation process of an open-source enterprise management system in the South African public sector. It provides useful background on the open-source phenomenon in South Africa including references not found in some of the other publications. The paper is based on an interpretive approach, using a single-case study focussed on the implementation an enterprise content management (ECM). The case study is revealing in terms of the dynamics between various actors in the department where the system was being implemented and the State Information Technology Agency (SITA) and an external open-source service provider that was responsible for setting up and implementing the new open-source ECM system.

Exploring the politics of Free/Libre/Open Source Software (FLOSS) in the context of contemporary South Africa; How are open policies implemented in practice (Handlykken, 2012) is an article published in The Journal of Community Informatics in 2012. The article reports on an investigation of the politics of FLOSS in the context of South Africa based on fieldwork, mostly interviews, conducted in the country in 2010. The "field note" identified and explored a gap between the promise and practise of the FLOSS policy in South Africa. The authors argue that "diverging interpretations and meanings of openness are interrelated with local context and making of policies" and that FLOSS policy is not sufficient for success and that attention must be paid to the politics of implementation and participation of communities. The publication contains useful information on the views of a number of actors that were involved in the South African open-source phenomenon and can serve as a source of potential respondents for the present study.

Deployment of open-source electronic content management software in national government departments in South Africa (Ngoepe, 2015) reports the deployment of open-source electronic content management software in national government departments in South Africa. The paper follows a qualitative approach in which interviews were held with four chief information officers, five information technology officials, two records managers from government departments, and one archivist from the National Archives. The study found that governmental bodies in South Africa preferred proprietary software over FOSS and that only one government department, the Department of Science and Technology, had migrated to FOSS. Various reasons were cited by the respondents including a perceived lack of support for FOSS, a lack of IT skills by records management practitioners, and hidden costs due to internal staff needing to support, tailor and enhance the software. The author is of the view that greater awareness of the benefits of the FOSS policy in South Africa is required to promote migration to FOSS.

2.3.3. Conclusion

Although the body of literature on the South African open-source policy included in the short-list is small, a few publications have documented aspects of the historical events leading up to the adoption of the 2006 open-source policy by the South African government. These include Sibisi et al (2002) and Sibisi et al (2004) and Gopalakrishnan (2006).

Most of the other publications are concerned with implementation of the policy after 2006 including Mtsweni and Biermann (2008), Ngeleza, Mkhize and Lubbe (2009), Van Beulen, Van Belle and Madhusudhan (2009), Mutula and Kalaote (2010), Weilbach and Byrne (2011) and Ngoepe (2015). Amongst these Van Beulen, Van Belle and Madhusudhan (2009) provide interesting documentation on open-source development in four companies in South Africa. Mosoval et al. (2006) explores the state of

open-source software in South Africa and investigates the supply and demand of open-source professionals.

Three papers in the collection offer different perspectives through different theoretical lenses or different empirical data. Specifically, Mac Lennan and Chigona (2010) analysed the 2006 South African open-source policy using critical discourse analysis (CDA) and Habermasian theory of communicative action (TCA), in the process revealing several communication distortion in the policy text. Gastrow and Parker (2009) report on uniquely South African data on open-source software development expenditure collected as part of the National RD survey since 2005/2006. Lastly Handlykken (2012) reports on the politics of open-source implementation through a field study with various open-source actors.

3. Qualitative Case Study

In this section we present case studies of Open Source Hardware (OSH) and OSS projects in Africa. Each case provides project information, lessons, challenges and insights of key players. Case studies were selected taking the following into consideration: (i) mature, well-known case studies that are greater than ten years old and may or may not be active are selected to factor in historic open-source environments in Africa; (ii) new case studies that are at early stage and are selected to ensure that the current African open-source environment and ecosystem is evaluated; and (iii) projects from multiple African countries are selected to ensure that the wider African continent is represented.

The majority of well-established open-source projects in the application space are from South Africa and Kenya. The section on open-source Internet protocol contributions from the African continent provides contributions from additional African countries: Mauritius, Egypt and Morocco.

The following case studies were selected

- Village Telco, South Africa;
- iNethi, South Africa;
- Masakhane, South Africa;
- Ushahidi, Kenya;
- Grassroots Economics, Kenya;
- OpenUp, South Africa;
- Translate.org, South Africa;
- Crane Cloud, Uganda;
- Open Source Community Africa (OSCA), Nigeria.

We carried out quantitative analysis on the projects that had presence on GitHub to understand the level of African contributions in each of them (see Section 6).

3.1.   Village Telco

Village Telco[9] is an initiative to build low-cost community telephone network hardware and software. Village Telco uses open-source telephony software and low cost wireless mesh networking technology to deliver affordable telephony to underserved areas. Village Telco was founded by a South African and its principal source of funding was from the South African entrepreneur Mark Shuttleworth via the Shuttleworth Foundation. However, most active contributions came from Australia, Germany, and other

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[9] https://villagetelco.org/about/

Western countries. Most African contributions were in terms of feedback, and to a lesser extent code development. Village Telco involved deployments in rural and under-resourced settings, and local communities participated in the deployment process. It is important to note that in 2008, when Village Telco launched, wireless hacking was still in its infancy. Most open-source focused on wireless networking was undertaken by hackers, that is interested individuals rather than projects or companies. Generally, it is a field with a steep learning curve, and even today it is not easy to find skilled contributors – not only in Africa but globally.

Overall, people who could make use of the project in a practical setting, those who had a problem to solve, also had a strong interest to contribute. A key learning from this is that when there is no place to deploy it, a product remains just an idea.

In terms of the business model, Village Telco sold hardware that enabled people located in close physical proximity to each other to make free local calls but were charged for connections to wider telecommunications networks (breakout). However sales were not sufficient for it to achieve economies of scale and thus become sustainable. That may have been because the upfront cost of the hardware was prohibitive for communities that would benefit from it most. The inhibiting factors therefore seemed to be access to capital both for potential purchasers and the project itself, and the dependence of the project on hardware sales (that relied on economies of scale).

It seems to be generally difficult to secure funding for open-source hardware, as investors normally want to secure return on their investments which is usually in the form of intellectual property. The costs of releasing a new version of a hardware product (including prototyping etc.) is enormous compared to new software releases. An interview with the founder of Village Telco revealed insights about contributions, funding, and major obstacles regarding developing open-source hardware.

Another interesting lesson that was highlighted during the interview was the attempt to run a global business from South Africa, a country where exchange controls were a giant obstacle, including limitations on amount of money that can be brought into the country, and what could be exported, including the bêtise treatment of intellectual property as capital subject to currency export control.

While the project became inactive it formed the basis for successful projects in Mexico and Argentina, namely LibreRouter run by Altermundi. (Shuttleworth Foundation, 2017)

Table 3: Summary of Village Telco case study

Project info	Name	Person/ Lead	Country	Years active	Standalone product or to be used as infrastructure?
	Village Telco	Steve Song	South Africa	Still active (y/n) 2009-2016 (n)	Infrastructure
Visibility	**Website** https://villagetelco.org	**Source code link** https://github.com/villagetelco http://download.villagetelco.org https://sourceforge.net/projects/villagetelco	**Blogs** https://villagetelco.org/blog http://wiki.villagetelco.org/Background https://manypossibilities.net/2008/	**Others (media, academic articles, social media)** https://en.wikipedia.org/wiki/Village_Telco	**Reflections: best way to increase visibility?**

			09/mesh-potato-gets-cooking/	https://www.linuxjournal.com/magazine/mesh-potato https://twitter.com/villagetelco	
Funding	**Principal funding source** Shuttleworth Foundation	**Additional funding source** Funder's own money	**Business model/ sustainability** Hardware product was for sale, however, didn't do well enough to become self-sustainable (startup limbo)	**Contributors: paid or volunteers?**	**Wishlist?** Difficult to secure funding for open-source hardware, as investors usually want to secure return on their investments which is usually in form of IP.
Stakeholders	**Core authors** Steve Song David Rowe Elektra	**Contributors** Steve Song Terry Gillett Elektra Keith Williamson	**Partners** Freifunk University of the Western Cape	**Similar projects** LibreRouter (successor to Village Telco)	**What does/ doesn't work? What makes it African?** Founded by a South African and principal source of funding from a South African.
Community	**Number of users**	**Coverage (countries)** Deployments in South Africa, Nigeria, Colombia, Brazil, Puerto Rico, East Timor https://villagetelco.org/deployments/	**Motivation to contribute** People who had a practical application of the project, and a problem to solve, they had a strong interest to contribute. If you don't have a place to deploy it, it remains just an idea.	**Barriers to participation** In 2008 wireless hacking was still in its infancy and only in the realm of hackers. Generally it's a field with a steep learning curve. Hardware is generally tricky; people prefer something supported by a vendor.	**What does/ doesn't work? What makes it African?** Most African contributions were in terms of feedback, not so much code development. When it comes to deployment, local communities were participating more.
Infrastructure	**Hardware** Open hardware	**Software**	**Hosting**	**Scalability (adding new features)**	**What's missing?**

3.2.　iNethi Technologies

iNethi Technologies[10] works with communities to co-design a content sharing and services platform for community wireless networks. This is made possible through the iNethi platform – an extendable docker-based locally hosted server that allows users to easily generate and share content and synchronise this content between the global and local cloud. To understand the inner workings of iNethi Technologies, we conducted a mixed-methodology study consisting of interviews, reviewing secondary data, and using platforms provided by iNethi technologies (like cloud storage and chat, which were used during interactions with the project team). Between April and June 2022, semi-structured interviews were conducted with three participants, who are contributing in various capacities on the iNethi project – a co-founder, a director and a student volunteer. These interviews sought to understand issues like the motivation and background of the project, funding and support, stakeholders, community support and ownership, current infrastructure, numbers of users, and wish lists, among others.

In terms of community support and ownership, participants indicated that their motivation was the desire to contribute to building their communities by using their technical skills to improve service delivery. For example, a student volunteer noted that contributing to the project equipped him with practical skills to supplement theoretical classes at the university, yet these skills are also contributing positively in the communities in which he lives. For one of the co-founders, co-designing and co-deploying are in her words "…not deploying it ourselves or designing it ourselves and then dropping it in, but really working directly with the communities to develop it together and develop a plan for ongoing deployment and sustainability".

In terms of funding, similar to many open-source projects, iNethi Technologies is mostly self-funded (by founders and directors). Supplementary funding has been received for infrastructure and particular training needs, but it is not enough to sustain the project. One of the co-founders informed us that: "I'm doing this because I believe it's important, and I'm driven because I see the potential impact. This is not driven by the fact that there's lots of good money."

However, it is important to establish more sustainable sources of funding for this community project.

Table 4: Summary of iNethi Technologies case study

Project Information	Name iNethi Technologies (inethi' translates to 'network' in isiXhosa)	Person/Lead Melissa Densmore David Johnson Senka Hadzic	Country South Africa	Years active Still active (y/n) 2016 to date	Standalone project or to be used as infrastructure Both. Infrastructure in terms of a WiFi mesh service. Additional services like Cloud and chat.

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[10] https://www.inethi.org.za/

Visibility	**Website** https://www.inethi.org.za/	**Source code link** https://github/inethi	**Blogs (recent)** Rastafarian community enjoying wind powered Internet through iNethi First residential Wi-Fi mesh access to iNethi services installed at Sevens Flats	**Publications** Stakeholder Relations and Ownership of a Community Wireless Network: The Case of iNethi [Paper]	**Reflections: best way to increase visibility** Share existing publications and key learnings with other similar projects (for example the African Community Network Summit)
Funding	**Principal funding source** Mostly self-funded	**Additional funding source** Indirect project funding from: The Internet Society, Facebook (to link iNethi to a locally owner cellular network) and CSIR in Morocco.	**Business model/sustainability** Relying on the Community, Volunteers and Directors	**Contributors: paid or volunteers?** Volunteers	**Wish list** Get more contributors
Stakeholders	**Core authors** David Johnson, Amreesh Phokeer and Melissa Densmoore	**Contributors** Multiple	**Partners** University of Cape Town	**Similar Projects** Zenzeleni Rhizomatica	**What does/does not work? What makes it African?** Communities have indicated benefits of the project. Project is based in South Africa.
Community	**Number of Users** Not well established yet.	**Coverage (countries)** South Africa. There are hopes to expand once this initial deployment in South Africa is successful.	**Motivation to contribute** Building community	**Barriers to participation** Cost	**What does / does not work?** Works: Project is run by Co-founders, Directors and the community, who can request for services. Does not work: Many regular and active contributors

| Infrastructure | Hardware

Server located in the community (fairly low cost: Intel NUC with SSD drive). | Software | Hosting

Amazon Cloud , synchronised and backed up locally. | Scalability (adding new features)

Requests mostly come from the community. This will depend on community needs. | What is missing?

Funding and active contributors |

3.3. Masakhane

Masakhane is a Natural Language Processing (NLP) community that aims to build machine translation infrastructure for under-resourced African languages. It addresses the problem that African languages are under-represented and under-resourced in natural language processing and machine translation. Masakhane is primarily a community, rather than a set of infrastructures, although Masakhane has been developing NLP software (JoeyNMT) and resources for NLP.

Table 5: Summary of Masakhane case study

| Project info | Name

Masakhane

(translates to 'we build together' in isiZulu) | Person/ Lead

Jade Abbott, Co-Founder | Country

South Africa | Years active

Still active (y/n)

2019 to date (y) | Standalone product or to be used as infrastructure?

Data and code to build open baseline for NLP for African languages. |
| Visibility | Website

https://www.masakhane.io/ | Source code link

https://github.com/masakhane-io/masakhane-community | Blogs

Publication List | Others (media, academic articles, social media)

The poetic process powering real time language translation in Namibia (Quartz Africa)

The Masakhane project wants Machine translation and AI to transform Africa (Venture Beat)

AI in Africa: Teaching a bot | Reflections: best way to increase visibility? |

				to read my mum's texts (BBC)	
Funding	**Principal funding source** Data Science for Social Impact, University of Pretoria. Translators without borders. RAIL LAB, University of Witwatersrand.	**Additional funding source**	**Business model/ sustainability** Open-source contributors on GitHub and community activities.	**Contributors: paid or volunteers?** Volunteers.	**Wishlist/Help needed?** Accessing or creating datasets. Training and analysing models. Mentoring budding practitioners. Capturing the journey.
Stakeholders	**Core authors** Vukosi Marivate Bonaventure Dossou	**Contributors** Dr. Johanna Havemann Sibusiso Biyela	**Partners** Same as principal funding source.	**Similar projects**	**What does/ doesn't work? What makes it African?** Most community participants are from Africa. See community section below.
Community	**Number of users**	**Coverage (countries)** The community consists of 1,000+ participants from 30 African countries and 3+ countries outside Africa.	**Motivation to contribute**	**Barriers to participation**	**What does/ doesn't work? What makes it African?** Most African contributions were in the form of feedback, that than code contributions. However, local communities were participating in deployment.
Infrastructure	**Hardware** N/A	**Software** N/A	**Hosting** Content hosted on GitHub	**Scalability (adding new features)** Requests raised by the community.	**What's missing?** N/A
Other relevant info	**Contribution** As of February 2020, over 49 translation results	**Award** Won the inaugural 2021 Wikimedia			

	for over 38 African languages have been published by over 35 contributors on GitHub.	Foundation Research Award of the Year.			

3.4.   Ushahidi

Ushahidi is an open-source software application which utilises user-generated reports to collate and map data for decision-making at individual, community, organisational and government levels.

Founded in 2008, as a tool to monitor and map post-election violence in Kenya, Ushahidi is a global not-for-profit technology company that develops integrated tools and services to enable people to generate solutions and mobilise communities for good.

We interviewed Ushahidi's chief technology officer , who has been with the organisation since 2014 and has held several roles. During our interview, we learnt that in 2015, the organisation started talking about sustainability and the need to charge for access to data – a decision that was caused by a decrease in available funding.

Historically, funding came from a handful of donors mostly based on achievements during the 2007-2008 Kenyan elections. Then it moved to being tied to specific programmes, though the aim continued to be making the tools as widely available as possible. At this point, the goal was to allow free access to data for 30 days and then request a small fee once the project had gained traction. This was not successful, because as noted by the chief technology officers: "As soon as you start charging a fee, people step back."

In recent years, the funding has been diversified but is still mostly sourced from philanthropic donors across the globe. The Ushahidi community is global, with a presence in most countries. The project started in Kenya, although the organisation is registered in the US and based in Nairobi Kenya, with 70% of the staff based on the African continent (mostly in Kenya). Their projects, a third of which have contributors from Africa, range from mapping, crisis response (including COVID-19 response), election monitoring, grassroots journalism and fun projects. The organisation helps designers to get involved in developing open-source solutions and contributions are not only limited to lines of code but may include data, design and research. Some other projects have spawned because of this success story, including iHub, BRCK and AkiraChix. When Ushahidi launched, there were not many data centres on the African continent, hence the decision for infrastructure to be cloud-based (i.e., rackspace on Amazon Web Services (AWS)) for stability and to give time for contributors to focus on software. There are plans to move to African-based data centres to improve speeds and access experiences for users in Africa.

In terms of challenges, it is difficult to make open-source and paid data co-exist, therefore the organisation will keep applying for donor funding to ensure Ushahidi projects continue running.

As the chief technology officer put it: "The challenge for us is rekindling the open-source connection but it may just be a matter of clarity – somehow, for people to understand that our purpose is not to grow an open-source community so that we can benefit economically from their work. That needs to be acknowledged that it could be in their minds."

Ushahidi's wish is to make it easy to contribute to open-source so that everyone feels that it is rewarding to contribute for civic reasons, getting their acknowledgements for contributions, and building a healthy, and self-sustainable ecosystem.

Table 6: Summary of Ushahidi case study

Project info	**Name** Ushahidi	**Person/ Lead** Erik Hersman, Ory Okollloh, Juliana Rotich, David Kobia	**Country** Kenya	**Years active** Still active (y/n) 2008 to date (y)	**Standalone product or to be used as infrastructure?** Open-source, software as a service (SaaS) application which utilises user-generated reports to collate and map data.
Visibility	**Website** https://www.ushahidi.com/	**Source code link** https://github.com/ushahidi	**Blogs** https://www.ushahidi.com/about/blog/	**Others (media, academic articles, social media)** 50 Disruptive Companies (MIT Technology Review) Ushahidi: crowdmapping collecting that exposed Kenyan election killings (The Guardian)	**Reflections: best way to increase visibility?**
Funding	**Principal funding source** Grants Subscription fees	**Additional funding source** Omidyar Network (US$1.4M)	**Business model/ sustainability** Grant funding and revenue generation from subscriptions.	**Contributors: paid or volunteers?** Volunteers and paid staff.	**Wishlist?** Make it easy to contribute to open-source.
Stakeholders	**Core authors** Erik Hersman Angela Oduor Lungati Juliana Rotich Nathaniel Manning	**Contributors** June Mwangi Cecilia Hinga	**Partners** (Supporters) Bylo Chacon Foundation, Cisco, Digital Impact Alliance, Ford Foundation, Google, Grant for the Web, Humanity United, Knight Foundation, MacArthur Foundation,	**Similar projects** iHub, BRCK and AkiraChix	**What does/ doesn't work? What makes it African?** Founded in Nairobi Kenya and a big percentage of contributors and staff are based on the African continent.

			Omidyar Network, Rockefeller Foundation, UKAID, USAID		
Community	**Number of users**	**Coverage (countries)**	**Motivation to contribute** Strengthen communities, improve lives and empower users to rapidly and purposefully father, analyse, respond and act on data and information.	**Barriers to participation** Costs needed to participate.	**What does/ doesn't work? What makes it African?** Most African contributions were in terms of feedback, not so much code development. When it comes to deployment, local communities were participating more.
Infrastructure	**Hardware** N/A	**Software** SaaS	**Hosting** Amazon Web Services (AWS)	**Scalability (adding new features)** Requests raised by the community.	**What's missing?** More contributors needed.
Other relevant info	**Contribution** 1,000+ examples of how Ushahidi has been used to help raise voices.	**Awards** The MacArthur Award (2013) Global Adaptation Index Prize (2012)			

3.5.   Grassroots Economics

Grassroots Economics is a Kenya-based non-profit seeking to empower marginalised communities through community inclusion currency programmes. Distributed ledger technology provides underlying protocols that allow community inclusion currencies to trade with each other directly through common reserve pools. USSD technology enables any cell phone (even without Internet) to have access to the Grassroots Economics platform. All their tools are fully open-source.

We conducted an interview with the founder, who noted that the community that has put in the work to build Grassroots Economics is 90% volunteer and about 10% paid. The main contributors are people who believe in the philosophy and want to build tools to build more cooperative and inclusive societies. The largest barrier to participation is lack of understanding – while not new, community currencies are still very niche. While team members and volunteers are based around the world (California, India, France, Germany, Kenya), according to the founder, "what makes this project uniquely Kenyan - is that its main users are people without internet living in rural Kenya."

The funding mainly comes from donations from family members and humanitarian organisations that have seen the effectiveness of the work. Increasingly, Grassroots Economics Foundation is finding groups

that want to be consulted on creation and management of community currency programmes and technology.

An interesting observation was that all the repositories are hosted on GitLab, an open-source repository that allows self-hosting but has a much smaller market share (less than 5%) for publicly listed open-source projects. The code base can run on any cloud platform (it is currently running on Digital Ocean but could run on a local off-line server) and the code can be hosted on an open-source repository. There is no specific tie-in to any of these platforms. Any decision would be based on a trade-off of code and data sovereignty, local availability as well as global reach.

Table 7: Summary of Grassroots Economics Case Study

Project info	**Name** Grassroots Economics	**Person/ Lead** Will Ruddick, Founder; Shaila Agha, Direcot	**Country** Kenya	**Years active** Still active (y/n) 2010 to date (y)	**Standalone product or to be used as infrastructure?** CIC Stack
Visibility	**Website** https://www.grassrootseconomics.org/	**Source code link** GitHub https://github.com/GrassrootsEconomics GitLab https://gitlab.com/grassrootseconomics	**Blogs** https://www.grassrootseconomics.org/category/blog.html	**Others (media, academic articles, social media)** Token Engineering https://tokenengineeringcommunity.github.io/website/ Sarafu Credit's Ruddick and Dama: Community currencies create a stable medium of exchange tied to local developments during covid	**Reflections: best way to increase visibility?**
Funding	**Principal funding source** Individual donations from family and friends; Humanitarian organisations	**Additional funding source**	**Business model/ sustainability** Open-source contributors on GitHub and community activities.	**Contributors: paid or volunteers?** Staff, volunteers, community groups	**Wishlist/Help needed?**
Stakeholders	**Core authors** Will Ruddick, Shaila Agha	**Contributors**	**Partners** Stichting Doen, Danish Red Cross, Government of Kenya, Institute for Leadership and	**Similar projects**	**What does/ doesn't work? What makes it African?** It was founded in Kenya, has been implemented in 45+ locations across

			Sustainability (IFLAS)		Kenya and assisted two in South Africa.
Community	**Number of users** 60,000+ small businesses, churches and schools.	**Coverage (countries)** The community consists of 1,000+ participants from 30 African countries and 3+ countries outside Africa.	**Motivation to contribute** Empowers communities to take charge of their own livelihoods.	**Barriers to participation** Access to resources	**What does/ doesn't work? What makes it African?**
Infrastructure	**Hardware** N/A	**Software** N/A	**Hosting** Content hosted on GitHub	**Scalability (adding new features)**	**What's missing?** N/A
Other relevant info	**Contribution**	**Award**			

3.6. OpenUp

Founded in 2013, OpenUp is a South Africa-based civic technology organisation with a goal to inform, empower and activate citizens. Their mission is to use data and technology to promote informed decision-making in order to drive positive social change. Their mandate is to use and develop open-source solutions, which promote sustainability in public sector companies.

We conducted an interview with the co-founder and director, who noted that their funding is diversified – grants from donors, public funds through the South African government and revenue generated from other activities and projects. The initial team at OpenUp was made up mainly of developers, making their open-source projects look appealing to funders, and which reduced the challenges of securing funding. All projects follow a user-centred design approach, though the project brief and requirements are often provided by the client and not the end users. On GitHub, OpenUp has been ranked as one of the top contributors in South Africa.

During our interview, we learnt that funders and some clients have pushed back on having open-source solutions or data, especially when they think that their data should not be in the public domain. The decision to maintain open data is determined on a case-by-case basis. One of their flagship projects (provided jointly with Media Monitoring Africa), WaziMap (from the isiXhosa word 'ulwazi' for knowledge), is a visual map that provides easy access to South African census and elections data.

When asked about challenges, we learnt that wrangling information into good quality (not just open) usable data is a big challenge. This issue is not discussed enough in the open-source community. In some cases, organisations are not ready to make data available, and communicating why some data – especially data from the public sector – is not easy. In addition to buy-in, there are capacity challenges and on some occasions, clients do not have a lot of confidence in using technology. Therefore,

communities and organisations need to be empowered to collect and upload data and contribute to open-source initiatives.

In their work, OpenUp has developed solutions in the southern African region, where sustainability, data generation (e.g., citizen monitoring and learning to market data pipelines), and project sufficiency are considered. The organisation has started to engage with communities to discuss climate change issues, with the hope of contributing data for global discussions.

3.7.   Translate.org

Translate.org is a non-profit organisation with a focus on the use of open-source software for the localisation of applications in South African languages. In our interview with the founder of Translate.org, we learnt that their objectives changed over time. The initial goal was not really FOSS, but to develop technology to support local languages. Later, the goals changed to focus on open-source tools aimed for the desktop and which would run on both Windows and Linux environments. This prompted the organisation to purchase keyboards that support multi-language characters. Translate.org's projects included translating OpenOffice and the Mozilla Firefox browser to African languages and to produce software that is usable by people in multiple languages.

The organisation relied on a deep desire by the community to contribute though translators that received payment for their services, sometimes in the form of payment towards their student loan debts or transport and meal refunds. It was highlighted that translators did not necessarily need to possess technology skills. While originally started in South Africa, projects and contributions were also completed in Namibia and with the Fula people (mostly in West Africa and Europe) and some Africa-wide projects where anyone was welcome to contribute. Data was initially hosted on infrastructure that was set up locally, slowly moving to GitHub. GitHub only became publicly available from April 2008 whereas Translate.org preceded this by several years. The organisation's successes included creating a map of characters needed to cover Africa. Currently 100 locales are covered in Unicode. The locals were collected using existing data formats at the time. Collaboration around common formats is key, as our interviewee explains: "What we found in the space, and this is a common thing in open-source is it is very easy to create something new, it is a little bit harder to collaborate but there is a lot of new stuff."

In addition to challenges of getting volunteers, the interview revealed that the organisation sometimes got backlash for breaking the code when translations were not done correctly. Sometimes, priorities between funders and local communities did not match. For example, some funding priorities were not relevant for certain local contexts (i.e., internationalisation versus localisation). This made it difficult to stay true to the organisation's goals. On other occasions, collaborating with other parts of the world made it complex as different organisations had different priorities and styles of work.

It was acknowledged that translation is a lot of work and should not be the reason for funders not supporting projects. In the case of text-to-speech for isiZulu, a tonal language, our interviewee noted the difficulty in balancing the academic approach where translations are not considered good enough until you get the tones right, vs the engineering approach to open-source where rapid prototypes are deployed and improved later. On some occasions, "good enough" is better than nothing:" If you are blind, and if your text-to-speech can read Zulu without tones, it is better than nothing."

3.8.   Crane Cloud

Crane Cloud is a managed cloud service platform that supports application deployment, application monitoring, service scheduling and auto scaling and replication. It is based at Makerere University, Uganda's biggest and oldest public institution. Currently, the service is hosted on servers at the

University, providing a platform for students, staff, and other projects within the University to deploy their own software projects.

In an interview with the project manager, he revealed many people still do not trust hosting services locally in Uganda and the institutions due to previous constraints like fibre cuts (that may cut the link to the local server), electricity load shedding, and expensive bandwidth costs, among others. He noted that it is difficult to set up a cloud service in Uganda due to the issues mentioned above, and the need to ensure availability. Interestingly, even government entities have opted for more popular and international providers, citing no guarantees for availability and reliability.

In terms of hosting on GitHub, the project initially created a public repository that has now been closed for internal contributions only. When asked why, the project manager noted that his team prefers to have a clearer model on contributions, so, currently, the code is open but contributions are limited to team members only. This is anticipated to change once a suitable model is developed.

The project experiences similar funding challenges, receiving funding mostly from the Government of Uganda (through Makerere University) and an individual donor, based in Washington, DC, and who prefers to remain anonymous to the public. So far, $140,000 has been donated to the project.

3.9.   Open Source Community Africa (OSCA)

Open Source Community Africa (OSCA) is a community of open-source enthusiasts, advocates and experts in the region interested in increasing the rate of credible open-source contributions from Africa. OSCA builds communities through Chapters, Open Source Festivals and open-source projects.

We conducted an interview with Samson Goddy, a co-founder of the OSCA, who maps the OSCA vision and coordinates their role of sustaining the open-source community in Africa. They work within the open-source network to fundraise and organise events that advocate forFOSS on the continent. Outreach is in two forms: The City Chapter Programme with more than 60 cities across Africa, and the Open Source Festival, which was held at the start of 2020. The volunteer-based community of over 5,000 people comprises students, early stage careers (mostly recent graduates trying to find employment opportunities) and experienced professionals who provide mentorship to newcomers.

The co-founder informed us that they "have been lucky" as funding has not been a challenge. Funding for events and activities has been sourced through personal connections and from donations from big technology companies like Meta, Mozilla, Google and GitHub.

In terms of barriers, the knowledge gap (i.e., ideas about open-source) is one of the biggest challenges, prompting their advocacy campaigns to get experienced people to contribute and provide mentorship to newcomers. Additionally, Goddy noted that currently most contributions are in English, though OSCA is working to bring in a variety of languages:"Diversity is still a major problem in the continent, particularly for example within our organisation we haven't seen anyone from the Francophone region. Language barrier is something we are hoping to solve. Even within Northern Africa, Arabic is something we need to work on [...] we still have a long way to go."

3.10. Discussion

Our analysis of the case studies shows that funding is the primary challenge for open-source projects. For many of the projects we analysed, the inception was challenging because it was hard to get funding without proof of prior experience or history of previously received grants. On many occasions, organisations and individuals relied on personal funds or support from family and friends in order to prove that their ideas were worth investing in.

"Our funding has come mainly from donations from family members and humanitarian organisations that have seen the effectiveness of our work. Note that our budgets for technology are never funded for the sake of tech, but rather for specific humanitarian applications." *Will Ruddick, Grassroots Economics, Kenya*

> A commonly adopted model by African non-profit organisations deploying open-source infrastructure is donor funding, complemented by providing consultancy services

Financial sustainability of open-source projects largely depends on sustainable business models. Many open-source projects are donor funded, and there is often a lack of vision on sustaining an initiative once the funding runs out. On some occasions, there was a mismatch between donor interests and an organisation's motivation to develop open-source solutions, which caused strains in communication. For example, some organisations or governments may fund an initiative but are not willing to make the data openly available.

A commonly adopted model by African non-profit organisations deploying open-source infrastructure is donor funding, complemented by providing consultancy services on either tools they build or subject matter expertise.

The analysis also shows a mixed motivation for participation in open-source projects in Africa. Some funded initiatives are only able to attract developers they require by paying a market rate for contributions. Other initiatives rely on voluntary work from

> In the case of African projects, code is largely written by students, as part of their studies

contributors whose main motivation is often to build their portfolio and reputation. Specifically in the case of African projects, code is largely written by students, as part of their studies or as they prepare to get into the job market, which makes regular contributions challenging. On the other hand, many contributors from the Global North decide to participate as volunteers, driven by philanthropic motivation as well as the desire to make an impact.

The review also finds that the majority of well-established open-source projects in the application space are from South Africa and Kenya. According to an interviewee, the average age of Kenyan developers is 23 - which is extremely young. However, unlike many software developers in the global north, coders usually start doing

> young developers are very likely to land a corporate job and make a living, rather than hacking around with open-source

personal-interest projects and open-source at some later stage of their career, often once they accumulate some money and confidence to do whatever they want to do. This might explain why the potential pool of contributors is relatively small in the continent.

"In Kenya, once you're in IT, you are the hope of your entire family and need to send money back home. The tech space is growing, so young developers are very likely to land a corporate job and make a living, rather than hacking around with open-source."

Participant, Kenya

There were other interesting insights around data. While contributions are an important aspect of maintaining open-source projects, some organisations are continuously working to ensure that data is not only open but is of good quality and usable.

> Fewer contributors from non-English speaking countries on the continent

Additionally, one of our participants expressed knowledge gap barriers and diversity issues that include not having a full understanding of open-source and getting fewer contributors from non-English speaking countries on the continent.

"Diversity is still a major problem in the continent, particularly for example within our organisation we haven't seen anyone from the francophone region. Language barrier is something we are hoping to solve. Even within Northern Africa, Arabic is something we need to work on [...] we still have a long way to go."

Samson Goddy, Open Source Community Africa (OSCA)

4. African Open Source Contributions to Internet standards

4.1. Background

The Internet is made up of two building blocks: (1) "the network" which is the underlying infrastructure that allows hosts to send information from one place to another, and (2) "the web" which allows users to consume the information in different forms. Both building blocks are powered by numerous open protocols maintained and developed by open standards organisations. The Internet Engineering Task Force (IETF) develops and promotes the "Internet standards", for example, the technical standards that comprise the Internet Protocol suite (TCP/IP) or the Domain Name System (DNS). On the other hand, the World Wide Web Consortium (W3C) supports the development of "web standards" typically implemented by browsers and other applications.

The IETF is a community-driven organisation where there are no formal membership requirements. Any person interested in any Internet protocol may join a working group on an individual basis and propose new standards or best practices or changes to existing protocols. All proposals in a working group start as a draft and are then debated publicly until 'rough consensus' is reached. Once the proposal is accepted[11], it becomes an Internet standard, also known as an RFC (Request for Comments). The consensus-building process is central to the work of the IETF and is documented in RFC 7282[12].

The IETF has an unofficial motto, "We believe in rough consensus and running code". This means that the implementation experience provides critical feedback to the standardisation process. This particular aspect is promoted via 'hackathon' events, which are coding boot camps organised at every IETF meeting and where participants get together to implement an existing or proposed Internet standard. Very often, these implementations are done on existing open-source software packages such as LibreSSL or OpenSSH.

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[11] An RFC starts as a draft document proposed by one or more authors. The members of the working group will determine via the consensus mechanism whether the draft is eligible. If there is consensus, the document moves from being an "individual" document to a "working group" document. Based on the feedback of the members, the document will undergo several revisions and through another round of consensus, the working group chairs will propose that this document becomes an RFC. The IESG (Internet Engineering Steering Group) provides the final stamp for the draft to become an RFC after review.

[12] https://datatracker.ietf.org/doc/html/rfc7282

Participation at the IETF is done on an individual basis and authors of an Internet draft[13] (a proposal) provide their contact details including their current address. Using this information provided we could infer which region this contribution is coming from.

In 2021, the IETF ran a community survey[14] to understand the IETF community size and demographics. One of the findings was that US/Canada and Europe still dominate IETF participation, and that this trend is only slowly changing. Representation from Africa remains considerably low.

4.2.   Statistics

Africa has the least number of documents (drafts and RFCs), as well as the least number of authors coming from an African country. There are currently 15 RFCs and nine drafts (both active and expired) from Africa. As of this date[15], there are 9170 RFCs that have been published, which means African contribution to the IETF is almost negligible (0.26 %).
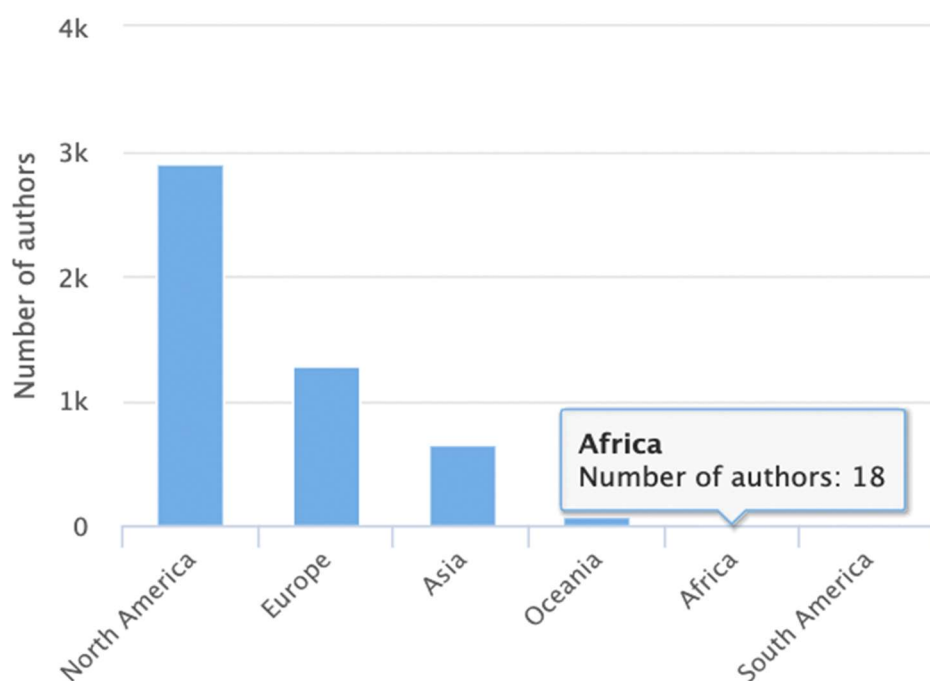
Figure 2: Number of RFC authors per continent (Source: IETF16)

We can also see the number of RFCs published over time categorised by continent. The number of contributions from developing regions (South America, Oceania, and Africa) remained consistently low. Figure 3 shows that North America, Europe, and Asia are the largest contributors to Internet standards.
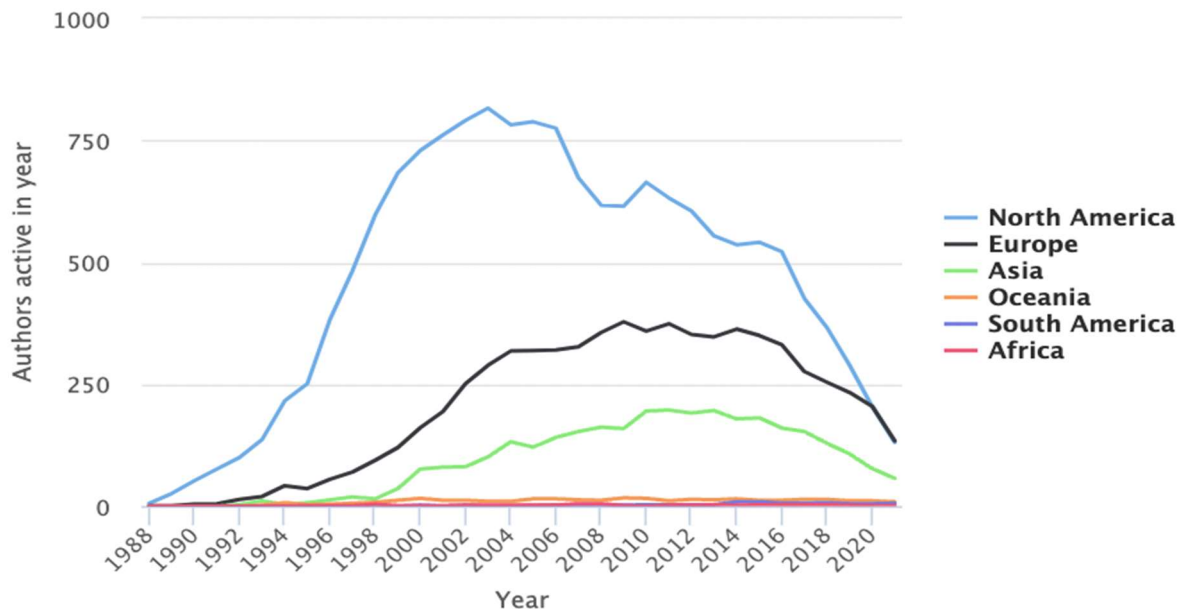
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[13] Internet drafts are proposals that are either active (under discussion) or expired (no consensus reached)

[14] https://www.ietf.org/media/documents/IETF_Community_Survey_2021.pdf

[15] 04 January 2021

[16] https://datatracker.ietf.org/stats/document/author/continent/?type=rfc

Figure 3: Number of RFCs per continent over time (Source: IETF17)

Table 8: Summary of the number of documents and their associated country of origin from Africa

Country	RFC published	Draft	Affiliations
Mauritius[18]	8	1	• Open-source community • Individual contributor • RIR
South Africa	2	6	• Network operator • Community network • Academia
Egypt	2	5	• Network operator
Morocco	1	1	• Academia
Algeria	1		• Network operator
Kenya		4	• Network operator
Cameroon		1	• Network operator
Uganda		1	• Network operator

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[17] https://datatracker.ietf.org/stats/document/author/continent/?type=rfc

[18] For Mauritius there is a concentration towards one author only, who is very active in the open-source community and organizes regular hackathons to implement IETF standards.

4.3. Qualitative Analysis of African Contribution to Internet Standards

To deepen our analysis on the success criteria and challenges faced by African authors with regards to participation at the IETF, we have conducted structured interviews of four different African authors who individually had different experiences with the IETF. We have based our selection on the following profiles: (1) An author from academia who has published an RFC, (2) an author from the open-source community who has published an RFC, (3) an author from a network operator, and finally (4) an author who failed to get an RFC published. The interviews helped us answer the following main questions:

1. What is the current level of involvement of Africans at the IETF?
2. Which areas or activities have Africans been involved in so far?
3. What are the motivations behind African contributions towards the development of Internet standards?
4. What are the main challenges hindering the participation of Africans in the development of Internet standards?

Interview 1: University professor who successfully published an RFC

Our first interviewee is a professor of Computer Science from Morocco. His IETF adventure started when he was first selected as an IETF fellow[19] after a first unsuccessful attempt. He said that "[t]he selection process for the fellowship is quite a stringent one where it is important to show previous participation and interest in the IETF mailing list".

He started to get involved remotely with the IPv6 and Vehicular Networks working groups where he volunteered to be part of the editorial team of a new draft (which started in 2013). The draft eventually became an RFC in 2020. The process of becoming an RFC took long as it involved external standardisation bodies such as the IEEE.

By participating physically in subsequent meetings, he was able to expand his network and was able to get traction on additional drafts in other working groups. His motivation to join the new Vehicular Networks working group was that it was related to his research activities in Morocco. He says that IETF can be a fertile ground for academics to look for research ideas.

One important consideration at the IETF is the concept of "running code". There can be more traction on a draft if it has been implemented and tested. The authors used the Linux kernel to write code to implement their design specifications.

The professor experienced no major setbacks or challenges in his IETF interactions, but he acknowledged that one of the main barriers is the language. It might be intimidating for non-English speakers to get started. Additionally, participation in the IETF requires in-depth technical expertise at the network protocol level. Finally, physical or online participation at the IETF requires funding, though a fee-waiver system[20] has been put in place to support those for whom the registration fee represents a barrier to participation.

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[19] https://www.ietfjournal.org/inviting-applications-for-fellowship-to-ietf-103/

[20] https://www.ietf.org/blog/ietf108-fee-waiver-new-policy/

Interview 2: Hackathon organiser, open-source contributor

Our second interviewee is a founding member of a group of open-source developers based in Mauritius. He is actively involved in two IETF working groups, namely CURDLE and TLS. He is also the co-chair of the ACE working group which deals with protocols for the authentication and the security of IoT devices. In total, he has published four RFCs and one draft is currently undergoing the review process in the working group.

His involvement with open Internet standards started when he was a university student.. – His end-of-year project was about extending SSH (Secure Shell) protocol (a cryptographic network protocol for operating network services securely over an unsecured network) to allow resuming file transfer. The idea was that in developing countries, bandwidth is scarce and networks are unstable, thus interrupted file transfers should be resumed rather than repeated. The initial version of SFTP (Secure File Transfer Protocol) did not have this capacity. Our interviewee tried to get in touch with people working on this protocol back in 2012, but received no concrete response. He then decided to modify SFTP to implement the download/upload resuming feature before proposing the change in the protocol at the IETF.

Our interviewee mentioned that thanks to his job as an Infrastructure Security engineer, he deals with network protocols on a daily basis. This allowed him to do a deep dive into protocols such as TLS (Transport Layer Security) used to access websites. He was the author of five RFCs which deprecates old algorithms and key sizes for increased security in different network protocols (rfc8270, rfc8709, rfc8758, rfc8997, rfc9155).

"It takes more or less one year for a draft to get accepted and changed into an RFC", he said. The bottleneck is sometimes at the steering group level for final feedback. With regards to challenges, he mentioned that it is sometimes more difficult for individuals to get their voices heard than it is for bigger companies, which already have a roadmap and a lot of influence on the system. Attending face-to-face events might be challenging due to lack of funding and this can delay the feedback process on protocol changes. This means "corridor chats" at the IETF are something important, and which increases the speed at which decisions are made. "The Internet Society has been very helpful in providing fellowships to attend IETF meetings and this has helped a lot," he reported. Gathering interest from local partners such as network operators in Mauritius helped create some synergies and attracted young students to participate in remote IETF hackathons.

Over the past few years, our interviewee personally contributed to several open-source tools such as OpenSSH, wget, and curl, on which he implemented TLS 1.3 (RFC8446). He also implemented RFC8758 on Putty.

Interview 3: Failed IETF attempts

Our third interviewee is a network and security engineer in Egypt. He is also involved with an Internet Exchange in Egypt and teaches networking. During an IPv6 course held by AFRINIC in Egypt, he discovered IPv6 and the challenges associated with deployment. He discovered that a lot of people in his community were sceptical about IPv6 deployment and the transition mechanism, so he decided to work on a new protocol that allows IPv6 networks to co-exist with IPv4 networks.

He first discussed his idea in 2014 and developed it further with the help of some IPv6 experts. However, due to a lack of financial support from his organisation, he was not able to attend IETF meetings in-person to present and defend his idea. This was considered as a major barrier as face-to-face interactions with IETF working group members and chairs can help gather support for an idea, which is very difficult to achieve when attending IETF meetings virtually.

Additionally, implementing the proposed Internet protocol to show that the idea works is something relatively important to gather support. Our interviewee mentioned that due to a lack of resources, he could not implement his idea. This was one of the reasons for a lack of success: there was no real support from the working group members.

He rates his overall experience with the IETF quite low and he mentions that his interactions with the IETF working group members ended up being quite unfriendly. He says a lot of feedback he received on his proposal was more destructive than constructive, mostly because his idea was solving a problem "where a solution already exists". Eventually, his drafts expired and were removed from the working group agenda.

Our interviewee feels that working group consensus at the IETF is very biased towards specific "cliques" within the IETF community. This is why it is difficult for newcomers (especially those coming from developing regions) to have their voices heard. The latter, in addition to the existing cultural and language barriers, makes it difficult for African engineers to participate smoothly.

Interview 4: South-African born IETF Routing Area Director

Our fourth interviewee is the chief technology officer of the R&D department of a large network operator with a very large footprint in East Africa. At the IETF, he has been active in the Source Packet Routing in NetworkinG (SPRING) Working Group which is the home of Segment Routing (SR) using MPLS (SR-MPLS) and IPv6 (SRv6). He also served as an Area Director[21] (AD) at the IETF.

Our interviewee's participation at the IETF is supported by his organisation, which believes that in order to defend a particular standpoint, on-site presence is necessary. "A lot of work at the IETF is achieved through negotiations and off-record conversations", he said.

On many occasions, a lot of the work presented at the IETF by vendors had already matured in their lab environment. They have running code and have probably already tested their new protocol or product on a large-scale basis. This means that at the IETF vendors provide very little margin for changes in the proposed protocols. African engineers usually come without much operational experience, as a result of not being exposed to latest technologies. This lack of exposure creates a divide between African engineers and the rest of the world, which is difficult to bridge. One of our interviewee's main motivations to start getting involved at the IETF was that some vendors would not take in his requests to optimise certain technologies, arguing that requests from the African market do not carry enough weight.

Furthermore, because of the nature of the work, i.e. network protocols development, engineers participating at the IETF need to know low-level details of how the operating system kernel works or how to write code that will operate at the network stack level. This very specialised knowledge, unfortunately, is usually not part of mainstream academic syllabi, especially in Africa.

It was also observed that nowadays a lot of the training materials about networking come from major networking hardware vendors. Students following vendor courses get certified on specific technologies, but in most cases, they are not taught the fundamental principles of networking.

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[21] The Area Directors for an area are jointly responsible for making sure the working groups in the area are well coordinated, that there is coverage for the technologies needed in the area, and that the challenges most important to the Internet in that area are indeed being worked on.

The result is that Africa is a net consumer of Intellectual Property (IP) and few new products or services are invented by Africans.

4.4.   The Internet Society's IETF-Africa initiative

The Internet Society launched an Africa wide initiative to increase the awareness levels and participation of various stakeholders from Africa to the IETF including universities, network operator groups, researchers, NRENs, policy organisations, ISOC Chapters and university students among others. The aim of this initiative is to encourage more researchers from Africa to take up Internet Standards development and eventually lead to Africa hosting its first IETF meeting. Over the past few years we have seen that a number of activities in relation to open Internet standards were led or coordinated by the Internet Society (ISOC) and AFRINIC. These include:

- Hackathon at the African Internet Summit;
- The setting up of various IETF viewing hubs around Africa;
- Promoting Open standards-related teaching content for university students.

The aim of the activities is to foster interest[22] amongst African researchers to explore new technologies that require standardisation such as the IoT, which may be relevant to the African community.

4.5.   Conclusion

In this section, we have looked at the level of African participation in the development of Internet standards by analysing the number of documents published by African authors. We observed that the numbers are extremely low and that there was not much progress in the last few years. In order to understand the reasons for this low participation of African network engineers at the IETF, we carried out four interviews with different persons who are connected to the IETF, examining both successful and failed attempts to participate in standards development.

On top of the financial and language barriers faced by African engineers at the IETF, one challenge that came up was the "technological barrier" to get involved. It is very difficult to partake in the activities of the different working groups if one has not been involved from the onset. In some working groups such as v6ops (IPv6 Operations), engineers working on protocol standardisation come with a lot of prior operational experience to which African engineers are not exposed to. This lack of operational exposure creates knowledge gaps, which take a lot of time and effort to bridge.

One of our interviewees also noted that there is an important "skills" problem, whereby students nowadays are not trained at doing low-level programming. The level of abstraction used in contemporary software engineering courses are more geared towards end-user products or applications rather than low-level networking or kernel types of software or processes.

To conclude, African participation at the IETF has been alarmingly low over the years but with initiatives by the Internet Society and AFRINIC, and with more awareness, African engineers will hopefully get more exposure to the world of protocol development.

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[22] https://www.internetsociety.org/blog/2016/07/promoting-internet-of-things-iot-through-ietf-africa-initiative/

5. Policy Case Study: "Go Open" In South Africa

5.1.   Introduction

During the 2000s South Africa was among a handful of countries that took to the open-source movement in a major way. A loose coalition of government technologists, hackers, policy entrepreneurs and open-source evangelists saw open-source as an opportunity to challenge the status quo and drive the then young democracy's development. Open-source was viewed as a way to transform bureaucracy inherited from the apartheid state and to contribute to development of a democratic state by moving from consuming technology to a playing a more active role in adopting, adapting and innovating digital technology. The movement would culminate in the adoption by the South African government of an open-source policy which stated that "[t]he South African Government will implement Free and Open Source Software (FOSS) unless proprietary software is demonstrated to be significantly superior. Whenever the advantages of FOSS and proprietary software are comparable, FOSS will be implemented when choosing a software solution for a new project. Whenever FOSS is not implemented, then reasons must be provided in order to justify the implementation of proprietary software"[23].

The open-source movement in the 2000s did produce some successes including adoption of open-source licensing of R&D outputs by South Africa's largest public research institute, the CSIR.

Although not a consequence of the policy process but rather an input to it, South Africa's own tech billionaire and the first African in space, Mark Shuttleworth, used open-source software to build a global enterprise, Thawte, which was sold to Verisign for $575 million. This brought further impetus and a degree of glamour to the open-source movement. It was in the same period that Shuttleworth would launch a new version of Linux-branded Ubuntu, named for the African concept of "humanity" which can be translated as "I am because we are". As will be discussed in more detail in this report, the translation of Firefox and OpenOffice into local languages also led to local language versions of the Microsoft Office Suite being developed.

For a while it looked like open-source could achieve success beyond its traditional domain as the bedrock of digital infrastructure and also become a mainstream alternative on the desktop. OpenOffice and its descendent, LibreOffice, was approaching the de facto standard of MS-Office in functionality and user-friendliness. OpenOffice implemented the open document standard Open Document Format which was adopted by ISO as the ISO/IEC 26300-1:2015rce. However, when Microsoft wanted the International Standards Organisation to adopt a second document standard, thus resulting in standards proliferation, South Africa led the resistance by developing countries in the International Standards Organisation (ISO) since proliferation of document standards undermines interoperability.

However, today, scarcely a decade and half later, there is little evidence of a sea change in South Africa's digital landscape. The ICT sector continues to be dominated by technology developed by international OEMs and sold and integrated through local intermediaries. The attempts to migrate whole government departments or significant institutions to open-source lie abandoned. Although the South African open-source policy focussed significantly on the adoption of open-source, there was also hope that it would lead to a more meaningful role in the creation of software and software systems by South Africans through participation in the creation of open-source software. Yet as shown by the quantitative analysis

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[23] https://www.gov.za/sites/default/files/gcis_document/201409/fosspolicy0.pdf

elsewhere in the report, contributions from South Africa to the now dominant open-source repository, GitHub, has stagnated in comparison to other African peers such as Nigeria and Kenya amongst others.

South Africa's development continues to be hindered by a significant lack of ICT skills, according to a skills survey conducted by the Joburg Centre for Software Engineering (JCSE) and the Institute of Information Technology Professionals South Africa (IITPSA) in 2021. It found 6,500 ICT professional positions could not be filled due to lack of skills, while thousands more professionals are needed (Schofield & Dwolatzky, 2021). In addition, the South African technology sector relies heavily on vendor certification for skills creation, which is ill-matched with the need for skills required in cloud computing, a domain dominated by open-source. It is also unlikely to provide the skills needed for the IoT since most lower-cost IoT devices rely on open-source.

An ICT sector supporting open-source, especially through government procurement, would not be so dependent on vendor training to produce these essential scarce skills. Of course the unmet demand for ICT skills cannot only be attributed to governments' lack of support and even hostility to open-source. Another important factor is the constraints that South Africa's foreign exchange regulations place on technology start-ups, prompting home grown ICT entrepreneurs, including Mark Shuttleworth, to take their skills elsewhere.

While Ubuntu, the leading Linux distribution, was named for the African philosophy of uBuntu, the Ubuntu project is now based outside of Africa, and the leading contributor, Canonical, is based in the UK.

Today the focus has shifted from open-source to the so-called 4th Industrial Revolution, a concept popularised by the World Economic Forum and which has been the subject of a national commission set up by President Cyril Ramaphosa. The report of the commission *Report of the Presidential Commission on the 4th Industrial Revolution* (2020) itself is publicly available only as a printed document, underscoring the gap between the aspirations of the report and the technological capacity of the government. The report, curiously, makes no mention of open-source even though it repeatedly stresses the importance of the government developing its own internal technological capabilities and of the centrality of the IoT. How the government could develop internal capabilities while relying on proprietary software is never explained. Similarly, the IoT is a key technology for the 4th Industrial Revolution, and is known to run on open-source software[24] and open standards, yet the importance of open-source is not recognised in the report.

The question that this study aims to answer is: what went wrong? Why did the energy of the early part of the 2000s dissipate and what can be learned from this experience? To answer this question, we have borrowed a construct from the sustainable transitions literature, namely the multi-level perspective (MLP). MLP is used to study a variety of socio-technical transitions, for example the transition from traditional energy regimes based on coal and nuclear to a renewable-based dispensation. MLP recognises that emerging niches will face resistance and even active opposition from the incumbent regime which has a vested interest in maintaining the status quo.

In this study we interviewed five individuals who were key players in the open-source niche in South Africa during the early and mid-2000s to develop a case study based on an MLP view of South Africa's open-source policy movement in the 2000s. In addition, both authors of the present study were active in the open-source movement in the 2000s and add their perspectives to that of the interviewees. Laurens

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[24] For example this list of IoT operating systems refers to open-source systems: https://ubidots.com/blog/iot-operating-systems/

Cloete led the CSIR's project to migrate to open-source software and Andrew Rens was the first Shuttleworth Foundation Fellow working on open standards, open-source and open licences.

Ideally a full case study would also include the perspectives of other actors in the socio-technical system including the incumbents, the regulators, and the users of the technology. Due to resource constraints, a complete study of all actors involved was not possible, and this task is left to future technology historians.

The study is structured according to the following research questions:

1. What led to the emergence of the open-source movement/policy process in South Africa in the 2000s?
2. Who were the key players and what motivated them?
3. What form did the open-source niche field take and how did it grow and gain momentum?
4. What achievements did they have?
5. What resistance did they experience? From whom? How did they overcome resistance? How did the incumbent regime receive them?
6. What is the legacy of what happened in the 2000s?
7. What now? What are the implications?

5.2.   The Multilevel Perspective

The MLP is a framework used to study how technological transitions come about and to understand the interactions between innovations, actors and the environment. Key concepts in MLP include niches, socio-technical regimes and the landscape. Niches represent the terrain from which radical innovations emerge, which may be due to changes in the landscape. The socio-technical regime denotes the status quo, or more formally the 'rule-set or grammar' of processes, technologies, skills, corporate cultures and artefacts embedded in institutions and infrastructure, whereas the landscape refers to the macro-level external structure within which the socio-technical regime exists. According to an evolutionary economic model, niches provide a vast array of possible innovations and the regime acts as a selection environment.
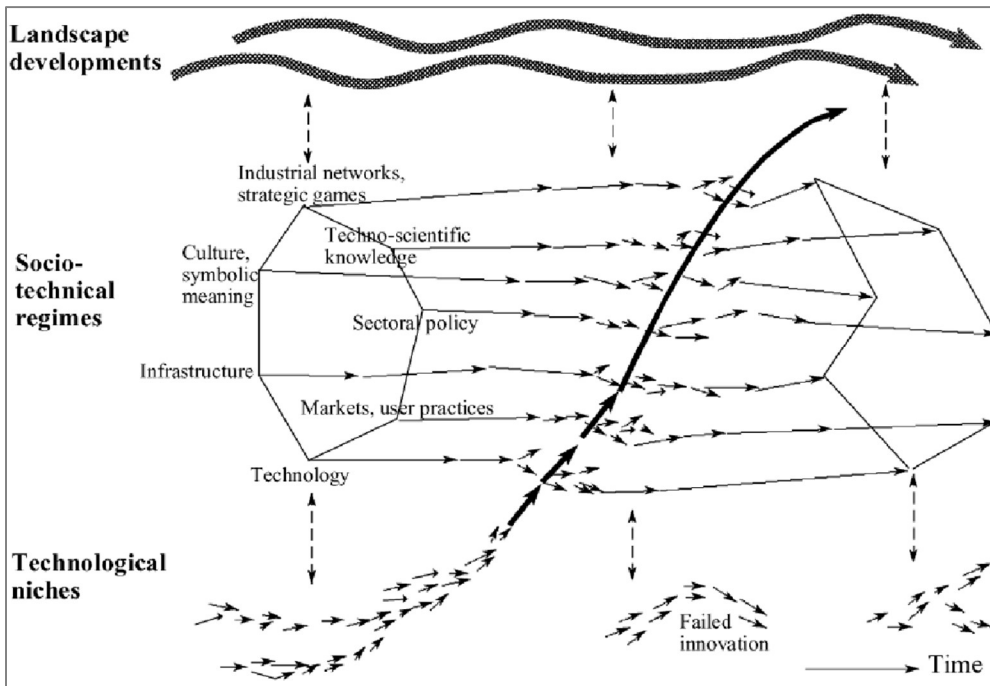
Figure 4: The Multilevel Perspective

As illustrated in the Figure 4, niches put pressure on the regime and successful niches enter the regime to become part of it. However not all niches are successful as incumbent actors in the regime will resist the emergence of the niches which may fail if not adequately nurtured or if they are too weak to become part of or change the existing regime.

In this study the open-source movement will be conceptualised as a niche field with the proprietary vendors and their systems integration partners seen as the dominant social-technical regime.

5.3.   Niche Motivations

The open-source niche that formed in South Africa in the 2000s consisted of an assortment of developers, entrepreneurs, activists, policy entrepreneurs and a sprinkling of enlightened government chief information officers (CIOs). Their motivations for promoting open-source and the way they viewed themselves varied. In this section we discuss the motivations of a number of individuals that we interviewed.

We start with an open-source entrepreneur and activist who indicated that they saw two dimensions to their purpose. Firstly there was a wonderment of the power of the global open-source phenomenon: "I remember thinking I can't believe all these people volunteered their time to do this, so I was quite enamoured by the sheer effect of volunteerism and its massive impact." Already in the late 1990s free and open-source Linux (Slackware installed from floppy disks) was offering far more in terms of design and functionality than the commercial UNIX offering to which they were accustomed. In this entrepreneur's field of interest and circumstance, he noticed a desire to "give back" and a need to solve a practical problem around translation of the service from English to isiXhosa for a Gugulethu township church. This merged into what would become a mission and vocation to develop localised versions of popular open-source software applications for most of the decade.

Another respondent related that the "dominant idea of the Internet [at the time] was that it offered this amazing liberatory potential. The biggest challenge was how were we going to get Internet access and computer access to Africans and people in developing countries?" In the words of John Perry Barlow,

"this new world that was external to governments, it didn't have any barriers and anyone could join and it was open and free. And that the free and open-source software and open content movement epitomised this freedom".

When asked to describe how they saw themselves as part of this movement one respondent said: "I felt like a Bible salesman. In the very early days, no one knew about any of this stuff and it was radical. It was radical to imagine, people giving up copyrights… I felt like I had seen a truth about the world and that people weren't involved because they just didn't know about it… I felt like I was telling the moral tale and that this was good."

Within the government, an open-source working group that was formed focused on the deployment of open-source software. Over time this expanded to interoperability and consequently the need for open standards.

Government actors who joined or contributed to the movement saw themselves as assisting the transformation of the state, from a state formed by apartheid to a state that would serve the majority of South Africans. This required the deployment of technology to replace the moribund, dated technologies that had been adopted in an ad hoc way by the state that hindered efficiency through lack of interoperability and lack of flexibility to customise the technology to the unique needs of government.

A leading figure in the movement in the 2000s indicated that they simply felt passionate about open-source, the adoption of open-source, its adoption by the public sector and the manner in which it could empower individuals to use it for themselves to be productive without necessarily going the proprietary route. They added that the availability of source code could empower the more technically minded to develop code and be potentially part of communities that were doing development. Expressing a sentiment that is consistent amongst members of the open-source niche in South Africa they concluded that "it was an idealism, you know, this was part of one's contribution to the development of the country".

5.4.   Emergence

A key event in the development of the open-source movement in South Africa that would lead to formal adoption of an open-source policy by the South African government, was the publication in 2002 of the first of two National Advisory Council on Innovation (NACI) papers, *Open Software & Open Standards in South Africa - A Critical Issue for Addressing the Digital Divide* (Sibisi et al, 2002). The paper, penned under Sibusisio Sibisi's leadership, featured major contributions from Mike Jensen, Philip Machanick, Edwin Blake, Evan B. Summers and Dwayne Bailey. The format of the paper quite deliberately – and certainly strategically – takes the form of a series of vignettes describing the benefits of open-source. These cover a range of real-world problems from enabling the use of older hardware that would be otherwise be useless without a commercial operating and office suite, open-source software enabling human capability development through its use in learning environments, the translation of software interfaces into local languages, and the dissemination of scientific software developed through the public funding of open-source.

The 2002 NACI document was the result of deliberations of a NACI Open Software Working Group and reads like a manifesto for open-source, making arguments for the government to play a leading role in the adoption of open standards and open-source. The paper highlights key issues such as the need for open standards to resist lock-in to proprietary solutions as well as the fact that open-source adoption and development faced different challenges from that which prevailed in rich countries. In these

countries "there is an implicit subsidy provided by wealthy institutions, well-funded universities and corporations" for open-source, which does not exist in poorer countries.

The paper also distinguishes between software infrastructure and software applications and highlights the symbiosis between open standards and open-source in the Internet's digital infrastructure. Regarding the aforementioned, open standards clearly enable open-source adoption through the transparent availability of specifications that open-source must attain to be able to interoperate with proprietary software, which in many cases has already established a dominant position. This aspect of the synergy between open standards and open-source is generally well understood, but the document makes the point that by the same token, open standards, such as the Internet standards and protocols, are enabled by open-source software.

Although the groundwork for the 2002 NACI paper was laid in 2001 while Sibisi was Vice Chancellor for research at the University of Cape Town (UCT), by the time it was published he was the newly appointed CEO of the CSIR. Sibisi's personal stature, his position as CSIR CEO and the publication of the paper as a NACI report meant that it could not be ignored.

The 2002 paper was followed by a revised edition in 2004 which featured additional contributors including Thomas E. Pogue, Bob Day, Adi Attar and Nhlanhla Mabaso. The 2004 report differs substantially from the original. Not only did it grow in length from 22 pages to 63 pages, the newer document has a different emphasis reflecting developments since the publication of the original report. The title of the report also changed from *Open Software & Open Standards in South Africa* to *Free/Libre & Open Source Software and Open Standards in South Africa*. Two of the scenarios in the original report, Funeka's awakening and Sipho's choice, were retained as FLOSS Parables and Language Translation – A True Open Software Story as an example of FLOSS application. Whereas the 2002 report "emphasised the public sector in its recommendations regarding use of FLOSS…", the 2002 "…version broadened and extended the recommendations to include public and private sectors, with specific recommendations for the environment, agriculture and education domains".

Sibisi et al (2002) and Sibisi et al (2004) were published during a period when various countries and regions such as the European Union adopted open-source policies and strategies. The World Summit on the Information Society (WSIS), a two-phase United Nations-sponsored summit on the information society, took place in 2003 in Geneva and in 2005 in Tunis. One of WSIS main aims was to address the global digital divide by increasing access to the Internet and ICTs in the developing world. As reflected in the subtitle of the two reports, "A Critical Issue for Addressing the Digital Divide", the recommendations on FLOSS were to a significant extent influenced by the issue of the digital divide.

In 2002 South Africa had recently experienced a major devaluation of its currency further increasing the cost of imported software. Despite the devaluation of the currency, by 2002 South Africa was at the beginning stages of one of the longest economic growth periods since the 1960s. ICT and the information society had high status under the Mbeki administration which had appointed the Presidential Information and Communications Technology (ICT) and the Advisory Council and established the Presidential National Commission on Information Society and Development (PNC on ISAD).

The open-source policy case and associated developments therefore have to be seen in context of the democratic transition in South Africa and the development of new institutions, other domestic developments, the globalisation phenomenon of the 1990s and 2000s and the emergence of the Internet as a mainstream global infrastructure.

Sibisi et al (2004) provides an update on various open-source related developments after 2002 including:

- January 2003: publication of "Using Open-source software in the South African Government". A document produced by the Government Information Technology Officers Council (GITOC), containing policy recommendations and implementation targets, and representing the accepted policy at the time of the South African government;
- May 2003: publication of "Designing and managing a framework for assessing results of use to OSS in South Africa: Phase 1". A document produced by SITA, that also supports the FLOSS implementation process;
- November 2003: commissioning by the PNC on ISAD of a study on South Africa's open-source policy which was expected to improve on the current open-source policy and provide guidelines for a move to the next phase of its implementation.

Other public sector developments that followed the publication of the NACI paper included the launch of the CSIR Open Source Centre in 2003 which had as its mission to promote understanding and the use of free/libre and open-source software (FLOSS) in the public, private, and civil sectors. The Department of Communications and later the Department of Arts and Culture funded Translate.org to translate open-source desktop software including the open-source office suite, OpenOffice, and the Internet browser, Firefox, into South African languages.

As well as the Ubuntu Linux distribution, Mark Shuttleworth started the Shuttleworth Foundation that would fund open-source projects such as the Freedom Toaster, a public kiosk that will burn copies of free software onto user-provided CDs and DVDs, SchoolTool, a student information system, and tuXlabs that installed Linux-based computer laboratories in over 208 schools across South Africa by June 2007. Like the organisations supporting the Ubuntu operating system, the Shuttleworth Foundation was subsequently relocated to the UK due to South Africa's stringent foreign exchange regulations.

In 2002 and 2003, the South African cabinet noted and adopted policy recommendations in the first NACI paper and the 2003 GITOC document mentioned above. However it would take until February 2007 before the *Policy on Free and Open Source Software use for South African Government* was formally adopted by the South African Executive. The policy stated that:

1. The South African Government will implement FOSS[25] unless proprietary software is demonstrated to be significantly superior. Whenever the advantages of FOSS and proprietary software are comparable, FOSS will be implemented when choosing a software solution for a new project. Whenever FOSS is not implemented, reasons must be provided in order to justify the implementation of proprietary software.
2. The South African Government will migrate current proprietary software to FOSS whenever comparable software exists.
3. All new software developed for or by the South African Government will be based on open standards, adherent to FOSS principles, and licensed using a FOSS licence where possible;
4. The South African Government will ensure all Government content and content developed using Government resources is made Open Content, unless analysis on specific content shows that proprietary licensing or confidentiality is substantially beneficial.
5. The South African Government will encourage the use of Open Content and Open Standards within South Africa.

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[25] Free & Open Source Software

5.5.   Struggles and Resistance

The policy adopted by the South African government in 2007, although written in somewhat drier officialese, retains some of the radicalism of the 2002 and 2004 NACI papers. If implemented it would have had a major impact on the ICT landscape in South Africa.

However, it is fair to say that the radical ambition of this activist policy was in the main not realised. The open-source movement and the policy intentions were bedevilled by a combination of factors that included active resistance by the incumbent regime of proprietary vendors and local systems integrations, passive resistance from unwilling government CIOs, and some discord within the open-source movement itself. In addition, some of the respondents in this study lamented the lack of volunteerism in South Africa required for a vibrant open-source movement. To compound the issue, the degree of resistance and tactics employed by the incumbent regime were underestimated by the open-source niche champions and the support that could be garnered from IT managers and other decision-makers was overestimated.

Overt resistance by the incumbent regime was observable in two areas in particular. The first of these revolved around the ways that Microsoft attempted to entrench their operating systems and office suite in the basic education system through donations and other means. The second was the Microsoft strategy to counter the threat of the Open Document Format (ODF) to their dominance in desktop operating systems and office utility software. Steve Ballmer, CEO of Microsoft at the time, claimed that "Linux is a cancer" ('Microsoft CEO Takes Launch Break with the Sun-Times', 2001).

In the 2000s, Microsoft saw the open-source movement as a major threat. As one of our respondents relayed: "on the ground what was happening was they were going to deploy massive Linux computer labs, and that's when Microsoft gave their free donations. Well, I think Thabo Mbeki in his mind persuaded Bill Gates to give them all their labs for free. I think Microsoft was faced with a very strong reality that they would have massive adoption of Linux in South Africa if they didn't do something."

A specific example of the animosity between some proponents of open-source and Microsoft, albeit at a local level, was the scuffle between Joris Komen, Founding Executive Director, SchoolNet Namibia and NetDay Namibia. This caused a major stir when, in an open letter[26] to the Regional Manager of Microsoft South and East Africa, Komen rejected Microsoft's offer of a terminal service solution for SchoolNet.

A similar letter to the editor penned by Sibisi, after an announcement by Microsoft on computing in schools, would ironically lead to the galvanising of the open-source niche when it led to a meeting between him and Dwayne Bailey from Translate.org around the time the first NACI document was conceptualised.

In May 2006 the International Standards Organisation (ISO) accepted the ODF as an international standard for saving and exchanging digital office documents. The ODF was based on the XML file format already used by the open-source productivity suite, OpenOffice.org and was intended to be a vendor-neutral standard for saving common office documents. At the time Microsoft's office suite used proprietary binary formats (.doc, .xls and .ppt). The adoption of ODF as an ISO standard was a major boost for open-source on the desktop with OpenOffice being available on a range of operating systems including Windows and Linux.

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[26] https://web.archive.org/web/20021121202814/http://www.schoolnet.na/pr/msftrelease.html

By the mid-2000s there was a growing trend amongst governments to mandate open document standards which could have led to a switch away from Microsoft's Office Suite to alternatives such as OpenOffice which was based on the ISO approved ODF. Microsoft responded to this threat through a rearguard action to get its own XML-based standard, Office OpenXML (OOXML), approved as an ECMA international standard and then pushing for Ecma to submit the standard as an ISO standard. In a widely reported strategy that is beyond the scope of the present study, Microsoft's OOXML was eventually approved as an official ISO standard in 2008 after initially failing to get ISO approval in 2007. Various allegations have been made regarding irregularities in national standards bodies internal voting processes, in which Microsoft was implicated, in Russia, Poland, Mexico, Sweden, Germany, and other countries[27]. As a consequence of the procedural issues during the ISO process, developing countries including South Africa issued the CONSIGI Declaration that challenged ISO's claims to be a vendor neutral standards organisation.

Technical standards had moved from obscurity to political issues: "The dispute over document standards highlights how technical specifications are no longer the domain of technical experts since they can limit or enable access to knowledge, affect mission-critical operations of government, and generate anti-competitive effects." (Rens, 2011).

With the adoption of OOXML as an ISO standard, Microsoft had effectively staved off the threat from ODF and by implication OpenOffice which had direct consequences for South Africa. One of the key tenets of CSIR's open-source migration was the adoption of ODF as the organisation's official document standard in 2006. This placed scientists and research managers using Windows or Linux, or any other operating system for which OpenOffice was available, on an equal footing and put an end to the need for a dual boot system which is often the death knell for a switch away from Windows. Since Microsoft's Office Suite at the time did not support ODF, CSIR users were compelled to use OpenOffice. Once OOXML was adopted as an ISO standard as well, the impetus for ODF faded and by the early 2010 most CSIR staff had reverted to using Microsoft Office and Linux users were again disadvantaged by a document format.

Some government actors resisted the move to open-source. This seems to have been motivated by three issues: personal, political and technical. On a personal level government decision-makers with ambitions for private sector roles predicted they would be able to secure such roles from proprietary vendors more easily if they purchased proprietary software. A career trajectory in open-source was less obvious. Politically some actors who were less familiar with open-source technologies seemed concerned that they would not be able to exercise control over the systems they managed. Technically it was perceived to be easier to purchase a solution than to build one. Government technology actors, less confident in their own technical ability, would find it easier to use proprietary solutions. With respect to CIOs, one responded remarked that "[i]n the UK, they (CIOs) are called 'yes minister'…" after the British television show that parodies the power that bureaucrats have to frustrate their political leader's plans.

One respondent felt that in South Africa the government "didn't really know we existed". This is in contrast with "Brazil where it could be authoritatively argued that there was a deep engagement with free and open-source software". Another problem encountered by open-source champions were the constant changes in government which led to a loss of skill and institutional memory.

Several respondents indicated that they overestimated the support that the open-source movement would get once there was sufficient awareness of the benefits of the mode. One respondent commented

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[27] See http://noooxml.wikidot.com/

that: "I think as activists, because I would regard myself as an activist in this space, very naively thought the logic would just win. This is... you can control this, we can write our own software."

An unexpected hurdle to building momentum on open-source in broader society was a lack of volunteerism in South Africa. One respondent commented that: "It's quite complicated because, just 'cause I was dealing with the language side of things and the dynamics of South Africa, so I'd have absolutely no volunteers. I don't think anyone volunteered to translate anything." The respondent added: "And to this day, I still struggle...... I'll see massive volunteerism in Europe. Well, that's unfair. There are very few people who volunteer to translate anything in the world. It just happened to be more of them in Europe who have a much more of a volunteerism mindset. Or give back mindset."

A different problem related to a degree of discord within the open-source movement itself. The following example speaks for itself: "We struggled to find anyone who would sell it (a book on how to leverage OpenOffice for practical business problems) and when I announced it somewhere, there was some discussion board where some guy said like 'Who are Translate, why they're selling this stuff that's free software and who like what have they done anyway?' Like 'what gives them the right to do this'... that's the kind of naming of things; like free software has caused so much pain and problems for us…"

While we commented on the positive aspects of the South African policy in terms of its radical commitment to adoption of open-source, the policy itself is also lacking in that it contains no commitment to developing or procuring major government IT systems according to an open-source model. One of the respondents cited the example of Hansard, the transcripts of Parliamentary debates in the UK and many Commonwealth countries, as a uniquely governmental need which could have served as a candidate for open-source procurement. Another example of a problem that is routinely dealt with by the government is case management. One of our respondents shared that "there's a thing on GitHub, … a link to GitHub/government. It will list all the repos owned by governments and South Africa has *one* repo that they've identified as being government-owned, whereas the UK has, you know, *hundreds and hundreds* of different [repos]". These deficiencies could have been addressed by an accompanying implementation plan driven by an enterprising government champion but in the end this did not happen.

Proponents of open-source were framed as 'idealists' by the public relations operations of the proprietary vendors, a characterisation borrowed wholesale from the US in which proprietary software vendors represented themselves as pragmatists battling the ideologues committed to software freedom. This borrowed dichotomy was adopted by some in the press and government opposed to open-source despite its poor fit. Ironically open-source proponents were energised by a very different vision to libertarian's controlling their own technology: the transformation of a society created by apartheid into one in which people would be able to increase their own capabilities – not least through writing software. This is more aligned with Amyarta Sen's view of development as freedom than a Haykian denial of the need for development.

5.6.   Signs of Success

The energy in the open-source niche and the policy processes did lead to some success, a few example of which are summarised below.

In South Africa, and elsewhere, the open-source movement was closely associated with broader trends around copyright and content licensing. In this regard the launch of iCommons was a significant development. Headquartered in South Africa and with the South African Heather Ford as executive director, iCommons was an non-governmental organisation (NGO) set up by Creative Commons to lead efforts to bring disparate movements together, including open-source software and free content all

around the world. A good deal of Ford's work between 2004 and 2009 was around movement building through speaking at events targeting universities, university students, activists, software developers, lawyers, artists, and other creative people. A highlight from these "heady days" were the global iCommons Summits held in Harvard (2005), Rio de Janeiro (2006), Dubrovnik (2007) and Sapporo (2008) that brought together hundreds of people and Internet leaders like Jimmy Wales, Lawrence Lessig, Joi Ito, and Gilberto Gil.

In terms of practical achievements from the open content movement, the Creative Commons licences allowed foundations, artists and educational institutions to licence their material under Creative Commons. The movement stimulated a debate about intellectual property and whether the current regimes were beneficial to African countries and whether there was a better alternative. It also enabled connections between creative people and developers in the open-source movement. Some went on to be involved in other kinds of innovative projects or small companies doing interesting work. These connections extended beyond South Africa and enabled global connections which persist to this day.

Perversely, one of the achievements of the open-source nich had been the pressure it placed on proprietary vendors to change. As one respondent said: "The only reason Microsoft is in many languages is because of our work. And they changed their attitude. That became much more responsive. They separated out the language modules from their applications, so you can translate stuff…So open-source is a very powerful vehicle to nudge the results."

5.7.   Legacy – Missed Opportunity or Shifting Battlelines?

Our respondents were unequivocal in their view that the open-source movement and the adoption of the open-source policy by the South African government was a missed opportunity. The opportunity that was missed related particularly to the opportunity to build a domestic ICT capability that amounted to more than installing and integrating imported technology. Closely linked to this was an opportunity to build ICT infrastructure that would enable the South African state to efficiently serve its people. This was not realised. Had the government commissioned major open-source projects to build key government systems it could have provided opportunities for individuals, startup and larger companies to develop their skills and to create intellectual assets for an indigenous ICT industry. For this to have been realised the baton needed to pass from the open-source pioneers interviewed in this study to people with the power to set strategy within the governmental ICT system. As it happens, by the late 2000s President Thabo Mbeki was ousted, and with a new leader in power ten years of state capture would commence.

More than two decades after the birth of the open-source movement and the associated policy process in South Africa, one could ask whether the debate is still relevant or whether the battle lines have shifted. Undoubtedly the need to transform the country's technological capability remains and although there continues to be some missteps, at least ICT, or "digital", as it is now referred to, is back on the country's agenda.

We conclude with a relevant quotation from one of our respondents: "The problems are the same but the answers are different. The mechanisms required to counter dominance are going to be very different and also the enemies are different… I think it is about remembering what all these solutions [open-source software and open content] were designed to solve".

The South African experience provides a number of lessons for other countries. The first is that the agenda setting power of global technology corporations is immense, able to manipulate international organisations and national governments. At the same time, aligning with such agendas is a fool's errand since the corporations setting the agenda may be rapidly changed either because the corporation is

eclipsed by competitors or because it pivots to a new strategy far more rapidly than any government can adjust.

Another important lesson is that the personal incentives of key technology decision-makers in the state are vital to successful open-source adoption. If they perceive that they will have career opportunities with local open-source providers to the government they will have less incentive to oppose open-source adoption than if they perceive their only career path as working for local vendors of foreign proprietary software.

The ultimate lesson is that failure to prefer open-source for government procurement will likely leave a country paying for technology products in foreign currencies and unable to innovate. Failure to grasp the opportunity can even lead to degraded capability within the public education sector which may be unable to provide the skills needed by the economy due to an over-reliance on proprietary vendor certification.

6. Quantitative Study

6.1. Introduction

The quantitative study looks at the contributions as a whole from the African continent as well as the level of African contributions in the case study projects. The African nature of contributions is based on the authors' stored location in GitHub[28], the most commonly used open-source code repository. We do yearly analysis of open-source contributions (i.e. from public repositories) and we capture the location of the author in the year the contribution was made. There are a number of challenges in detecting African authorship of code: (i) many authors do not capture their location (approximately 79% of contributing authors according to our analysis in 2020); (ii) authors who do capture their location often use a town or city without the country name or a university name or pseudonyms – this increases the complexity required to convert this location data into countries; and (iii) an author may not update their location after moving.

The first challenge can only be overcome by using advanced techniques such as geolocation of IP addresses but would require privileged data access at GitHub. The second challenge can partially be overcome by making use of Google's location API that can convert a place that is not a town, city, or country, such as a university, to a country location. The third challenge is similar to the first problem and would need privileged access at GitHub to carry out IP geolocation to check if an author's captured location matches the result of the IP geolocation process. In our work, the second challenge is partially dealt with as we make use of GHTorrent data which attempts to convert some of the ambiguous location data using the Google location API. The first and third problems are reserved for future work once privileged access to IP addresses converted to country locations are available.

6.2. GitHub Study of African Contributions

This GitHub study investigates the level of African participation in open-source projects that use GitHub. GitHub currently represents 95% of all open-source projects globally.

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[28] https://github.com/

6.2.1.   Methodology

To extract GitHub data over the past 11 years, the GHTorrent[29] project was used. GHTorrent constantly monitors the GitHub public event timeline. For each event (commits, forks, pulls etc.), it retrieves the contents and their dependencies exhaustively. It then stores the raw responses as well as structured data in a database that users can download. The current dataset is available between 2010 and 2021. We only study contributing GitHub users each year; that is, a user that makes at least one GitHub commit or submission each year.

GitHub stores location data as unstructured data due to the location input being free-form. GHTorrent attempts to find the country and town/city from this data by using the Google location API. For example, a location entry like "University of Cape Town" would be converted to "Cape Town, South Africa".

In 2020 the number of contributing users (users that made a contribution in 2020) stored on GHTorrent was approximately 6.46 million with about 196.55 million commits. If only users with known locations are extracted this is reduced to approximately 1.36 million users (21% of users) with 71.7 million commits.

We analysed all countries located in Africa over 11 years from 2010 to 2021 to look for overall trends in contributions from the continent and the trends in the share of contributions from each African country. We analyse both the number of contributing users as well as the total number of contributions. A contribution is classified as a commit to the GitHub repository by a user.

6.2.2.   Overall Yearly Trends of Users and Contributions to GitHub

The overall growth in GitHub users from Africa as well as contributions (a code or documentation submission to GitHub known as a commit) is shown in Figure 5. Although the fraction of users and submissions from Africa is low, it's clear that there has been steady growth over the past decade. The proportion of African GitHub users has grown from just below 0.5% in 2010 to 2.79% in 2020. Our figures for the fraction of contributing GitHub users from Africa (2.79%) are higher than GitHub's Octoverse report for 2020 (2.0%). This is likely due to a mix of factors: (i) We only look at users that have made a GitHub contribution; and (ii) we have limited access to location data compared to GitHub. After discussions with GitHub, we found out that they are able to use IP address geolocation on data for locations without a country.

> The proportion of African GitHub users has grown from just below 0.5% in 2010 to 2.79% in 2020

On average, there has been a 0.23 percentage point increase each year for contributing African GitHub users from 2010 to 2020 but there have been periods of accelerated user growth. From 2014 to 2017 users grew by 0.24 percentage points compared to 0.13 percentage points on average in the three prior years. From 2018 to 2020 users grew by 0.52 percentage points on average each year. It is possible that as open-source has been embraced by the 'Big Five' (Google, Amazon, Meta, Apple, and Microsoft), more African programmers on these platforms have started to contribute to open-source projects.

The fraction of contributions (code or documentation submissions) grew slowly from 2010 to 2014 (only a 0.06 percentage point growth on average) but contributions accelerated between 2016 and 2020 (a 0.36 percentage point growth on average). African contributions per user have fluctuated quite widely between 2010 and 2020. Contributions per user averaged 50 between 2010 and 2020, but the maximum

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[29] https://ghtorrent.org/

achieved in any year was 75 contributions per user in 2018. To put this in perspective, the average GitHub contributions per user in the US in 2020 was 117.
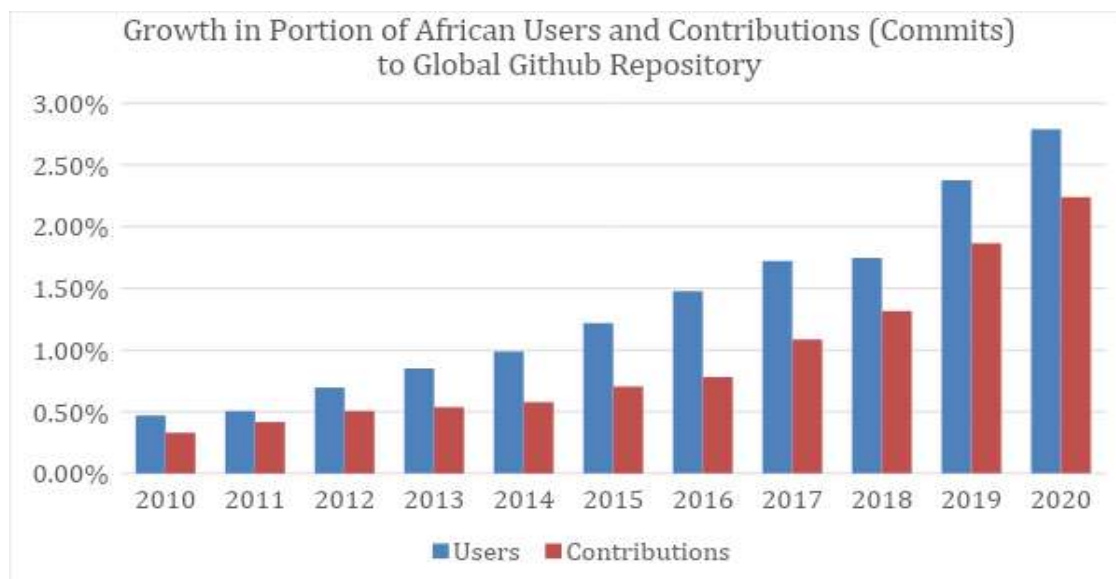
Figure 5: Growth in portion of Africa users and contributions to global GitHub repository

To understand where the growth is coming from in Africa, we also tracked the user growth and contributions from each African country (shown in Figure 6). We only track the top four African countries as all other countries did not have a significant enough user base or number of contributions to warrant being captured on the plot. All African countries apart from the top four had less than 5% of the share of users or contributions.

The share of GitHub users has largely been dominated by South Africa over the past decade but the share of contributions from Kenya and Nigeria has been growing at a rapid pace over the past few years. Egypt has always been the second top African country, in terms of the GitHub user base, but this second place position was replaced by Nigeria in 2017. Nigeria finally overtook South Africa in 2019 and the most recent order of the top four countries, in terms of GitHub users, in 2020 was:

> Nigeria overtook South Africa in 2019 as the top country for contributing GitHub users

1. Nigeria
2. South Arica
3. Egypt
4. Kenya

Figure 7 shows the GitHub contributions from various Africa countries. The fraction of contributions is similar to the fraction of GitHub users, but Kenya and Egypt swap 3rd and 4th place due to Kenyan users being more active. In 2020 the order of top four countries, in terms of GitHub contributions, was:

1. Nigeria
2. South Africa
3. Kenya
4. Egypt

The number of South African open-source contributors stagnated from 2016 and has not changed from just over 4,000 users between 2016 and 2018, whereas the number of users in Nigeria grew from 996 in 2015 to 3,154 in 2018. Kenyan open-source users also grew rapidly from 838 users in 2015 to 1,598 in 2018.
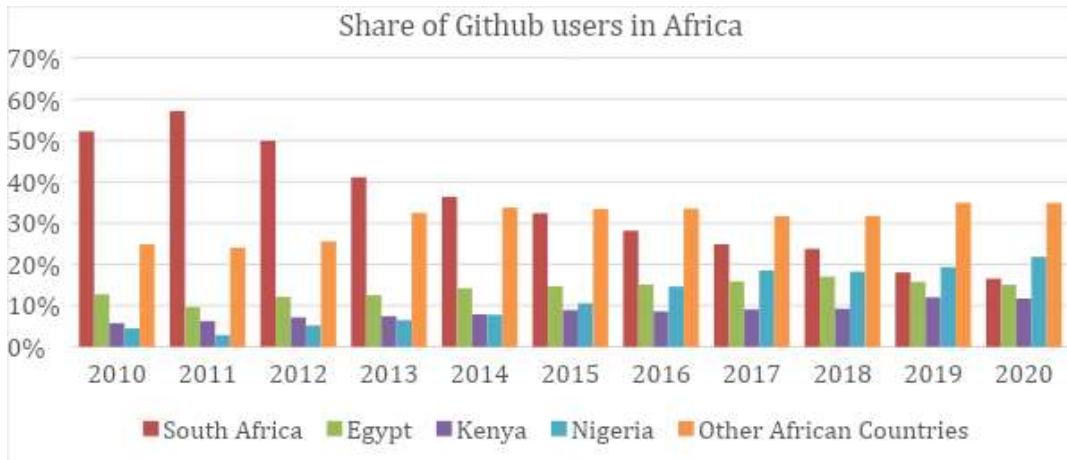

Figure 6: Share of GitHub users in Africa
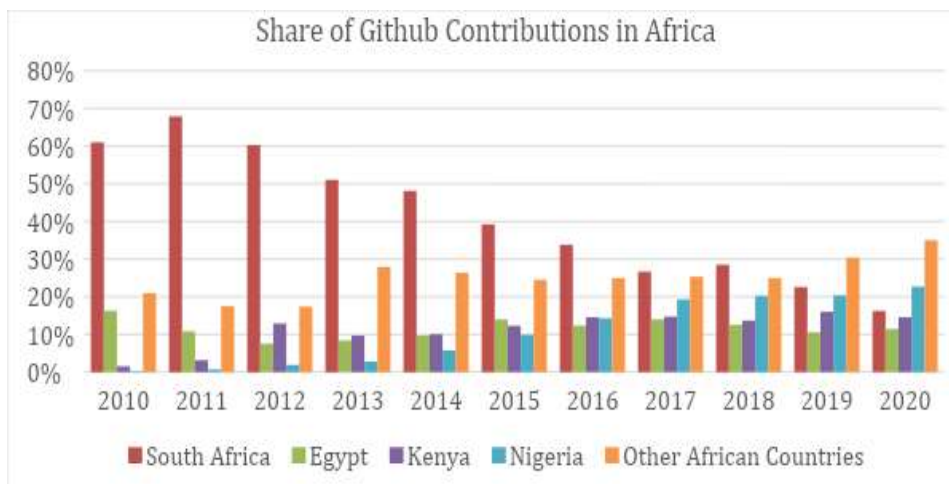
Figure 7: Share of GitHub Contributions in Africa

6.2.3.   Breakdown of Users and Contributions to GitHub from Africa

In this section we provide a breakdown of users, contributions, per capita open-source contributions, and ratio of contributions to user base in the top 15 African countries.

The most recent data from 2020 (see Figure 8) shows that Nigeria leads the top four countries with 8,217 users (21.35% of the users), followed by South Africa, Egypt, and Kenya with 6,277 users (16.18%), 5,672 users (14.74%), and respectively. North African countries, Morocco and Tunisia are in 5th and 6th place with 1,975 (5.13%) and 1385 (3.60%) of the GitHub users.

> In 2020, Nigeria had 8,217 contributing GitHub users (21.35%), followed by South Africa with 6,277 users (16.18%) that captured location information
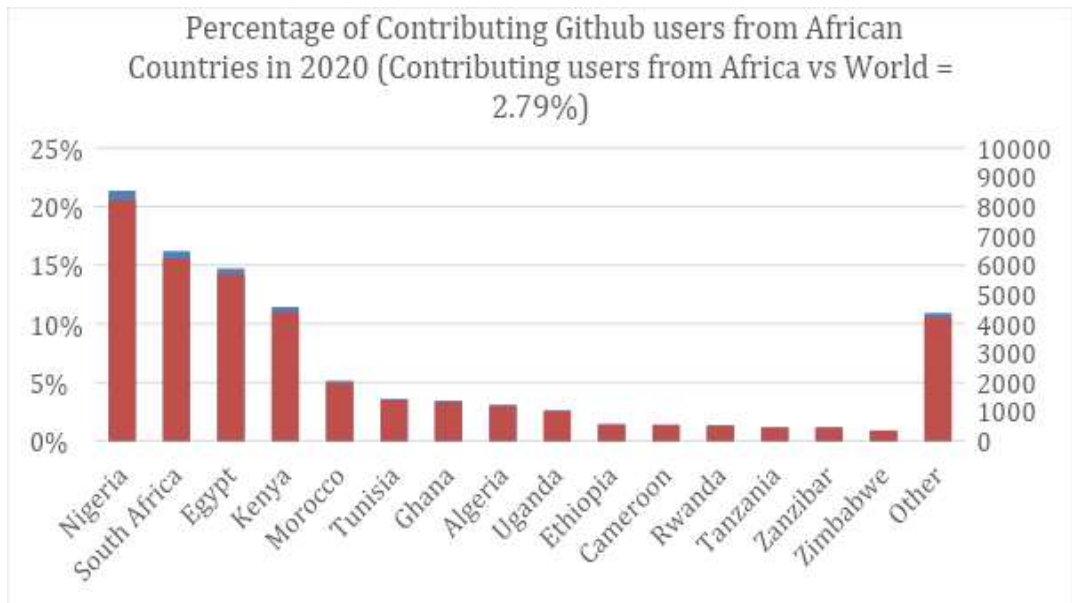
Figure 8: 2018 Contributing GitHub users from African countries in 2018

In terms of GitHub contributions (see Figure 9), Nigeria also leads the top four countries with 364,476 commits (22,13% of commits), followed by South Africa, Kenya, and Egypt, with 260,877 commits (15.84%), 234,032 commits (14.21%), and 184,117 commits (11.18%) respectively. Tunisia and Uganda are in 5th and 6th place with 65,897 commits (4.00%), and 58,569 commits (3.56%). Uganda was in 9th place in terms of GitHub users but moved to 5th place in terms of contributions due to the few active (1,010) being very active contributors.
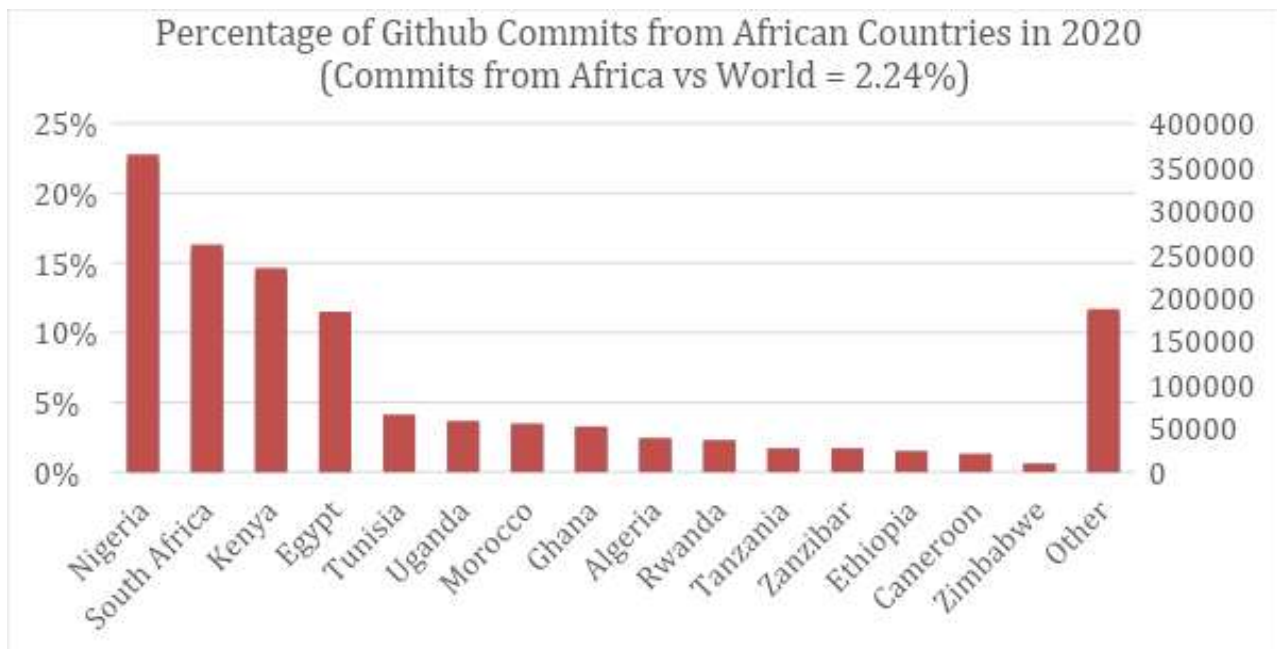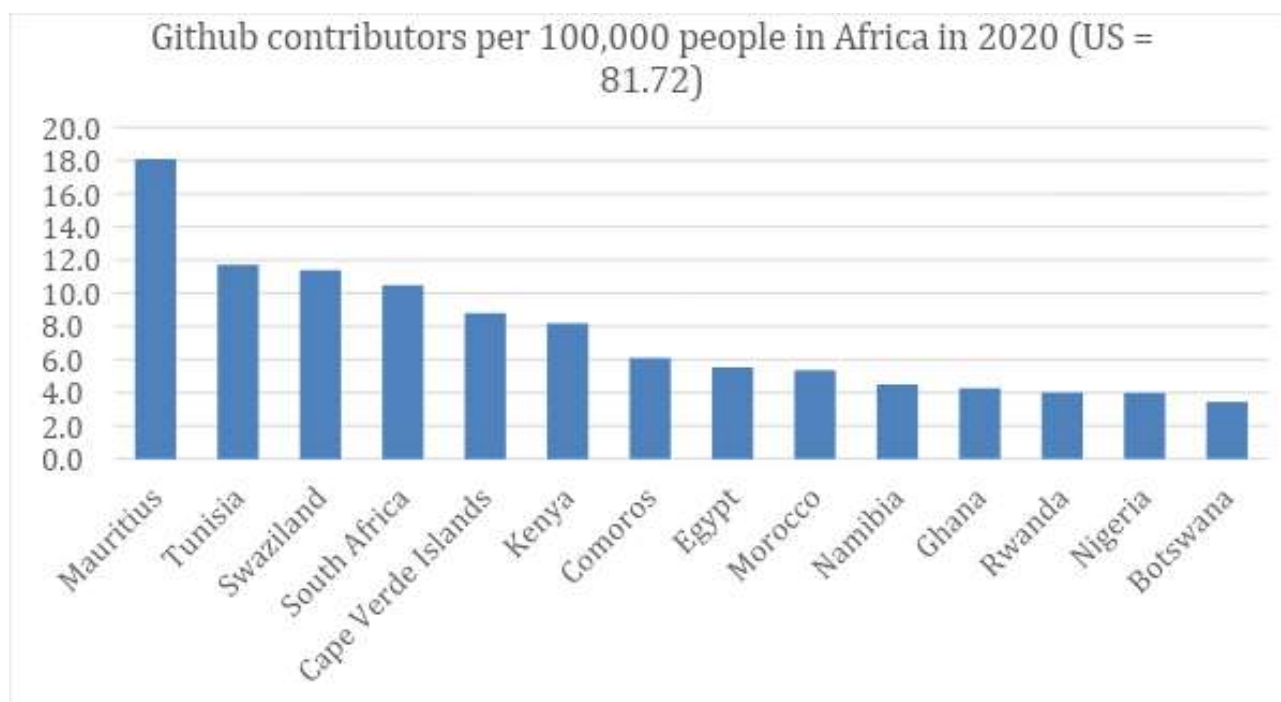

Figure 9: GitHub commits from African countries in 2018

Measuring the number of users and commits per country to some extent mirrors the population size of that country. To avoid this bias, we also studied the number of open-source users per 100,000 people in each African country (see Figure 10). The results are somewhat surprising.

The top eight countries are as follows:

1. Mauritius: 18.8 users per 100,000 people (229 users)
2. Tunisia: 11.7 users per 100,000 people (1,385 users)
3. Swaziland: 11.4 users per 100,000 people (132 users)
4. South Africa: 10.5 users per 100,000 people (6,227 users)
5. Cape Verde Islands: 8.8 users per 100,000 people (49 users)
6. Kenya: 8.2 users per 100,000 people (4,407 users)
7. Comoros: 6.1 users per 100,000 people (53 users)
8. Egypt: 5.5 users per 100,000 people (5,672 users)

Mauritius is a leading country in terms of GitHub users per 100,000 people by a wide margin and has a solid base of programmers that contribute to Internet Protocol Standards (See Section 4). South Africa and Kenya drop from 2nd and 3rd place in terms of fraction of GitHub users to 4th and 6th place when considering the per capita number of GitHub users. To benchmark the per capita number of GitHub users, we compared the number of contributors per 100,000 people with the US. In the US there are 81.72 contributing GitHub users per 100,000 people which is approximately eight times the number in South Africa and four times the number in Mauritius. Mauritius has a strong open-source culture and have been leading contributors to Internet Protocol standards as shown in Section 4, which most likely explains its leading position in terms of per capita open-source contributions.

Figure 10: GitHub contributions per 100,000 people in Africa in 2018

The ratio of GitHub commits to users for the top 15 African countries is shown in Figure 11. Here there are also some surprising results that show that countries with very few GitHub users, such as Burkina Faso with only 36 active GitHub users, can be very prolific and push the country to first place in terms of the most active GitHub contributors. However, with such a low number of GitHub users, it would be overreaching to conclude that this high number of contributions per GitHub user in Burkina Faso would be a general trend as the number of GitHub users increase in the country.
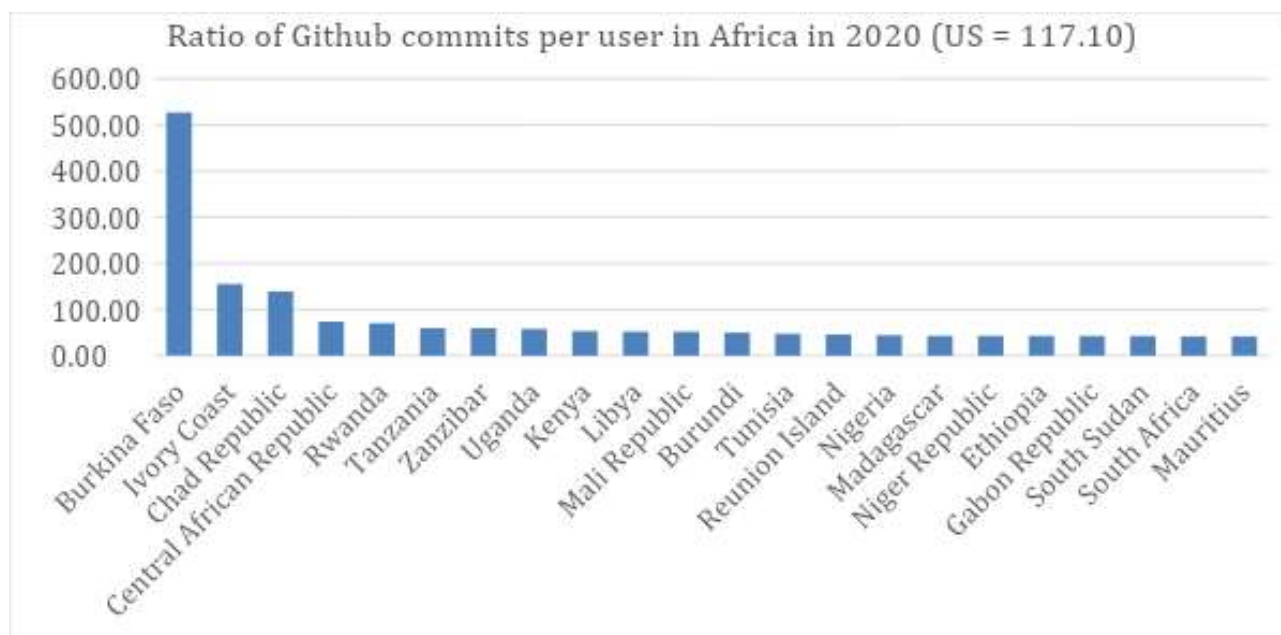
Figure 11: Ratio of GitHub commits per user in Africa in 2020

6.3.   Quantitative Study of Case Study Projects

We assessed the contributions for all our case studies on GitHub. The analysis sought to understand the size of these projects, period of activity, percentage of African contributors, level of concentration of contributions measured using the Herfindahl-Hirschman Index (HHI)[30] and the interest in the project by looking at the number of forks. A high HH-index over 5,000 (maximum possible is 10,000) shows a high degree of concentration by one or two authors.

In the case of Masakhane, Ushahidi, and OpenUp, approximately one third of author locations were not provided – a similar proportion of authors without location information reported in the literature for active users. Only Translate.org had a higher proportion of authors with unknown locations (44%). Further investigation will be required that uses alternate methods, such as IP address geo-location, to attempt to know these contributors' locations. If one assumes that the statistical probability of an author not providing location is the same for African and non-African countries, then the fraction of African authors will still be accurate.

The following results were obtained using the GitHub API.

	iNethi	VillageTelco	Ushahidi	Masakhane
Number of repositories	10	9	153	10
total contributing authors	3	5	229	56
Total contributions	99	359	29402	639
African total contributions	99	30	4843	265

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[30] If 40% of contributions where from author 1, 30% from author 2 and 30% from author 3, the Herfindahl-Hirschman Index (HHI) is calculated as $40^2 + 40^2 + 30^2 = 4,100$

African contributions (%)	100.0%	8.4%	16.5%	41.5%
Unknown Author location (%)	0.0%	0.0%	34.0%	35.0%
First contribution	09/04/2017	22/04/2013	12/05/2009	10/08/2019
Last contribution	14/07/2021	14/06/2021	23/07/2021	25/07/2021
Number of forks	3	17	2,558	197
HH-index average	4,082	7,536	1,211	929

	Translate.org	**Crane Cloud**	**OpenUp**
Number of repositories	44	11	141
total contributing authors	321	12	127
Total contributions	48,317	2,747	25,404
African total contributions	14,199	2,711	14,872
African contributions (%)	29.4%	98.7%	58.5%
Unknown author location (%)	44.0%	8.0%	35.0%
First contribution	19/03/2012	30/04/2019	26/03/2013
Last contribution	09/08/2021	16/03/2022	13/03/2022
Number of forks	810	5	214
HH-index average	2,465	7,083	722

iNethi is still a new project with only three contributors – all of whom are African, but this may change as more user interest grows globally. VillageTelco only had one African author and only 8.3% of contributions coming from Africa. It also had a high degree of contribution concentration from outside Africa with a high HH-index of 7536.

Ushahidi is a project that had its genesis in Kenya but has gained interest from around the world (seen by the high number of forks, 2,558) and now has a wide global set of contributors. As a result, only 16.47% of its contributions are coming from Africa. Its HH-index is low – showing that there are a wide and well distributed number of contributors.

Ushahidi and VillageTelco had the lowest number of African contributors with 8.4% and 16.5% respectively. Both these projects attracted a wide amount of interest from international contributors and their product was relevant to domains and applications outside the African continent.

OpenUP, a civic technology organisation that is currently mostly applied to empowering citizenry in South Africa, has a high number of African contributors (58.5%) from a high number of repositories (141) and contributing authors (127). It also had the least amount of contributor concentration, with an HH index of only 722. The Masakhane project – which is an African human language technology project – also has a relatively high number of African contributions (41.47% of the contributions are African) and an excellent HH-index of 920 showing that the contributions are also well distributed.

Crane Cloud develops a platform for cloud management that is not specific to the African domain and surprisingly still has a very high number of African contributions (98.7%). However, the high HH index of 7,083 for its 12 contributing authors, suggests that the bulk of these contributions came from one or two authors.

6.4.   Conclusion

The current data from GitHub shows that Africa still contributes a small fraction of open-source code to GitHub (2.24% of the contributions and 2.79% of the contributing users in 2020). However, on the positive side, there has been consistent year-on-year growth on the continent due to the rapid growth of contributing users in countries like Kenya, Nigeria and Egypt.

> Consistent year-on-year growth of GitHub users in Africa is due to the rapid growth of contributing users in countries like Kenya, Nigeria and Egypt.

Although South Africa used to be the dominant country contributing to open-source projects a decade ago, with over 50% of the users in 2011, this is no longer the case. The portion of open-source contributing users in South Africa dropped to just over 16% in 2020 and the user base effectively stagnated from 2016 with some recovery starting in 2019. The cause of this stagnation in South Africa is likely due to a mix of a lack of growth of skilled programmers that make use of open-source tools compared to other African counterparts, and a lag effect of the abandonment of the policy to use open-source in government.

Considering the low number of contributing users that provide their country in their user profile (approximately 21% of users), it would be naive to make hard conclusions on the absolute number of African contributions to open-source projects; a more accurate assessment will only be possible with the cooperation of GitHub. However, we believe the general trends observed here, such as Nigeria and Kenya's impressive growth of open-source contributions over the past few years, will still hold.

7. Conclusion and Recommendations

Globally open-source has become mainstream. Alphabet, Amazon and Meta, ranked as the fourth, fifth and seventh most capitalised companies in the world at the time of writing, run the majority of their operations on open-source software. Innovative electric vehicle manufacturer Tesla has released much of the software used in their vehicles under open-source licences. Even Microsoft, once the avowed opponent of open-source, purchased GitHub, a hosting site for open-source, and releases some of its own software under open-source licences. A senior Microsoft leader admitted "Microsoft was on the wrong side of history when open-source exploded at the beginning of the century" (Warren, 2020).

This makes the relatively low input of resources into open-source in Africa all the more surprising, perhaps indicating both a greater dependence on legacy technologies in lower resource settings as well as policy lag on the part of governments. Yet at the same time quite a number of African countries have policy initiatives aimed at the 4th Industrial Revolution without much acknowledgement of the central role that open-source would have to play in the development of technologies for African countries seeking to be technology co-creators rather than technology consumers.

We return now to our opening research questions and look at what has been learnt.

What is the extent of African contributions to the code-base of critical digital infrastructures?

When we look at the data from GitHub (which currently represents 95% of open-source contributions), although the share of African GitHub users is only 2.79%, there are signs of recent growth across the continent. In Nigeria and Kenya the share of open-source users in Africa has grown from approximately 5% in both countries in 2010 to 22 % and 12% respectively in 2020. South Africa was the leading

contributor to open-source a decade ago, but was overtaken by Nigeria in 2019, and began to stagnate in terms of open-source users in 2016. This may be due to a lag effect of South Africa abandoning its policy to implement open-source by the late 2000s. However, there are some signs of new growth in South Africa in the past two years perhaps due to the growing startup culture embracing open-source by companies like Open Up[31] and VoxCroft[32].

What are the challenges, constraints, and obstacles to the development of critical digital infrastructures on the African continent?

The most obvious constraints to the development of critical digital infrastructure is the lack of access to ICT resources in Africa, including low Internet penetration, the relatively high cost of computing devices and unreliable electrical power. However it would be facile to conclude that relatively low global contribution to digital infrastructure, especially open-source software, is a simple correlation with the resource challenges. Open-source software has a number of features that should have led to greater open-source adoption as well as production. Open-source does not require payment of licensing fees, which overcomes the barrier of currency differentials. At the same time open-source emphasises learning by doing rather than formal educational qualifications. There thus seems to be an under-utilised opportunity for African ICT professionals to earn high value foreign currency by offering remote coding services. Further research on this issue may uncover not only why this opportunity has not been seized, but ways in which it may be.

Other constraints include misdirected government policy in some countries that focuses on cost than promoting the local ICT sector. As a result of these constraints there is a further constraint: the relative paucity of skills, especially the absence of in-depth technical kernel-level skills, that are required in areas like embedded systems, IoT, and developing IP.

In South Africa, historically the most promising locale for development of digital infrastructure, two important barriers stymie contribution to digital infrastructure: the failure of government to adopt open-source despite a promising beginning, and the foreign exchange regulations that act as a push factor for IT professionals planning to start new enterprises to relocate off the continent. More research on the negative effect of the capital controls on innovation in South Africa is needed. However a single incident clearly illustrates the issue: Mark Shuttleworth found the exchange controls inhibited running an international technology business and he relocated from South Africa and established Canonical in the UK. Canonical is a corporation that contributes to and offers services using Ubuntu Linux . It employs 600 people and earns revenue of $138 million   per annum. If it were not for the foreign exchange regulations, Canonical would have most likely been located in South Africa. On its own that would have significantly affected the African contribution to open-source digital infrastructure.

What lessons can be learned from successful African-led open-source projects?

Each of the case studies is successful in their own right – they have been able to achieve their objectives, have managed to attract contributors (even if it is challenging sometimes), and have attracted some funding to keep their projects going. The most successful projects were those with community ownership, where communities suggested ideas and were given the freedom to adapt projects to their needs. Additionally, responding to particular needs (e.g., COVID-19 response, crisis mapping, community

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[31] https://openup.org.za/

[32] https://www.voxcroft.com/

currency, etc.) made projects more desirable and easier to adapt to other contexts. In terms of meeting objectives, some organisations opted to forego funding options that did not align with their project goals, which earned them respect.

How, if at all, are digital infrastructure different in the African context?

Unlike many software developers in the Global North, coders usually start doing personal-interest projects and open-source at some later stage of their career, often once they accumulate some money and confidence to do what they want to do. This is why the potential pool of contributors is small. Contributing to open-source requires access to resources, a good Internet connection, a decent device and time, which many new entrants may not be able to afford. Additionally, a large percentage of GitHub contributions are in English, making it challenging for speakers of other official languages on the continent like Arabic, French or Portuguese.

How could the African contribution to digital infrastructure be increased?

Education

Introduce open-source at school level; for example, by making use of Linux in school computer laboratories and teaching programming courses that make use of open-source tools, libraries and frameworks. In higher education more advanced kernel-level projects in are necessary to build the desired technical expertise. Research should focus on the technological challenges of African contexts, which coincide with the challenges of IoT, energy constraints and high latency.

Procurement

Require open-source for use by government departments and entities using a phased approach. Begin with increasing government decision-makers' knowledge about open-source infrastructure. Build on this knowledge with public policy that encourages meetings, networking, mentorship, skills development, and community building around open-source software and that facilitates the   participation of startups and the private sector in large-scale government projects.

Make open-source mandatory for systems used only by technologists. Do not begin with technologies used by non-technologists such as desktop software. Migrate government technology to cloud-based services accessible through browser and mobile app interfaces. Reconstitute government information systems from document-based systems to data-based systems. Eliminate the desktop, replacing it with mobile apps for as many functions as possible, rather than migrate to an open-source desktop for users who are not technology staff.

Entrepreneurship

Create more open-source-based technology startup friendly environments by ensuring laws, such as exchange control laws and taxation laws, encourage international and local companies to stay in Africa. Favour local open-source enterprises in public procurement.

Research

Encourage publicly funded research to focus not just on open-source but on open-source solutions to problems of low bandwidth, high latency, low power devices and networks, thus ensuring the open-source software solves challenges in African environments. Since many of these are the same challenges facing the IoT, African researchers will become experts in issues affecting an important frontier technology. Ensure that regulation, such as the Intellectual Property Rights (IPR) act in South Africa is reformed to encourage an open-source approach for publicly funded research.

Corporate support for African contributions to digital infrastructure

Technology corporations that use external contractors to create open-source software should prioritise finding African contractors.

International standards bodies

Bodies such as WC3 should attempt to increase participation in technological standards making through: (i) building links with African educational institutions to encourage participation, and (ii) offering paid internships and paying for travel for African participants.

Philanthropic funders and development agencies

Funders should require that all software created with the funds that they supply should be released under open-source licences. Whenever possible software developed for projects relating to Africa should be developed by African contractors.

8. References

Bidwell, N. (2020). Women and the Sustainability of Rural Community Networks in the Global South. ICTD conference 2020.

Eghbal, N. (2016) Roads and Bridges: The Unseen Labor Behind Our Digital Infrastructure. https://www.fordfoundation.org/work/learning/research-reports/roads-and-bridges-the-unseen-labor-behind-our-digital-infrastructure/

Fink, L., Shao, J., Lichtenstein, Y., & Haefliger, S (2020). The ownership of digital infrastructure: Exploring the deployment of software libraries in a digital innovation cluster. Journal of Information Technology 2020 35:3, 251-269.

Hoe, N.S. (2006). Breaking barriers: the potential of free and open source software for sustainable human development; a compilation of case studies from across the world. https://www1.undp.org/content/dam/rbap/docs/Research%20&%20Publications/democratic_governance/RBAP-DG-APDIP-2006-Breaking-Barriers.pdf

IDRC. (2007, October 7). African Virtual Open Initiatives and Resources (AVOIR) Internal Evaluation.   https://idl-bnc-idrc.dspacedirect.org/bitstream/handle/10625/37578/127917.pdf

Lin, Y., den Besten, M. (2018). Gendered work culture in free/libre open source software development. Wiley online library . https://onlinelibrary.wiley.com/doi/full/10.1111/gwao.12255

UNICEF. (2016, September 16). UNICEF Office of Innovation: Open Source - Business Model. https://www.unicef.org/innovation/reports/unicef-office-innovation-open-source-business-model

Amreen, S., Bichescu, B., Bradley, R., Dey, T., Ma, Y., Mockus, A., Mousavi, S., & Zaretzki, R. (2019). A Methodology for Measuring FLOSS Ecosystems. In *Towards Engineering Free/Libre Open Source Software (FLOSS) Ecosystems for Impact and Sustainability: Communications of NII Shonan Meetings* (pp. 1–29). Singapore : Springer Singapore : Springer; WorldCat.org. https://doi.org/10.1007/978-981-13-7099-1_1

Boyle, J. (2010). *The Public Domain: Enclosing the Commons of the Mind*. Yale University Press.

Comparison of source-code-hosting facilities. (2022). In *Wikipedia*. https://en.wikipedia.org/w/index.php?title=Comparison_of_source-code-hosting_facilities&oldid=1083884760

Cukier, W., Bauer, R., & Middleton, C. (2004). Applying Habermas' Validity Claims as a Standard for Critical Discourse Analysis. In B. Kaplan, D. P. Truex, D. Wastell, A. T. Wood-Harper, & J. I. DeGross (Eds.), *Information Systems Research: Relevant Theory and Informed Practice* (pp. 233–258). Springer US. https://doi.org/10.1007/1-4020-8095-6_14

Frederickson, B. (2018). *Where Do The World's Software Developers Live?* https://www.benfrederickson.com/github-developer-locations/

Frischmann, B. M. (2012). *Infrastructure: The Social Value of Shared Resources*. Oxford University Press.

Gastrow, M., & Parker, S. (2009). How much is free? Quantifying open source software development in South Africa. *African Journal of Science, Technology, Innovation and Development*, *1*(1), 190–209.

GitHub. (2021, June 9). *The State of the Octoverse (2020)—Web archive*. https://web.archive.org/web/20210609223800/https://octoverse.github.com/

Gopalakrishnan, J. (2006). Lessons in open source wisdom from South Africa. *Linux for You*, *Query date: 2021-03-15 10:52:29*.

Handlykken, A. (2012). Exploring the politics of Free/Libre/Open Source Software (FLOSS) in the context of contemporary South Africa; How are open policies implemented in practice. *The Journal of Community Informatics*, *Query date: 2021-03-15 10:52:29*. https://www.researchgate.net/profile/Asne_Handlykken-Luz2/publication/330882025_Exploring_the_politics_of_FreeLibreOpen_Source_Software_FLOSS_in_the_context_of_contemporary_South_Africa_how_are_open_policies_implemented_in_practice_The_Journal_of_Community_Informatics_-_Special_I/links/5c59a20da6fdccb608a97cfd/Exploring-the-politics-of-Free-Libre-Open-Source-Software-FLOSS-in-the-context-of-contemporary-South-Africa-how-are-open-policies-implemented-in-practice-The-Journal-of-Community-Informatics-Special.pdf

Hoffa, F. (2016, September 14). *What countries have more open source developers per capita than the US?* Medium. https://hoffa.medium.com/github-top-countries-201608-13f642493773

Lippert, S. K., & Govindarajulu, C. (2006). Technological, organizational, and environmental antecedents to web services adoption. *Communications of the IIMA*, *6*(1), 14.

Mac Lennan, E., & Chigona, W. (2010). A Critical Analysis of the Policy on Free and Open Source Software Use for the South African Government. *IDIA2010: Proceedings of the 4th International Development Informatics Association Conference*.

Microsoft CEO takes launch break with the Sun-Times. (2001, June 1). *Chicago Sun Times*.

Mombach, T., Valente, M. T., Chen, C., Bruntink, M., & Pinto, G. (2018). Open-source development around the world: A comparative study. *ArXiv Preprint ArXiv:1805.01342*.

Mosoval, F., Gardiner, J., Healey, P., Prestedge, A., & Johnston, K. (2006). The State of Open Source Software (OSS) In South Africa. *PACIS 2006 Proceedings*, 68.

Mtsweni, J., & Biermann, E. (2008). *An investigation into the implementation of open source software within the SA government: An emerging expansion model*. *338*, 148–158. Scopus. https://doi.org/10.1145/1456659.1456677

Mutula, S., & Kalaote, T. (2010). Open-source software deployment in the public sector: A review of Botswana and South Africa. *Library Hi Tech*.

Ngeleza, B., Mkhize, P., & Lubbe, S. (2009). The Application of an Organic Model for Strategic Management to FOSS Migration Within the South African Public Sector. In J. Politis (Ed.), *Proceedings of the 5th European Conference on Management Leadership and Governance* (pp. 133–140).

Rastogi, A., Nagappan, N., & Gousios, G. (2015). *Geographical Bias in GitHub: Perceptions and Reality*. IIIT-Delhi Institutional Repository. https://repository.iiitd.edu.in/xmlui/handle/123456789/388

Rens, A. (2011). Open Document Standards for Government: The South African Experience. In L. DeNardis (Ed.), *Opening Standards: The Global Politics of Interoperability* (1 edition, pp. 63–71). The MIT Press.

Report of the Presidential Commission on the 4th Industrial Revolution. (2020). 222.

Schofield, A., & Dwolatzky, B. (2021). *2021JCSE IITPSA ICT-Skills Survey* (No. 11). Joburg Centre for Software Engineering and Institute of Information Technology Professionals South Africa. https://www.iitpsa.org.za/wp-content/uploads/2021/09/2021-JCSE-IITPSA-ICT-Skills-Survey.pdf

Shuttleworth Foundation. (2017, September 26). Telecoms: Our story so far. *The Shuttleworth Foundation*. https://shuttleworthfoundation.org/thinking/2017/09/26/thinking-telecoms-story/

Sibisi, S., Jensen, M., Machanick, P., & Blake, E. (2004). *Free/Libre & Open Source Software and Open Standards in South Africa* (p. 63). NACI Open Software Working Group.

Sibisi, S., Jensen, M., Machanick, P., Blake, E., Summers, E. B., & Bailey, D. (2002). *Free/Libre & Open Source Software and Open Standards in South Africa*. NACI Open Software Working Group. https://nats-www.informatik.uni-hamburg.de/pub/OSS2004/PaperCollection/OpensourceInSouthAfrica.pdf

Takhteyev, Y., & Hilts, A. (2010). *Investigating the Geography of Open Source Software through GitHub*.

Van Beulen, I., Van Belle, J.-P., & Madhusudhan, M. (2009). Open-source adoption in South Africa by organisations: An exploratory study. *Euro-India Cooperation 2nd International Event, International Management Institute*.

Warren, T. (2020, May 18). Microsoft: We were wrong about open source. *The Verge*. https://www.theverge.com/2020/5/18/21262103/microsoft-open-source-linux-history-wrong-statement

Weilbach, L., & Byrne, E. (2011). Implementing open source software to conform to national policy. *Journal of Systems and Information Technology*, *13*(3), 286–302. Scopus. https://doi.org/10.1108/13287261111164862

Woods, Dan., & Guliani, Gautam. (2005). *Open-source for the enterprise: Managing risks, reaping rewards* (1st ed.). O'Reilly; WorldCat.org. http://catdir.loc.gov/catdir/toc/fy0702/2006284117.html