Extending African Knowledge Infrastructures:

Sharing, Creating, Maintaining

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Executive Summary

A bird cannot know where the sorghum is ready to eat unless it flies. — Burundi proverb.

Solving the "digital divide" in Africa will not put food in mouths, knowledge in heads, clean water in households, or make healthcare accessible to those who need it most. Leveraging knowledge, skills, and capacities holds out the possibility of doing all of these things. This is what extending knowledge infrastructure is about: building robust and sustainable networks and communities that mobilize a broad range of information practices, institutions, and technologies (old and new) – and put these in the service of locally-defined needs**,** aspirations, and broad developmental goals.

This report summarizes current thinking and action around African knowledge infrastructures. It highlights innovative approaches and grounded solutions (old and new, high-tech and low) pointing to wider lessons and fresh ways of thinking that might help guide African development down alternative and more promising paths. It addresses multiple audiences: development policymakers, practitioners, and funders; decision-makers in key knowledge institutions like universities, libraries, research councils, and institutions of cultural heritage; grassroots and community leaders who play key roles in the extension and circulation of knowledge; leaders in fields such as health, education, and agriculture; and leaders and innovators in the business community, in Africa and elsewhere. Above all, the report learns from and seeks to support the work of African knowledge innovators themselves.

Contrary to frequent portrayals, we believe that the story of African knowledge infrastructures is a rich and dynamic one, marked by abundance, diversity, and often overlooked innovation. Present innovations in African knowledge infrastructures extend from the grassroots and local to the pan-continental. They can be found in sectors as varied as agriculture, health care, scientific research, and education. They are linked, though not always effectively, through a variety of networked forms, ranging from cell phone networks and the infrastructures of print, to formal and informal institutions in the market and educational sectors, to cultural patterns of authority, trust, cooperation, and competition. The report moves beyond a narrowly technical focus on connectivity and infrastructure that has sometimes limited development thinking. Instead, it advances a concept of knowledge infrastructures that is *dynamic, extensive, relational,* and *practically and socially embedded.*

The report is divided into 5 main sections. Part 1, "How to Think About Knowledge Infrastructures," explores the distinctive notions of knowledge and infrastructure that inform the report. Part 2, "Rethinking African Connectivities," explores recent developments in African networking. It points to the limits of tech-centered approaches to connectivity that have dominated IT for development (ICT4D) thinking and practice to date. Parts 3 through 5 constitute the main body of the report, and emphasize lessons and examples drawn from diverse African knowledge infrastructures. ***Sharing knowledge*** emphasizes the collective or distributed nature of knowledge, and points to promising African developments, old and new, in this direction. It argues that mechanisms and practices of knowledge sharing constitute the single

most promising area for the development of African knowledge infrastructures moving forward – and the one most neglected in scholarly literature and developmental practice to date. ***Creating knowledge*** points to promising developments in the creation of "new" knowledge – but emphasizing the work of compilation, repurposing, and other forms of mixing over *de novo* acts of invention. It focuses in particular on acts of open knowledge production, in which creators draw on, rework, and give back to distributed knowledge stocks. ***Maintaining knowledge*** points to practices, old and new, supporting and enhancing the movement and sustainability of knowledge through time. It emphasizes systems and practices of memory at scales ranging from the local and institutional to the social and broadly cultural. The report concludes with a set of guidelines, questions, and potential events intended to guide further research and practice in the field.

The organization of the report into the three meta-functions of sharing, creating, and maintaining reflects our belief that: a) significant innovation already characterizes many of the vastly-diverse knowledge infrastructures of Africa; b) such innovation is in fact the best source of learning moving forward; and c) learning to date has been hampered by the typically sectoral organization of development research and practice (which our perspective cross-cuts). We believe that careful, collaborative, and practically grounded thinking around African knowledge infrastructures may help to improve their effectiveness, equity, and broad-based social and developmental returns. This report constitutes a modest contribution to that larger goal.

I. Introduction

When the dog was told that there was food for everyone at the wedding feast, he replied, "We'll check that out at the ground level!" — Niger proverb

Solving the "digital divide" in Africa will not put food in mouths, knowledge in heads, clean water in households, or make healthcare accessible to those who need it most. Leveraging knowledge, skills and capacities holds out the possibility of doing all of these things. This is what extending knowledge infrastructures is about: building robust and sustainable networks and communities that mobilize a broad range of information practices, institutions, and technologies (old and new) – *and put these in the service of locally-defined needs, aspirations, and broad developmental goals*.

This report introduces the concept of knowledge infrastructures and outlines how it might be applied within the varied developmental terrains of sub-Saharan Africa. By exploring the dynamics, tensions, and design challenges entailed in sharing, generating, and maintaining knowledge, we seek to:

- Move beyond tech-centric ('connectivity-first') accounts of African infrastructural development;

- Understand and foster knowledge flows across existing knowledge institutions (universities, libraries, research councils, etc.) and socio-economic sectors (health, agriculture, education, etc.);

- Support, extend, and leverage the existing work of African knowledge innovators by sharing best practices and building collaboration across previously disconnected efforts; and

- Provide guidance to the practical efforts of funders and other stakeholders (including the development community and leaders in the NGO, governmental, and global information technology sectors) working in the knowledge and IT for development fields.

This report aims to gather and give new language to a set of conversations that we see springing up across numerous places and sectors throughout Africa (and indeed, elsewhere in the developing and developed world). That these conversations have too often occurred in isolation is part of the problem. We start from the premise that: a) there is already significant innovation going on within the vastly-diverse knowledge infrastructures of Africa; b) such innovation is in fact the best source of learning moving forward; and c) learning to date has been hampered by the more typical sectoral organization of development research and practice. Careful, collaborative, and practically grounded thinking around African knowledge infrastructures may help to improve their effectiveness, equity, and broad-based social and developmental returns. This report is intended as a modest contribution to that larger goal.

II. How to Think About Knowledge Infrastructures

Every country with its way of dressing a chicken. — Cape Coast, Ghana

In recent decades notions of "information" and "infrastructure" have become commonplace. Put together, "information infrastructure" typically invokes some vision of systems (usually technical) dedicated to the management and exchange of "information" of various sorts (for example, facts, reference materials, texts, images, diagrams, etc.). The functions of storage, organization, and retrieval (think for example of the Internet, or your local public library) differentiate information infrastructures from transmission or communication infrastructures like the publicly-switched telephone network, or broadcast media such as radio or television. The potentials embedded in this difference have led to much excitement, not least in the field of international development. But "information infrastructure" alone remains too narrowly scoped to achieve much of what has been promised on its behalf.

In the 1990s, a new discourse of "knowledge management" arose that promised to leverage and extend the possibilities of information infrastructure. Corporations, governments, and other entities would distill their knowledge — including that held in the minds of appropriately-identified "experts" — into representations that could be managed within information infrastructures, providing easier and more systematic access, and transforming the "information society" into a "knowledge society." In general these efforts floundered, in large part because their concept of knowledge was based in the same framework as that of "information infrastructure." They saw knowledge as something readily codified, entered into a database, and handled like any other documentary material. Despite lip service to the human and social complexities of knowledge, their repertoire of tools and ideas proved too limited to incorporate those elements. In particular, they did not appreciate the degree to which creating, sharing, and maintaining knowledge depends on long-lasting and deeply-embedded social, material, and cultural infrastructures.

This report argues the need and provides some signposts for rethinking the roles of knowledge infrastructures – past, present, and future – in the contexts of Sub-Saharan African development. A full understanding of the term, which draws heavily on our work in the interdisciplinary field of science and technology studies, will be developed across the body of the report itself. To begin, let us define knowledge infrastructures as enduring, widely shared sociotechnical systems consisting of (at minimum): communities; organizations and institutions; languages and other sign systems (e.g. mathematics); standards, norms, and values; theories, frameworks, and explicit or implicit worldviews; mechanisms for the production, dissemination and storage of information (hardware and software, high-tech or low); and 'non-informational' goods and spaces like classrooms, laboratories, and local markets. Thus, knowledge infrastructures constitute *robust networks of people, artifacts, and institutions that generate, share, and maintain specific knowledge about the human and natural worlds*.

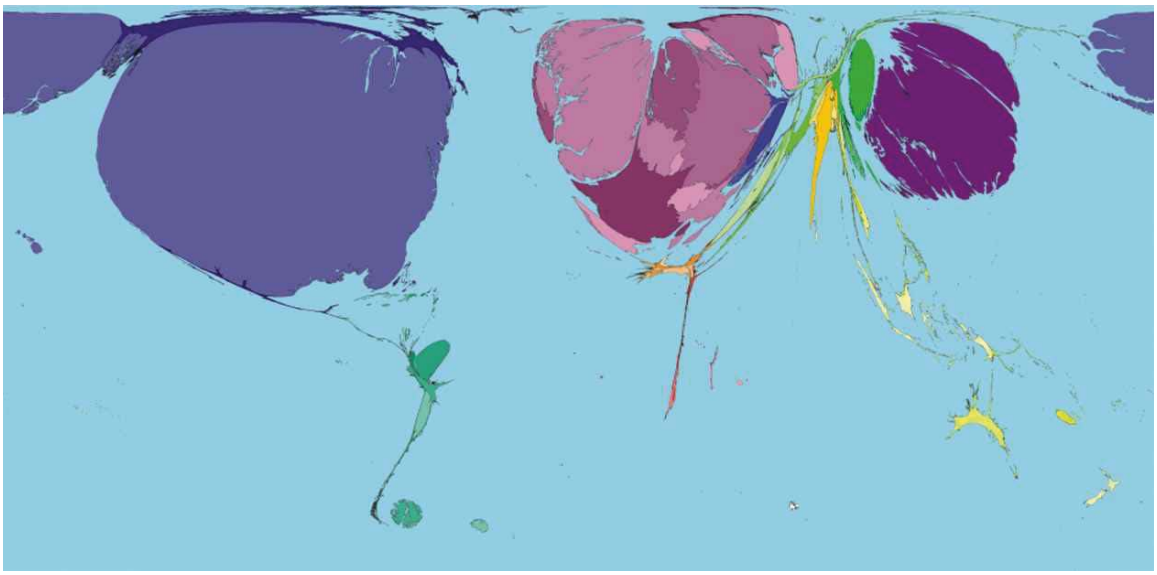
By way of example, consider the type of knowledge about the natural world that we in the West (and increasingly globally) have come to call science. We have a set of respected organizations

(universities, disciplines, research labs, etc.) which cut the world up in particular ways. Each of these tells authorized stories about some aspect of nature, deploying a suite of accepted models and theories as well as specialized vocabularies and mathematical expressions. Practitioners undergo long, demanding training, during which they are taught to think according to prevailing standards of logic; to interpret and judge evidence according to disciplinary norms; to use and trust particular instruments and research methods (and to reject others); to design experiments around well-established and community-specific principles; and to communicate with others according to certain kinds of protocols and conventions. We store scientific knowledge in "archival literature" (now in danger of being usurped by the ubiquitous preprint), and transmit it through a variety of material and human forms (not least the minds and bodies of our acolytes, who we call students). We have institutional arrangements for moving money between taxpayers and disciplines, we have policies about saving original data, we have laws governing intellectual property, human subjects protection, and scientific fraud … and so forth.

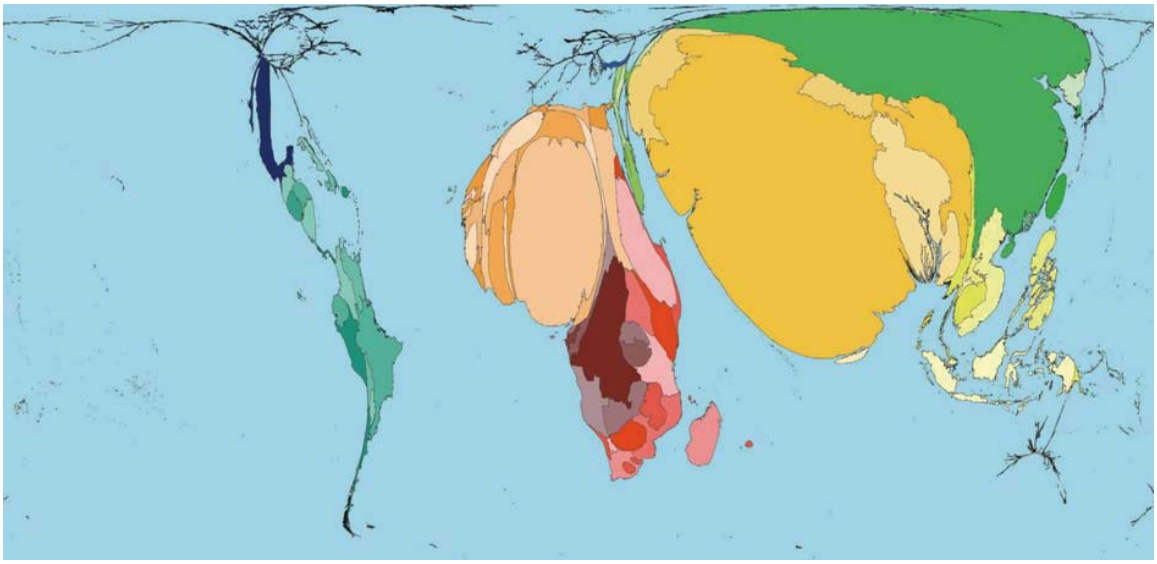
But this represents only one possibility among many. Any even-handed application of the term must extend beyond facts, logic, and scientific reasoning to include *other* culturally-embedded ways of knowing, including those sometimes celebrated and/or subtly devalued as "local" or "indigenous." As the above example suggests, knowledge shows up in many forms, ranging from the embodied and skillful (e.g. weaving a rug, texting a message) to the abstract and conceptual (e.g. the double helix model of the DNA molecule). Knowledge can be fleeting or provisional (e.g. the long and growing list of initially promising therapies and folk remedies subsequently abandoned in the fight against AIDS), or relatively enduring (e.g. the knowledge embedded in proverbs and stories). Knowledge may be more "in the air" than "in the head," a property of groups and cultures more than of individuals.

Where it does endure, knowledge takes *work* to maintain. Embodied skills, organizational memory, and even abstract concepts can ossify, shed meaning, and decay when taken out of active use. Thus the persistence and value of any form of knowledge depends on its ongoing reproduction through use by communities, institutions, and organizations. For this reason, shared and sustainable knowledge depends deeply on social arrangements, including those structuring the allocation of trust, credibility, and the appropriate forms and standards of truth. Knowledge is simultaneously dependent on the various material supports (books, blackboards, satellite links and countless others) that enable its transmission and preservation. All of this argues against simple reductionist positions: for example, those imagining knowledge after the manner of a production chain, a collection of documents, or a simple commodity; that is, as an aggregate body of fact which, once produced, can be stored, transported, distributed, reproduced, etc. without limit.

It may be that development thinking is particularly prone to such reductionist views. As a case in point, note the cover of the recent *UNCTAD Report on Least Developed Countries 2007: Knowledge, Technological Learning, and Innovation for Development*, a document useful in many other respects (UNCTAD 2007). The cover is dominated by two cartograms. In the first, the countries of the global North (especially the United States), are swollen beyond all proportion, while the southern continents shrink dramatically (and Africa disappears almost entirely):



In the second, it is Africa and parts of Asia that grow dramatically, with North and South America, Europe, and parts of East Asia reduced to mere crescents:



Like all maps, these tell a story: as relayed on the report's back cover, the cartograms respectively indicate "the global distribution of knowledge and the global distribution of extreme poverty." The visual message is dramatic and crystal clear: that "the global knowledge divide is almost a mirror image of the global poverty divide" – and that therefore "reducing poverty requires increasing knowledge, learning, and innovation."

But reading on, we learn other information. We find that what the first map counts as knowledge is in fact something much more specific: namely, "the proportion of worldwide earnings derived from royalties and license fees." What the map is really about, it turns out, is a relatively narrow (and hardly neutral) slice within the wider field of knowledge: that which has been formalized,

registered, and appropriated under the prevailing rules of intellectual property (themselves in notable flux and organized in radically different ways across different regions and spheres of human activity). Once this is acknowledged, the "global knowledge divide" the maps purport to represent appears in a distinctly different light. (We will leave Amartya Sen and others to unpack the distinct and problematic notion of poverty that underlies maps like the second one (Escobar 1995; Sen 1999).) The maps do indeed tell us something, but not what they claim to.

We intend the concept of knowledge developed in this report as an extension or alternative to representations like the one above (which we see as widespread in current knowledge and IT for development thinking). Our primary goal is expansive. We seek to move beyond discussions of knowledge in its most abstract and formalized versions, and towards an understanding of developmentally-useful knowledge in its diverse and everyday guises: as a property of individuals, organizations, communities, technologies, and ordinary social practice. In the distinctive sense of the term developed below, we argue that *knowledge inheres in infrastructure*, generated, shared, and maintained through a diverse and changeable set of peoples, artifacts, and institutions. Knowledge is an infrastructural accomplishment.

Understanding Infrastructure

People often think of infrastructure as a fixed (and usually boring) baseline or substrate: something upon which something else "runs" or "operates," as railroad cars run on railroad tracks, or packets travel through the Internet. This image presents infrastructure as something designed and built in a more-or-less straightforward and technical way. Once built, it is assumed that infrastructure stays in place, ready-to-hand and naturally, or even unconsciously, used. At its seamless best, it will become so reliable and obvious to all involved that it will disappear entirely, leaving only the content or object of the activity at hand (for example, as we ignore the details of TCP/IP and packet-switching when sending email).

Recent scholarship, including our own, presents a more complex picture. For us, working infrastructures are characterized by most or all of the following properties:

- **Embeddedness**. Infrastructure is "sunk" into, inside of, other structures, social arrangements and technologies;

- **Transparency**. Infrastructure is transparent to use, in the sense that it does not have to be reinvented each time or assembled for each task, but invisibly supports those tasks;

- **Reach or scope**. This may be either spatial or temporal -- infrastructure has reach beyond a single event or one-site practice;

- **Learned as part of membership**. The taken-for-grantedness of artifacts and organizational arrangements comes with membership in a community of practice (Lave and Wenger 1991). Strangers and outsiders encounter infrastructure as a target object to be learned about; new participants 'internalize' infrastructure in the process of becoming members;

- **Links with conventions of practice**. Infrastructure both shapes and is shaped by the conventions of a community of practice, e.g. the ways that cycles of day-night work are affected by and affect electrical power rates and needs;

- **Embodiment of standards**. Modified by scope and often by conflicting conventions, infrastructure takes on transparency by plugging into other infrastructures and tools in a standardized fashion;

- **Built on an installed base**. Infrastructure does not grow de novo; it wrestles with the "inertia of the installed base," with all its strengths and limitations. Thus optical fibers run along old railroad lines; new systems are designed for backward-compatibility; and failing to account for these constraints may be fatal or distorting to new development processes (Monteiro, Hanseth et al. 1994);

- **Becomes visible upon breakdown**. The normally invisible quality of working infrastructure becomes visible when it breaks: the server is down, the bridge washes out, there is a power blackout. Even where back-up mechanisms or procedures exist, their very strangeness calls attention to the broken and therefore suddenly visible infrastructure.

The precise implications of these features of infrastructure have been explored at length in other contexts (Star and Ruhleder 1996; Bowker and Star 1999; Edwards, Jackson et al. 2007; Jackson, Edwards et al. 2007). Here, let us note five:

First, infrastructures are deeply heterogeneous phenomena, made up of a good deal more than pipes and wires. They are rarely if ever free standing, instances of pure technology existing free and clear of other infrastructures, or indeed the social structures, conventions, competencies, etc. which structure their implementation and use. If this is true of infrastructures in general, it is even truer of knowledge infrastructures, which implicate questions of cultural and social value at their very core. For this reason, social relations of trust, value, and belief loom large.

Second, unlike individual technologies or discrete systems, infrastructures are not themselves typically objects of design, in the sense that they have no single designer and follow no central plan. Rather, where infrastructures achieve scale, it is typically by building bridges and links to previously existing entities and practices, many of them invented or evolved for entirely other reasons. In this process, gateways may be central. These can take several forms, ranging from standards (e.g. the TCP/IP protocol for connecting between computer networks), to objects (e.g. AC/DC power converters), to social conventions or agreements (e.g. those allowing drivers to use their home country licenses when renting a car abroad). Some gateways will appear as official or high-level solutions to deeply-felt problems, but many more will emerge ad hoc, created by specific users for specific purposes before becoming more globally distributed. Examples of such grassroots infrastructural development might include farmers building out early telephone networks using barbed wire to carry the signal; or 19th-century messenger boys – human gateways – carrying messages between stock exchanges, telegraph offices, and corporate offices (a function carried on by the bicycle couriers of many present-day metropolitan areas).

Third, because developing infrastructures are made up of multiple and interlocked components, they are frequently subject to "reverse salients": i.e. sticking points on which the growth possibilities of the whole may catch and founder. These are the thorny or intractable problems that can delay or derail whole lines of development for years or decades at a time (e.g., the challenge of delivering power over 'lossy' lines that delayed for years the build out of Western power grids). Once resolved, systems that have been stalled in this way may undergo periods of rapid transformation, expansion, and innovation; this is one way of accounting for alternations between periods of dynamism and apparent stasis that some historians have noted in the history of large-scale technical systems (Hughes 1983).

Fourth, because they spread costs and benefits unevenly, the development of infrastructure may well be a deeply contentious affair. Infrastructures that empower certain types and classes of actors may carry few or even deeply negative effects for others: the formerly prosperous river town bypassed by the new rail infrastructure, the agricultural or industrial workers de-skilled by new forms of automation. Such groups are likely to resist (directly or subtly) certain forms of infrastructural development, including by advancing competing or alternative visions. For the same reason, system builders often resist building gateways to other systems, fearing they will lose control (and profits) if their system is linked to another one that may overwhelm it. (America Online, for example, for years tried to prevent its clients from connecting directly with the World Wide Web, fearing loss of advertising revenue.) Deep-seated conflict is thus a frequent concomitant of infrastructural development. Appropriately managed, such tensions can be turned into sites of learning and innovation. Left unmanaged, such tensions can be socially, culturally, or economically destructive, and a major barrier to infrastructural innovation and development. Collateral damage is the Darwinian law of growing infrastructure.

Fifth, infrastructures – even "twenty-first century" ones – need not be high-tech. Indeed, simple but robust techniques, such as transmission through direct apprenticeship and oral tradition, have been among the most stable and significant mechanisms of knowledge transfer in human history. (Arguably, these remain fundamental to all contemporary forms of knowledge, including scientific.) As examples of highly robust, traditional knowledge infrastructures, consider knowledge of medicinal plants, midwifery, animal husbandry, or pre-industrial agricultural techniques. In both developed and developing worlds, these and other knowledge infrastructures coexist alongside more recent print-, image-, and digitally-based forms whose technological aspects are more salient.

Knowledge Infrastructures and the African Context

Here, roughly, is the hopeful vision: In parallel with changes witnessed to date in North America, Western Europe, and parts of East Asia, emerging knowledge infrastructures in African contexts hold the potential to develop local capacity for creating, sharing, and maintaining knowledge, while at the same time linking users to vast external resources, both regionally and beyond. Knowledge infrastructures can help routinize and facilitate the collection, organization, presentation, and distribution of technical and cultural "data." They can help validate and stabilize knowledge, allowing for wide and efficient sharing and reuse. By supplying templates and frameworks for the interpretation and use of new information, they can enable rapid

propagation and learning across disciplinary, institutional, sectoral, and potentially cultural divides. Appropriately constructed, they can activate and connect local sites of knowledge and creativity, growing new collective capacities for endogenous and locally appropriate innovation.

At the same time, external interactions enabled by transport, communication, and economic infrastructures have often been experienced as primarily one-way and/or deeply unbalanced in their distributions of agency (i.e. who is granted effective power to act and choose) and outcome (i.e. who gains and loses in consequence of the new modes of connection). This can amount to a colonial or imposed presence, which sometimes interferes with locally valuable work and/or recreates new and damaging forms of dependency. Global connections have often carried with them local forms of disconnect, introducing new and developmentally-damaging forms of stratification. Externally-championed forms, models, and technologies may lack applicability in developing world contexts, proving ineffective or worse. Global "solutions" may crowd out local endeavor, undermining both appropriateness and local capacities for innovation and endogenous change. At their worst, forms of global connection may simply be imposed, with little regard for local capacities, resources, and needs.

Cast in these terms, confrontations between knowledge systems can seem to provoke a stark choice between old and new, local and global, "traditional" and universal — requiring participants either to abandon their past in favor of a wholesale paradigm shift, or to cling to tradition, denying all validity of the new alternative in a desperate quest to maintain cultural integrity against the tidal wave of globalization. Both academic and popular debates about knowledge tend to divide along these lines, presenting a choice between a supposed universal rationality and a corrosive cultural relativism that accepts all beliefs as equally valid.

This split is reflected in much of the literature on indigenous knowledge that has emerged in recent decades:

> Indigenous knowledge is the local knowledge – knowledge that is unique to a given culture or society. IK contrasts with the international knowledge system generated by universities, research institutions and private firms. It is the basis for local-level decision making in agriculture, health care, food preparation, education, natural-resource management, and a host of other activities in rural communities (Warren 1991).
>
> [Indigenous knowledge is] the unique, traditional, local knowledge existing within and developed around specific conditions of women and men indigenous to a particular geographic area (Grenier 1998).

Underlying such positions are strong and admirable commitments to respect, and no less important commitments to cultural preservation (though we should note that all cultures, including western ones, are moving targets, better preserved in growth than in stasis). But it is possible to overrate these distinctions. For one thing, the purity of these two categories, neat in the abstract, is hard to maintain on the ground. It is difficult, perhaps increasingly so, to point to indigenous or local knowledge systems which don't interact with other systems of value in some way. Scientific knowledge systems, for their part, remain subtly but resolutely local, though

often at the same time far-reaching. Indigeneity can celebrate and respect local value, but it can also ghettoize it. Conversely, the label of scientific or international knowledge may accord western forms of rationality a universalism they haven't earned (and don't possess). More prosaically, debates around the merits of indigenous vs. global knowledge forms have too often been staged as defenses of value, i.e. efforts to show that indigenous knowledge is as true, or in any case as valuable, as knowledge generated through science. This way of conceiving the problem has led to futile debates over the superiority of one or the other ways of knowing. The most profound effect of the common distinction between traditional and universal knowledge may be to alternately "traditionalize" or "universalize" knowledge practices more helpfully compared on a common analytic plane.

An infrastructure perspective adds weight and analytic focus to this debate. Instead of considering the product (facts, beliefs) in isolation, it focuses on the process. What are the underlying frameworks for creating, validating, sharing, storing, and changing knowledge? How do they compare? In the case of certain types of Western/international knowledge, these include such things as scientific instruments, communications networks; written records (e.g. journals); formal standards; linguae francae such as English (and formerly French and German); and socio-political movements such as scientific internationalism that produce both conformity to widespread norms and competition for success within them. In many "Western" regions, knowledge production processes once carried out as crafts, with wide variation among local practices, have converged on internationally standardized, factory-like techniques over vast areas based on the communication systems and social norms just mentioned. (Consider the global weather forecast system or the vast pharmaceutical industry.)

The infrastructures supporting knowledge production in Africa, by contrast, have very often included things like master-apprentice transmission models, oral traditions, local natural settings (e.g. flora, fauna, minerals) and low-tech material processing (e.g. plant extracts, seed storage, tools). These are very often slower (though for that reason remarkably durable), more local, and less standardized. Further, because they are often passed on as holistic practices involving an entire habitus of expressions, gestures, and other embodied actions, they have tended to lend themselves poorly to the documentary model of information. As for generating new knowledge, master-apprentice systems generally encourage a cautious approach to innovation and discovery. In these knowledge infrastructures, innovation is rarely an end in itself – a fact reflected in the organization of knowledge-generating practices.

A knowledge infrastructure perspective does not stigmatize these distinctions, but simply recognizes the differing qualities of dissimilar support structures. At the same time, it can produce insight into similarities. For example, scientific training also typically begins on a master-apprentice model; key skills taught mainly by apprenticeship include how to decide which published literature can be trusted, and where new research is most likely to succeed. Similarly, oral tradition matters greatly in science; the insider/outsider distinction on which scientific communities (like all communities) depend are learned orally, informally and in person, from peers and mentors.

In recent years, for many of the reasons noted above, strong distinctions between geographically local knowledge islands and the supposedly universalized, abstract, dominant global system have

begun to break down (Agrawal 1995; Agrawal 1995; Agrawal 2002). In their place, a more diffuse and complex, yet also more useful, definition of indigenous knowledge has emerged:

> …an all inclusive knowledge that covers technologies and practices that have been and are still used by indigenous and local people for existence, survival and adaptation in a variety of environments. *Such knowledge is not static but evolves and changes as it develops, influences and is influenced by both internal and external circumstances and interaction with other knowledge systems.* Such knowledge covers contents and contexts such as agriculture, architecture, engineering, mathematics, governance and other social systems and activities, medicinal and indigenous plant varieties, etc. (Onwu and Mosimege 2004)

Building from this perspective, development specialists have begun local experiments that join indigenous and "Western" or international knowledge as complementary, mutually informing practices. For example, the Amazon Conservation Team has opened several medical clinics housing traditional shamans and Western medical practitioners side by side. At the clinics,

> Joint workshops inform the Western-trained caregivers about indigenous concepts of illnesses, and shamans learn about preventive health practices. They often refer patients to each other. For instance, villagers who show up at the Western clinic suffering from the parasitic disease leishmaniasis will be sent next door to the shamans for an ointment that's more effective than any modern tincture. …The clinics' practices are also helping in a larger effort, pushed by the WHO, to develop stronger evidence of traditional medicine's quality, safety, and efficacy. The clinics in Suriname have begun keeping records, and pharmacists there have introduced shamans to standardized measurement methods for collecting, preparing, and storing their medicines--efforts that will shed light on their efficacy and facilitate the production of medicines….

Such experiments indicate the possibility of going beyond superficial respect and static preservation of indigenous knowledge systems, towards more dynamic and collaborative models capable of working across divides previously thought to be absolute. This raises the possibility of leveraged or hybrid development models, which bridge and blend forms of knowledge previously segregated as "indigenous" and "international." Such models suggest large rewards from efforts to build *gateways, bridges, and collaborative links aimed at building reciprocal and locally appropriate links between knowledge practices of various types and scales.* Many of the examples cited in the following sections will share some flavor of this principle.

This section of the report has sketched the distinctive notions of knowledge and infrastructure that inform the analysis that follows. We believe this approach may support new ways of thinking and enacting the complex relationship between knowledge and development in Africa. This relates to but departs from recent work in both the knowledge and ICT for development fields. We turn to these questions in the section that follows.

III. Rethinking African Connectivities

No matter how long a log stays in the water, it doesn't become a crocodile. — Bambara (Mali)

Connection and access models form a crucial dimension of contemporary knowledge infrastructures in Africa. Relative to other sections of the report, this field has received greater and longer attention than most others, with roots in the communication, telecom, and ICT for development literatures and practices going back several decades. Connection and access issues have also attracted the lion's share of donor and domestic country funding in recent years, much of it mobilized around some version of the digital divide argument – and frequently based on a naïve "build it and they will come" view of connectivity. While such approaches have delivered some notable successes, they have also suffered from a number of common deficiencies: the tendency to reduce connection and access to primarily technological challenges, without regard for the competencies, social forms, and use patterns that make connection and access meaningful; the tendency to bound definitions of connection too tightly (e.g. immediate access to the Internet), missing potentially beneficial practices of second-order or proximal connection; and the common failure to coordinate effectively across the content / conduit divide, foregrounding the physical act of connection while neglecting larger questions around knowledge flow and social value that are, in this model, assumed or set aside for later consideration. The net result of these tendencies has been to see and support models of connection that are immediate, highly structured or systematized, recognizably technological in orientation, and relatively divorced from the content or substance of connection.

An additional set of limitations stems from what we might term the "broadband imagination," a mode of thought that takes the always-on high-speed networks of the global North as the universal ideal for African infrastructural development. Under this mindset, local, kluged, and heterogeneous models of connection that flow between high-technological and other forms have been routinely underappreciated. Recent scholarship shows that adaptations, workarounds, and mixed-media engineering may constitute the lion's share of innovation, and the main source of resilience and sustainability, in most infrastructures. Local tailoring tends to improve efficiency, sustainability, and the general "fit" of infrastructure by mapping it more realistically to local needs and incentives. Like most instances of local innovation, this type of work tends to fall within what William Easterly has identified as the "search" space, and has regularly eluded the grasp of development planners of all stripes (Easterly 2006).

Within the broad field of African connectivity, efforts to extend the reach, speed, and capacity of networks have occupied a significant portion of IT for development efforts to date. As numerous U.N., World Bank, and donor country reports have noted, Africa remains the least-connected continent, with the lowest and slowest access to basic telephony, to computing, and to the Internet.

This point is nicely captured in the interesting "bits-per-capita" map produced by the International Development Research Centre's Acacia Program (IDRC 2002):

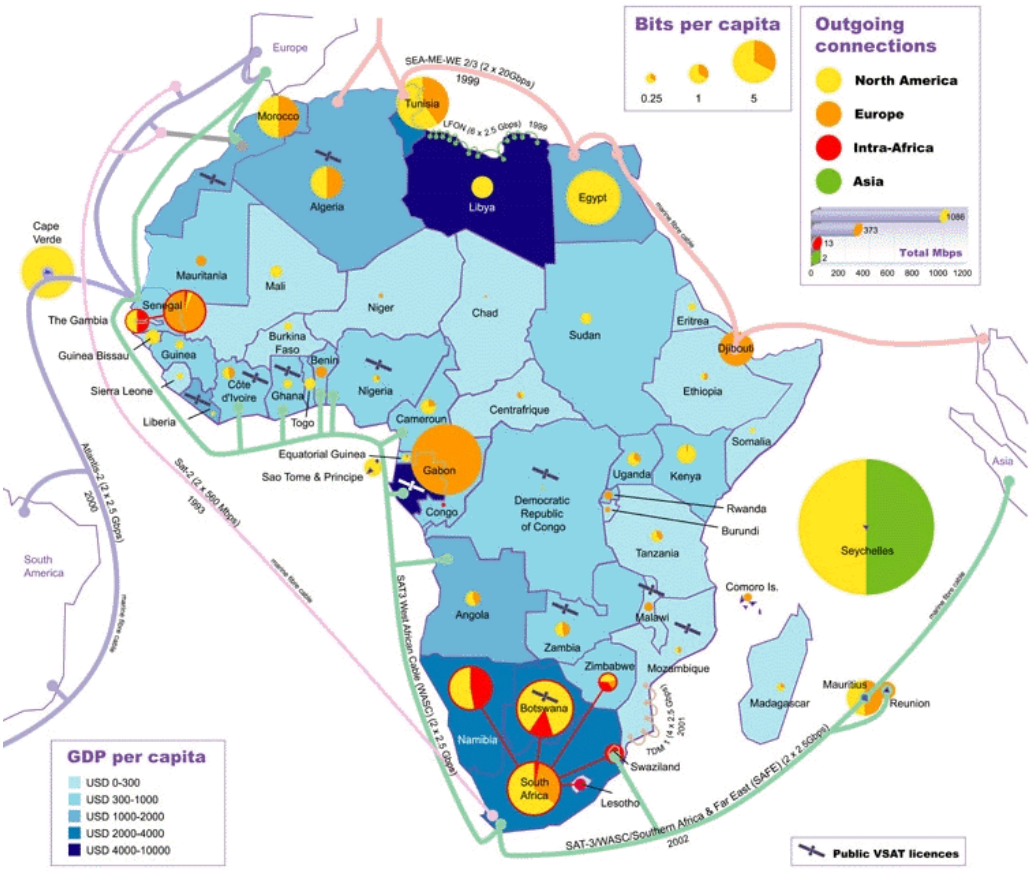


Figure 1: Map of major network connections in Africa, the number of bits transferred per person, and the destination of those bits (source: International Development Research Centre: http://www.idrc.ca/en/ev-6568-201-DO_TOPIC.html.

But such overall figures also mask important local variations: for example, national rates of connectivity in parts of southern and eastern Africa that compare favorably to those of Latin America and Eastern Europe, and stark rural-urban and even intra-urban divides (e.g. between wealthy neighborhoods and business districts in major centers and their surrounding shantytowns) that make general connectivity rates both overstate and understate the problem. They also mask important vectors of change – for example, that the highest growth rates worldwide in mobile telephony since 2000 have come in Africa.

Recent efforts in African network development have taken many forms. In some instances, these have been directed at the construction and operation of wired networks (telecoms, LAN-based, etc.). Important efforts now link and share knowledge between network operators across the continent (see, e.g., the African Network Operators Group, http://www.afnog.org/). Other networking efforts have sought to tap the advantages of satellite transmission, either as end-to-end solutions – including to the formidable challenge of the "last mile" – or as components within an integrated multi-modal network. Beyond satellite, terrestrial and community radio has been a particularly powerful and long-standing developmental tool. Arguably the most

significant recent extension in basic network capacity has come in the field of mobile telephony, with annual growth rates through the early 2000s climbing to the hundreds, and even thousands, of percent. Beyond straight subscription figures, the developmental impact of mobile networks has been extended through community-access initiatives such as the Village Phone model pioneered by the Grameen group in South Asia and now operating in Uganda, Cameroon, and Rwanda; there are now many variations of the same basic model operating throughout the continent.

Other projects to improve access and connection have followed a centers model, with computing, communication, and often textual resources collected at a single point and made available for common use. In some, predominantly urban settings, this is accomplished through some version of the Internet café, with computing and connection times provided for general use on a commercial basis. Elsewhere, particularly in rural settings, access may be provided through government, donor-supported, and/or locally-sustained telecenters. Under either model, centers allow for the efficient pooling of scarce resources around equipment, expertise, and network connectivity, supporting a wider base of regular and occasional users than are likely to achieve connectivity on a direct-to-network basis. Extensive and long-running telecenter programs have been developed by both international organizations (IDRC, UNESCO, etc.), and a number of country governments (e.g., the South Africa Universal Service Agency). Recent evaluation reports of IDRC, UN, and other telecenter programs suggest both strengths and limitations of center-based approaches to expanding connectivity and access.

Both network and center-based access models have faced severe costs in the form of equipment costs, both for initial purchase (often the main constraint on up-front investment) and for ongoing maintenance (routinely under-budgeted for, and thus a serious check on sustainability). In partial response, governments, corporations, and international organizations have initiated projects targeting the development of information appliances aimed at developing world conditions and price points. Arguably the most famous of these is the "$100 laptop" championed by Nicholas Negroponte and other members of the One Laptop Per Child movement. A similarly inspired project is the Emerging Market Handset (EMH) initiative of the GSM Association, with the lofty goal of extending access to mobile communication to 80% of the world's population by 2010. This joins a long list of government-sponsored cheap or recycled PC programs, designed to extend access to basic computing equipment among poor, rural, and frequently school-age populations (e.g., Brazil's Computador Popular program; or in an African context, the Computers for All Nigerians Initiative). Such programs have been courted and sometimes sponsored by the emerging market (or "base of the pyramid") strategies of multinational IT vendors like Microsoft, Intel, Cisco, Qualcomm, and IBM, all of whom have introduced programs and/or products matched to the price points of developing world markets. Joining these high-profile government and corporate initiatives are a truly vast number of smaller initiatives currently under development in universities, non-profits, and small enterprises around the world. Many of the latter build on some version of open source – leading to widespread excitement (arguably premature) around the prospects of "open development."

Each of these broad connectivity strategies – networks, centers, and devices – have logged important accomplishments, and in some cases led to significant instances of local innovation. But each has also demonstrated limitations. Network development efforts have produced some

notable improvements in specific sites, but have not yet come close to solving the problem of reliable and affordable access, especially outside of urban centers. Center initiatives have been useful in extending access (not least to basic telephony) to areas previously unserved, but have been plagued by persistent problems of sustainability and maintenance, with a disappointingly small number of centers, especially of the rural telecenter variety, surviving beyond initial periods of donor funding. The range of "devices for development" initiatives, with a relatively shorter track record, nevertheless face significant barriers to implementation and impact. Many of the government programs adopted in Africa and elsewhere have experienced significant delays, cost overruns, and/or questionable levels of quality control. The industrially-based programs, by contrast, have tended to start and stop at the edges of proprietary interest (and have in any case shown little serious inclination to move beyond emerging markets in the BRIC countries and/or the large African markets of Nigeria and South Africa). Lacking effective distribution channels, production support, and/or necessary connections to allied products and services, many of the smaller and most innovative initiatives have failed to proceed beyond the experimental design and piloting stage.

Beyond individual limitations, African connectivity efforts to date have experienced a more general and shared class of problems. Each has struggled with issues of sustainability, showing a tendency to decline, break down, and/or fall into disuse once initial periods of funding (and perhaps novelty) elapse. Learning effects across these initiatives, both individually and as a set, have tended to be weak, leading to the unnecessary repetition of mistakes, poor design choices, inappropriate economic and organizational models, etc. With a few notable exceptions, they have also tended to proceed with little connection to existing knowledge practices, institutions, and infrastructures. This has left them weak on questions of content, and arguably hampered both their sustainability and longer-term developmental potential. Finally, by beginning from technology, such work has tended to mistake or misrecognize the real sites and forms of social innovation. From this perspective, a good deal (arguably the majority) of effective innovation in infrastructure cannot be "localized" in networks, centers, or devices (however well-designed), but lies in the adaptive responses of individuals, groups, and institutions to the changing landscape of possibility. Put differently, there is nothing inherently innovative or developmentally positive about any of the efforts around connection and access listed above; without understanding the local practices by which actors (users, planners, entrepreneurs, etc.) incorporate and deploy the changing technologies, we miss the greater and more complicated part of the innovation and development story. This indeed has been one of the principal failings of ICT for development research and practice to date – and one of the main drivers of recent moves to "mainstream" IT in the broader development debate.

Growing evidence, both North and South, suggests that the narrowly tech-first approach which has tended to characterize connectivity and ICT for development efforts to date is no longer tenable or desirable. Instead of connectivity, what is most needed is connectedness: infrastructures that facilitate connection across social, cultural, and institutional divides, tapping and extending local sites of knowledge production and innovation. In the remainder of this paper, we will explore exactly why this is so, and point to the projects, activities, and efforts that show signs of linking and leveraging the diverse knowledge infrastructures of Africa.

IV. Sharing Knowledge

The blacksmith in one village becomes a blacksmith's apprentice in another. — Cape Coast, Ghana

People learn by sharing. Words, ideas, traditions, skills, habits of action — most things people do starts with learning something from somebody else. Knowledge infrastructures relay knowledge from one person or group to another. In the process, they pass knowledge from generation to generation; from place to place; and from culture to culture, across regions and communities. Like most of our metaphors for knowing, sharing conjures images of one person handing some object to another. In reality, sharing knowledge is not merely about passing bits of data along a human chain. It has informal, tacit, and cultural dimensions, as well as complex organizational dynamics and tensions; all of these affect how, why, and where knowledge flows, and even whether it flows at all.

Shared information only results in shared knowledge under certain conditions. Both those who create the knowledge and those who receive it must share a cognitive framework that allows them to interpret data in a compatible fashion. Transmission of raw data is insufficient; rather, accompanying metadata that elaborates and aids interpretation of the primary data is vital. This may seem to be merely a matter of spending the time and energy to make the knowledge portable and understandable to others. Yet such “extra” work on data is often not a standard institutional practice of African researchers or the plethora of development organizations working within Africa, nor institutions in the West, for that matter (Edwards, Jackson et al. 2007). Across knowledge creation entities, the culture of data use and sharing is laden with differences of epistemology and opportunity for mistrust, further complicating knowledge sharing. Typical vehicles for disseminating findings include media reports and journal publications. Project organizers are more likely to seek publication of their work if it is “successful,” and it is more likely to be accepted for publication if it is “successful.” Yet there is great value in learning from failures. This common flaw of would-be knowledge infrastructures might be addressed through properly engineered incentives. Economists studying incentive-centered design have noted the necessity of having visible benefits to individuals in order to promote behavior that benefits a group (Roth 2002).

Successful knowledge infrastructures include mechanisms that reward individuals and organizations that share knowledge. Incentives can be either positive or negative, and may involve financial payments, prestige, reciprocated knowledge access, or qualification for future funding. Both governments and aid agencies should therefore emphasize incentive structures that encourage honest, truthful sharing of results — both positive and negative.

The issue of contextualization also illustrates the basic tension of glocalization, in which systems (of knowledge, in this case) need to be both tailored to work well in a local context, and yet be generalizable in order to effect larger change across many locales (Graham and Marvin 2001). Bertand and Hunter, for instance, cite the need for an “African Index Medicus” that supplements the deficiencies of the dominant medical literature databases (1998). They argue that Western

medicine has dominated the global literature, to the neglect of medical research in the context of non-industrialized regions. Such systems of local knowledge play an important role in promoting local knowledge generation, and by providing an outlet for localized knowledge to be distributed and integrated into global knowledge distribution infrastructures.

Just as forms of connectivity are heterogeneous, so are the disparate models of sharing. Knowledge may be broadcast to some set of people as enabled by various broadcast media. Such public knowledge sharing is intended to disseminate knowledge of general interest, or of interest to some substantial subset of the recipients. Alternatively, groups may grow their own base of knowledge, sharing within themselves or between groups. Or knowledge sharing may occur at the individual level as people share with each other. Such peer to peer knowledge sharing is increasingly possible with new technologies, enabling a direction of knowledge sharing previously difficult to manage without the intervention of more organizational structure. Another model facilitated by technology is that of commons-based knowledge production. Individuals' contributions to a knowledge base are aggregated into a larger and more comprehensive set of knowledge (e.g., Wikipedia).

Electronic Information for Libraries (eIFL)

It is tempting to simplify knowledge transfer to a technical problem, but the reality is much more complex. Electronic Information for Libraries (eIFL) is a good example of an organization that assists in solving the social and legal complexities of knowledge sharing. eIFL partners with library consortia in countries around the world, currently including 15 African countries. Organization activities include:

- Negotiating with publishers
- Training national library consortia
- Sharing knowledge among consortia
- Advocating libraries' interests in copyright discussions
- Supporting open source software in the library
- Using open access publishing to develop local content

Models of sharing typically include both publication and retrieval components, or more colorfully, "push" and "pull." Knowledge sharing requires effective mechanisms for both of these. Knowledge creators want to publish in a way that will reach the intended audience, and audiences would like to successfully search for, identify, and retrieve the knowledge they desire. Traditional mechanisms such as academic journals have facilitated the publication to a certain audience, and the ability of interested parties to search for certain types of knowledge. Newer forms of publishing, retrieval, and searching exist through the Internet's Really Simple Syndication (RSS) standard. Comprehensive knowledge sharing systems attack both push and pull directions, and sometimes even support a "broker," such as an editor or public RSS aggregator, that helps connect those who are publishing to those who are retrieving knowledge. At a larger scale, knowledge infrastructures push and pull information around the globe. Recent research in development work has emphasized the importance of providing more explicit opportunities for Africans to pull information from around the world, rather than having it pushed to them (Godlee, Pakenham-Walsh et al. 2004; Rhine 2006). Sensitivity to local knowledge needs is a clear priority.

Sharing occurs on different scales and in varying directions. Intercontinental sharing has historically been seen as a one-way flow of knowledge into Africa, bringing Western science and technology to bear on African problems. In practice, the relationship also included a significant back channel as Africans then did some extra work in adapting the European ideas to be effective in the local context. For instance, while French colonists sought to grow cotton in Niger, African farmers pushed back on the local administrators. Eventually they succeeded in persuading them to switch to rice, influencing France's colonial development strategy and forcing Europeans to realize that their development strategies could not purely dictate the adoption of European agricultural systems (Van Beusekom 2002). This historical pattern of information flow between African nations and their European colonists continues now through strong social and institutional ties. Intra-African sharing, on the other hand has been both less common and more difficult. Knowledge sharing, or spillover, typically accompanies trade arrangements and is facilitated by the routes established by business. The Economic Commission for Africa advocates regional integration as a means for addressing this constraint, and developing means for trade and knowledge sharing (ECA 2004). At a yet smaller scale, sharing within a local village or community is very well supported through tight-knit communities and oral traditions. There may be particular benefit in increasing sharing in under-utilized directions, namely within Africa and from Africa out to the global West.

The movement of people is an important mechanism for the mobilization of knowledge. Africa's professionals have been particularly likely to leave the continent altogether, bringing their skills and knowledge with them. The Diaspora of skilled Africans leads to an increased reliance on expatriate professionals, who carry with them a Western-learned knowledge set. Tebeje found that "Africa employs up to 150,000 expatriate professionals at a cost of US $4 billion a year," absorbing 35% of development assistance (2005). The ongoing export of African knowledge workers, and import of Western ones, perpetuates a Western style of knowledge and impedes the growth of Africa-specific knowledge sets. In the West, the exodus may carry African knowledge with it, yet it is less likely to have a significant impact on the large, stable knowledge infrastructures in the West. Constraints on the movement of people also impede intra-African knowledge sharing. Due to the legacy of colonial transportation infrastructure, it is often easier to travel from Africa to Europe than to other regions within Africa. This serves to limit the rich knowledge exchange that occurs in face to face meetings among Africans.

Perhaps the most explicit form of knowledge sharing occurs in educational systems. For top-level researchers, reputation (and therefore success) is determined by publication (both quality and quantity). With the bulk of publication systems based in the global North, African scholars must engage with non-Africans and topics of interest to non-Africans in order to gain repute (Hountondji 1995). The former director of University of South Africa Press, Abebe Zegeye, has written that African publishing is an appendage of European and American publishing enterprises (Zegeye and Vambe 2006). The costs for printing in Africa are higher in most areas with the exception of labor costs, but materials, the presses themselves, and distribution is more costly than in Europe. A locally printed children's book retails for ten dollars in Ouagadougou, Burkina Faso. This is a very high price for the local market and much more than a comparable book in the United States. Partly for this reason, knowledge sharing both within professional research communities and among the public at large retains a strong and entrenched North-South component.

Still, recent efforts are beginning to exploit open-access, electronic systems to encourage intra-African sharing. For instance, the Association of African Universities runs the Database of African Theses and Dissertations which provides free full-text access to thousands of works for anyone in Africa (2008). A further approach of interest would be to engage African diasporic communities abroad with knowledge production on the continent itself (Meyer 2001).

Easton argues that "IK [indigenous knowledge] activity is fundamentally educational" as well and we can see both "education as a vehicle for IK and IK as a model for education" (World Bank 2004). In sugar cane winemaking, for instance, knowledge about the process is passed through apprenticeships or trade associations. Because these transfers are without cost, it is easier for entrepreneurs to form a new business since the overall startup cost is lower (Luzietoso, Khonde et al. 2000).

The process of sharing is both afforded and constrained by the forms in which knowledge was generated. Standardized forms of knowledge facilitate sharing with others who know how to interpret those standards. Mature knowledge infrastructures have understandings about the standards that are to be used for different types of knowledge, and have mechanisms known as gateways that allow shared understanding (Egyedi 2001). Just as standard rail gauge permits and (sometimes deliberately) constrains interchange of rail cars across borders, knowledge standards facilitate and constrain interchange among people from different cultures. Historically, engineers have addressed standards differences through gateways that facilitate interoperation between the two standards. Just as the development of the rotary converter allowed the connection of AC and DC electrical infrastructure (Friedlander 1996), interpretive interfaces may be necessary to unite currently diverse and incompatible knowledge infrastructures. For instance, oral traditions underlie many African indigenous knowledge systems. Pidatala documents the 20 year Eritrean effort to capture indigenous knowledge from Elders. The Elders enthusiastically contributed to a repository in the hope that it would preserve and propagate their accumulated knowledge. However, the information remains largely in a raw format, flowing straight from mouths onto paper. This raw form has proven inaccessible; as a result, the rich resource has been under-utilized. Additional work is needed to transform the "raw" oral genre into a functional work within written, "academic" genres of knowledge (Pidatala 2001). To connect local knowledge base with larger scale knowledge infrastructures, interface systems are needed to convert oral content to the broadly used print tradition, and vice versa.

A key component of all knowledge infrastructures is genre, a shared template or script for action that enables effective sharing. For example, Yates details the importance of the business memo as a genre that enabled managers to communicate efficiently; header conventions such as date, "to," "from," and "re." ("in reference to") and brevity of content (usually no more than one page) communicate much about its function in organizational action (Yates 1989). Genres give people crucial clues about the type of communication they are about to be involved in, and their conventions make their contents easier for others to grasp — if they know those conventions. Meetings are an example of a scripted action genre; such features as how meetings are opened and closed, who leads them, how (or whether) an agenda is set; conventions for getting attention or speaking; and so on are all part of the genre.

Notably, while all cultures have something vaguely resembling a meeting genre, where people gather to discuss something and perhaps make decisions, their genre conventions vary enormously. Induction into a genre and its conventions generally happens not through direct instruction, but through participation. People unfamiliar with this or any other genre need more time to understand the knowledge being shared, and may make mistakes in the interpretation. Many indigenous knowledge systems use genres of communication such as oral stories, where narrative frames, narrator gestures, audience participation, and other genre features join with the words of the story to create its overall meaning. For those who habitually exchange knowledge using the journal article genre, the point of an oral story may be quite difficult to grasp. Conversely, those used to oral story conventions may have a harder time understanding and evaluating the content of journal articles. To do so requires induction into the genre; again, this occurs in a social setting, through participation. Learning genre conventions (and others) requires a certain minimum social status, named by some researchers "legitimate peripheral participation" (Lave and Wenger 1991). In other words, a new participant's bona fides must be recognized by the group, and that person allowed to act as an "insider," even if only as a silent learner. Where wide cultural divides exist, therefore, knowledge infrastructures need to provide mechanisms for one group to acquire another's genre conventions, or else for translating between different genres. "Genre translators" need to do more than merely translate the grammar of language, as the tacit, participatory dimensions of genre make this task more difficult than it may sound. Development efforts might therefore seek to support key individuals able to navigate the conventions of multiple groups.

Knowledge is shared not only between groups, across geographical space, but also over time. In both cases, key goals include knowledge integrity, portability and reusability. For instance, consider knowledge about how to choose, cultivate, and harvest agricultural crops. Whether sharing one group's knowledge with another group far away, or teaching the next generation of one's own people, what information scientists call "meta-data" are always important. Things like the circumstances and methods used in planting the crop, the climate where crops do well or poorly, water requirements; soil characteristics, and many other factors play a part in whether one group will get the same result as another. Both the farmer who originally planted the crop, and others from similar climates, would need the meta-data to properly interpret the crop performance at a later time. Emphasizing this overlap of vested interests for both knowledge creator and sharing recipient is one way to align incentives for mutual benefit.

As knowledge is shared between individuals and organizations it is re-created by the recipients. At the simplest level, this results in "copying" of the knowledge. Yet any piece of knowledge is intimately tied to its context. Most skills and ideas have to be adapted, at least to some degree, to work in a new context. Further, new knowledge arriving from somewhere else can trigger new ideas and lead to the creation of "original" knowledge by the recipients. So the creation of knowledge is by no means an isolated event, but results from the sharing of knowledge over time and space. In discussing capacity development, Lopes and Theisohn summarize "…knowledge cannot be transferred. It has to be acquired, learned and reinvented." We should "scan locally and globally; [but] reinvent locally" (2003). As knowledge infrastructures promote more sharing, they simultaneously enable the creation of new knowledge.

V. Creating Knowledge

Knowledge is like a garden: if it is not cultivated, it cannot be harvested. — Guinea

Under the long-standing production chain model of knowledge development, lines between creation and sharing are easy to maintain. Knowledge or facts (and we might add technologies) are "born" somewhere, and then are applied, transported or diffused outwards through some mostly separate set of processes or mechanisms. A classic example is the presumed split between basic and applied research, which has long shaped science funding and policy in the U.S. and other western countries. Under this model, public agencies are to invest in basic or fundamental research (often in academic settings) with little to no consideration of immediate social benefit. The payoff comes later, in the largely separate sphere of application, where basic knowledge gets translated, applied, exploited, etc. in the service of specific social challenges and problems. A technological parallel to this split can be seen in the distinction sometimes made between invention and innovation.

This model of knowledge development, which underlay the "social contract for science" in the U.S. and other countries through the immediate postwar decades (Bush 1945; Guston and Keniston 1994), is suspect on at least two grounds. First, there is significant question as to whether the conceptual split between basic and applied, invention and innovation, was *ever* as neat in the real world as the production chain model implied. Second, even if marginally true in *some* places (e.g., U.S. and Western Europe) and times (e.g., 1950s, 60s, and 70s), there is growing evidence that the divisions are getting harder and harder to maintain. Even within the relatively formalized structures of the scientific world, scholars have pointed to new spaces of discovery (e.g., "Pasteur's Quadrant") and modes of science / society interaction (e.g. "Mode 2 science"; instances of "co-production") where processes of creation, application, and end use are hopelessly and productively intertwined (Stokes 1997; Nowotny 2001; Jasanoff 2005). Distinctions blur even further when we move to discussion of more obviously "cultural" spheres of production, both long-standing (e.g. jazz and other musical genres with deep histories of blending and repurposing) and more recent (e.g., open source software communities, such as the one formed around the Ubuntu Linux operating system). As this happens, the idea of knowledge creation as a distinct and separable 'moment' within broader knowledge processes gets harder and harder to maintain.

The understanding of knowledge creation informing this report owes much more to this latter tradition, and therefore tends to emphasize the work of (re)assembly, translation, repurposing, and mixing over *de novo* acts of creation. It focuses in particular on acts of open or distributed knowledge production, in which creators and innovators draw on, rework, and give back to shared and widely distributed knowledge stocks. From this perspective, sharing is integral to the work of knowledge creation — not something that happens only later, when (autonomously produced) knowledge walks out the door.

On a cautionary note, the existence of overlaps between *de novo* production and modes of knowledge creation based on sharing (repurposing, remixing, etc.) points to the dangers of policy

precession, i.e., instances in which policy choices taken in one domain are placed in fundamental tension with those in adjacent or entangled fields (e.g., where intellectual property regimes designed to 'incentivize' knowledge production conflict with science and education policies dedicated to its sharing) (Braman 2006). More hopefully, overlaps may be regarded as sites for the leveraging of knowledge, where strategic investment and modest interventions may yield locally transformative effects.

Production chain models suffer from an additional, "geographical," problem: in assuming a sharp break between basic and applied, invention and application, they tend to set up the first as placeless and universal, and reserve questions of context or culture for the second. From this perspective, 'basic' knowledge (or basic technology) is presumed to travel the world culture-free, with questions of context and local conditions only mattering at the application stage. We see this split in the frequent division between global science (universal, placeless, and culture-free) and local knowledge (specific, place-bound, and culture-laden). An example even closer to home can be found in efforts from the 1950s through 70s (but arguably continuing through today) to construct a global "science" of development, capable of speaking authoritatively across the vast diversity of societies targeted as the objects or beneficiaries of development. (Note that while this does *not* preclude the possibility of comparative learning, it *does* argue for a certain caution and humility in the extrapolation and generalization of development 'lessons'). Fifty-plus years into the postwar project to 'develop' Africa, it remains the case that most new development knowledge (at least of the sort typically recognized by major donors and development institutions) continues to be born, assembled, and stored outside of Africa itself. The unequal geography of development knowledge matters more than is commonly realized – and shows signs of worsening rather than improving over time.

African Open Source

Recent years have seen rapid growth in the African FOSS (Free and Open Source Software) movement, and promising explorations in the design and use of free and open-source software solutions in African development contexts. Much of this work has focused on questions of application and fit – for example, debates over the pros and cons of proprietary vs. open source models in developing country contexts (the benefits, it turns out, are mixed). No less interesting has been the nature of design tasks undertaken by African open source programmers: for example, optimizing code to run on the aging machines dominating schools, universities, telecenters, and government offices in many African countries. This sets the African FOSS movement some distance apart from its counterparts in North America, Europe, and elsewhere – and provides a nice example of both context-sensitive design and a nascent knowledge community that is both high-tech and distinctively African.

Recent work in Africa and elsewhere has shown the extent to which relations of sharing, collaboration, and exchange are embedded in the very heart of knowledge generation. A clear parallel here may be drawn with recent efforts to understand and build scientific cyberinfrastructure in North America, Europe, and elsewhere. As this work has shown, new computational technologies for processing, storage, visualization, etc. (however promising they

may be) cannot transform the face of science *by themselves*; they do this only in conjunction with understanding, reflecting, and perhaps subtly inflecting the social relations of science itself. Acknowledging this, science funders have begun to study the characteristics of 'virtual organizations' and other social forms, in search of patterns, opportunities,h and constraints. In the process, the fundamentally distributed nature of scientific discovery, at even the most micro of levels, has come into view. If standards, protocols, and conventions structure relationships between fields (as noted in the *Sharing* section, above), they also make knowledge creation even within single sites possible – for example, by rendering data collected through different times, places, and methods functionally interoperable, thus allowing local scientific teams (say, ecologists studying species diversity, or epidemiologists tracking the spread of a particular disease) to produce common understandings and results.

If the development of scientific cyberinfrastructure provides a nice lesson in distributed knowledge production, it also raises questions about the generative capacities of African science, both nationally and inter-regionally. As is frequently noted, African scientific communities face challenges unique in type and scale. Outside of a small number of relatively well funded and globally connected institutions (most of them in South Africa), scientific research and education throughout Sub-Saharan Africa has faced chronic funding shortfalls, lukewarm and shifting political support, and a significant and sustained out-migration of skilled personnel. Many countries have seen massive disruptions or suspensions of organized scientific activity altogether, for example those caused by war, famine, and social unrest. In line with the patterns of technical connectivity noted in earlier sections, these challenges have severely restricted possibilities of collaborative development above or across national boundaries; indeed, scientific flows connecting Africa to Europe, North America, and parts of Asia are very often stronger than those circulating within the region. Partly because of this, the modes and forms of science practiced remain defined by standards and criteria set by external actors.

Emergent and locally-appropriate forms of scientific knowledge infrastructures, while hardly a magic bullet, might begin to ameliorate the worst of these tendencies. At the high end, this might include experiments in distributed storage, processing, and a variety of scientific group and middleware applications, in rough parallel with those being developed in the U.S., Europe and elsewhere. The Internet is being similarly (re)discovered as a venue for scientific communication, both among researchers (for example, through open access publishing initiatives like the African Journals Online project) and with more popular audiences (for example, the online magazine Science in Africa). Such digitally-mediated initiatives are emerging alongside (and occasionally in connection with) efforts at institution-building: for example, those dedicated to strengthening and linking scientific academies and/or research councils across a range of sub-Saharan African countries.

Important contributions to the creation of knowledge that might emerge from such processes include the more effective pooling of resources (leading to better science economies of scale); improved inter-regional scientific communication and exchange (diminishing the role of Western institutions as external nodes within African-African scientific traffic); and the articulation of specifically African modes, styles, and topics of inquiry as an alternative to present global hierarchies of scientific value (themselves subtly and not-so-subtly skewed toward Western interests and concerns). In this process, the programs followed by funders, universities, and

scientific communities in North America, Europe, and elsewhere should be taken as illustrations rather than models or measuring sticks: in any well-articulated development process, cyberinfrastructure and institutional solutions appropriate to the highly varied terrains of African science are likely to look markedly different from those pursued in the West.

Finally, as noted in earlier sections of the report, academic science provides just one among a range of possible knowledge infrastructures, and, despite its many accomplishments, should not be taken as the model or yardstick against which all other knowledge forms are to be judged. Indeed, in many African (and we might add, North American) contexts, the most effective instances of knowledge generation are hybrid in nature, combining elements of science and vernacular, the "modern" and "traditional," in locally effective combinations. (That these combinations still strike us as surprising may say less about their novelty than about the false divide we've constructed between the categories). Consider the following two knowledge infrastructures:

The Famine Early Warning System Network (FEWSnet) is a system being used by international agencies to determine the degree of food aid to be given to Ethiopian farmers. Where in the past agencies relied on local knowledge of conditions on the ground, they now take what they perceive to be the more objective measure of satellite observations of ground cover. These measurements have their own problems – inedible weeds are indistinguishable from food crops; crop production does not guarantee distribution – but they are being preferred precisely because they seem to be non-political. What we need in this case – and by extension as we work together to build an African knowledge infrastructure – is ways to integrate the two ways of knowing in creative, organic ways, so that what results is not a subsumption of one mode by another but a whole which is greater than the sum of its parts.

A potential example of this can be found in an unusual forest mapping exercise currently underway in the Congo Republic. Under the program, members of the semi-nomadic northern Mbendjele Yaka people use handheld GPS devices equipped with a novel interface design to mark out areas of economic and cultural significance. These points are then uploaded via satellite, grouped, and mapped, and the resulting regions of locally-assigned value placed off limits to the encroachments of loggers. While the mapping initiative is unlikely to slow or halt the ongoing destruction of forest lands in this region of central Africa (outside of the defined protected areas, logging continues unabated), it does offer some small protection to the culture and livelihoods of the Mbendjele Yaka – and a nice illustration of how local knowledge hybrids may be produced and shared, with developmentally beneficial outcomes.

VI. Maintaining Knowledge

Until lions have their own historians, tales of the hunt shall always glorify the hunter. — Igbo, Nigeria

The developed countries have over the past several hundred years converged on ways of storing their collective knowledge in standardized packages. Although starting from very different roots, the convergence seems now as inevitable as the convergence between the Apple and Windows interfaces. For these latter, because most of us have been trained in one or the other and because they have been generated by people of our own culture (broadly speaking) they seem natural and intuitive. It is only when we move to different cultures and settings – as demonstrated by Bryan Pfaffenberger – that we see how constraining they can be (Pfaffenberger 1988).

Broadly, the systems of knowledge maintenance we have developed come out of the Enlightenment tradition. Central features of it are the belief that there is a clear division of knowledge into different branches, which bear an hierarchical relationship with each other (physics, chemistry, biology being one descending sequence); that knowledge is progressive; that the progression is achieved by institutional arrangements which mirror the major "disciplines"; and that true knowledge is sustained forever in archival form (acid free paper being the best, but there are now dreams of a perpetual electronic memory).

It is only when we turn to other cultures that we realize what a straight jacket this constitutes. In sub-Saharan Africa much knowledge is maintained in oral traditions. Where there are memory devices of various kinds these have been difficult for Western anthropologists to recognize and understand. Atkins et al. point out that in order to build a good educational infrastructure we need to explore and learn to honor ways of learning that are not apparent to those blinded by the vision of education as being that which is done in schools and universities and subject to the regime (in the US) of no child left untested – with its insistence on single right answers to complex questions (Atkins 2003). Similarly for knowledge maintenance. Consider for example the memory of the Luba. This palmtop device contains a wealth of knowledge. It gives the topography of a village, the division into clans, a history of tribal chiefs and an account of important historical events – among other things. Many cultures hold their knowledge in this way. Where in the developed world we have concentrated on scattering knowledge into a million far flung folders, in Africa many cultures instead fold knowledge into rich symbolic artifacts.

Further, much knowledge in Africa is sustained orally, through storytelling. Proverbs, and the stories they generate, are key here. Thus another "unrecognizable" memory device – the Kivu proverb string, acts as a mnemonic device stringing together a wealth of knowledge woven into stories about the land and the people's collective wisdom. This is a device you will not recognize, and a form of knowledge representation you will not design for if you fail to "listen forth" to other cultures.

At the same time, because of urbanization there are generations of Africans who have grown up in towns with much less contact with past customs, and some who have rejected tribal language and allegiance for syncretic mixes of influences from media, other urban associations, and their own educational experiences. They are as disconnected from tribal ways of passing on knowledge as are western information architects. We need to accumulate a richer understanding of the plurality of knowledge storage practices within local African contexts in order to design systems which can flourish within that context.

Now there is a codicil to this. This is not about preservation of the traditional. We are currently, as a globalizing presence, seeking to preserve many kinds of diversity – linguistic, cultural, ethnic, genetic to name but a few. And yet that preservation has its price – ethnic and linguistic diversity can best be sustained by sequestration: which is good for the connoisseur of the diverse, but not necessarily for the diverse themselves. Databases are often seen as a good site for preservation without politics: from the Mayan cultural atlas through the efflorescence of museums of indigenous knowledge. Really listening to other ways of knowing entails more than databasing. In many instances (including well-intentioned ones), indigenous knowledge tends to end up in text fields in scientific databases: collocated with the real data, but unmanipulable and hence unusable. In the developed world, our convergence to a single form of knowledge preservation has blinded us to the richness of other ways of knowing – and in turn this has prevented us from working with African colleagues to develop new modes of representation which would be of great benefit for both parties.

An inventory of knowledge maintenance in sub-Saharan Africa has to start from the recognition that broadband penetration is remarkably low across the continent, and that even where broadband is available it is often prohibitively expensive both to use the electricity to run the computer and to print documents for later study. There are two kinds of response here. First is to concentrate one's efforts on the information rich professions – notably teachers, doctors and bankers – allowing them to act as gateways between the vast databases of the developed world and conditions on the ground in Africa. There have been some innovative projects here. For example, eGranary, a program in the United States regularly downloads slices of the web for specific educational topics onto hard disks, ships the hard disks to universities in Nigeria and sets the schools up with local Wi-Fi. Students and teachers thus get access to Web resources in quasi real time – including a synchronous component if local dial-up is available. Many universities

are connected by VSAT to the Internet, and these systems make use of caching technologies to minimize the download of frequently accessed web site and other information. Ubuntu Alliance is a two year old project to establish research and education networks linked by fiber in seven east African countries. Of paramount importance to the directors is assuring financial sustainability before they establish the network.

A second strategy is to adapt design targets to the existing field of capabilities. At one end of the range here is mobile telephony. Mobile phones have far higher penetration than computers, and so knowledge that can be distributed over this platform has a far higher chance of being used. There are a number of projects being developed for voice-activated Internet – where one dials into a local server and then through voice-recognition one navigates to websites and gets their content read back. At the other end of the range – and this must not be forgotten – is paper. Low prestige projects to build libraries in African villages (for example Michael Kevane's Friends of African Village Libraries) must be supported alongside the development of innovative storage mechanisms in new media. Knowledge maintenance infrastructure must be flexibly designed to access information through mechanisms sensitive to local conditions.

This leads in turn to the question of provenance. Vast volumes of information and knowledge about Africa are stored in developed countries (frequently those of former colonial powers) and are accessible largely in those countries. Thus the databases of AllAfrica — an organization, headed by an African, that aggregates articles from 130 African news sources as well as others from outside of Africa — are held in Washington, DC. The web site is managed from an office in South Africa, and there are bureaus in Lagos, Nigeria as well as Monrovia, Liberia. In purely access terms this doesn't seem particularly problematic – the Web is, after all, *relatively* geographically independent. But consider what happens when you type "Africa" into Google: the first three pages feature all of two sites generated by Africans and only one which seems to be housed within the continent. This occurs because Google rewards those sites which have most links into them, and so sites in developing countries have a particularly difficult time getting representation within the search engines. And so, once again, African knowledge about Africa gets buried by Western knowledge about the continent – despite our hopeful belief in the Web as an open, democratic forum for the organization and distribution of knowledge. Just as books and journals about Africa are overwhelmingly held in the West (and the World Bank's "archives of development" are, predictably, housed in Washington), electronic databases and access to them threaten to follow the same route. In line with the concerns outlined in the creating section, efforts to build infrastructure for the maintenance of knowledge must take seriously the geography of knowledge, and ask hard questions about how – and *where* – developmentally-relevant information is generated, stored, and accessed.

Finally, any discussion of knowledge maintenance must recall that users themselves are a moving target, inevitably more dynamic than the collections being maintained. Their needs change, especially among the young who may have different experiences and expectations of available technologies than teachers, elders, curators, and other keepers of knowledge. In Nigeria there are now schools where each child has his or her own computer for home and school use. Their expectations will be much higher than even affluent adults who have had access for years. Users of university networks, aside from faculty, will change every four to six years, and the knowledge infrastructures will need to adjust to meet their changing requirements. Maintaining

knowledge involves not only preserving it in a permanent form, but making that knowledge accessible through accepted conventions and local capabililties. To stay active in the world, knowledge (including very "old" knowledge) must be made to migrate, across platforms, across social and organizational forms, and across successive user generations with their distinctive competencies and needs.

VIII. Conclusion

Many words do not fill a basket. — Yoruba

There are already a lot of wise words out there about how to improve knowledge for development in Africa. Our charge in this report has been to advance a concept of knowledge infrastructures which might help agencies like the National Science Foundation and the World Bank facilitate the move from scattered wisdom to collective action.

An overarching theme of the report is that although much innovation already goes on within the varied knowledge infrastructures of Africa, it has too often proceeded in relative isolation. The usual panacea for this ill has been "connectivity," understood as information and communication technology. But as we have shown, these provide, at best, the physical possibility of knowledge exchange. Wired or wireless, simple or sophisticated, nothing guarantees that once the network is built knowledge will actually flow across it. Instead, when we grasp the full complexity of sharing, creating, and maintaining knowledge, we see hidden, deeply embedded backgrounds of culture, language, local technology, and history — knowledge infrastructures. Extending connectivity to connectedness involves taking a hard new look at how knowledge actually travels, where it lives, and what preserves it. These are at least as much matters of community as matters of communication.

Our principal recommendation is about building on and extending what is already there. We need to mobilize sets of heretofore unconnected actors into stable communities of practice capable of generating and maintaining more effective and sustainable knowledge infrastructures for Africa. Present silos come in many forms. First, there is the hardware/software/content divide. Many people claim that we need just one of these (e.g. broadband connectivity, open source software, or a digital library). Second, there is the sector divide. Good practices and creative solutions are not consistently shared between given communities organized around particular endeavors (health, education, agriculture). A third, which we have only touched on here, is the foundation and aid agency silo: the failure to share and preserve the vast quantities of knowledge generated by thousands of projects and groups over many decades. This is a problem space that can only be reasonably addressed by coordination among the various donor bodies that are in the business of supporting knowledge infrastructures.

A number of ideas and directions emerge immediately from our initial look at the knowledge infrastructure concept. For example:

- Gateways, bridges, and other collaborative models for reciprocal and locally appropriate links between knowledge practices of various types and scales might become an important area of focus.
- More explicit attention to the geography of knowledge might generate ways to map and foster knowledge sharing within Africa and from Africa to the West, directions only weakly supported by current knowledge infrastructures.

- Techniques may be found to better engage African diasporic communities in the creation, maintenance, and extension of African knowledge infrastructures.
- New (or previously overlooked) developmental actors might be better identified and supported within existing development practice. This would include, at minimum, local innovators, translators, and other sorts of connectors capable of acting as gateways or nodes between disparate knowledge systems.
- Capacities for cross-sectoral and cross-regional learning might be improved, leading to new and accelerated forms of distributed or combinatorial innovation.
- By recognizing continuities and overlaps in the creation, sharing, and maintenance of knowledge, development actors might better harmonize and leverage investments and policy decisions across multiple moments in broader knowledge processes.
- Attention to where knowledge is generated, how it is shared, and ways in which its accessibility is guaranteed might lead development actors to question forms of knowledge and practice that purport to be global, universal, or neutral (including their own), and come up with richer, better grounded, and locally-appropriate knowledge sets.

We believe that developing these ideas may lead to substantive and significant new directions not only in development work, but in approaches to notions of "knowledge societies," "information infrastructures," and other currently important ways of conceiving the flows of knowledge and information in a globalizing world, which lie (as always) in tension with locally specific practices and meanings.

To push this project further and begin to orient it toward practical projects, would require at least three things. First, we would need a richer understanding of knowledge practices within local African contexts, in order to imagine and begin to design systems which can flourish within that context. Second, we would need to articulate further the concepts described in this paper, and better attach and test these against concrete projects on the ground. Finally, to achieve both of these goals, we need to initiate long-term conversations and practical engagements with a wide range of African and non-African partners, including scholars, development experts, and interested business leaders. Such conversations would be aimed at refining the concepts, applying them practically, and building awareness of the most promising ideas and projects that emerge. In some sense we are proposing, on a small scale, to create, activate, and cross-link a knowledge infrastructure about African knowledge infrastructures.

As a next step, we suggest staging two events – one in Silicon Valley and one in Africa – which might help to achieve these goals. The role of the first conference will be twofold: first, to produce a detailed needs analysis for African knowledge infrastructure, based on interventions from the African participants and interactions amongst all participants; and second, to identify, from among the African participants, a subset who can provide leadership for the primary event and seed the new kinds of development projects which will emerge. The second conference, at an African location to be determined, will build awareness, local engagement, and the beginnings of a learning community in Africa and around the world which could adopt, benefit from, and further develop the knowledge infrastructure perspective. (These events are described in greater detail in an event proposal accompanying this report). In the short to medium term, such a community might initiate collaborative projects and developmental networks within and across

countries, agencies, and sectors. In the longer term, the project might lead to: reform of information science and development curricula, both in Africa and elsewhere; an African center for the study of knowledge infrastructures; and new lessons (and possibly funding streams) for international development institutions. All of this work would contribute to and help shape World Bank thought and policy around knowledge and development.

Clearly there is work to be done in this country as well. As this report has argued, we need an integrated and robust program of research and practice around the development of knowledge infrastructures: not just for Africa, but around the world. Our core recommendation here is that the National Science Foundation, possibly in partnership with the World Bank and other national partners, begin to conceive a cross-directorate program aimed at building genuine interdisciplinary collaboration on such theoretically rich and practically important issues as representing indigenous knowledge; understanding the ways in which social and cultural values get built into knowledge infrastructures; and designing systems which incorporate the resulting insights.

This report offers no simple solutions. It is meant to begin, not conclude, a necessary conversation. But it does carry a positive message: although the problems are daunting, many local, partial solutions are already in place. Ways exist to facilitate their integration in Africa. And a growing cohort of actors, innovators, and scholars, in Africa, North America, and elsewhere, stand ready to contribute new thinking and new approaches to understanding and developing more effective, innovative, and sustainable knowledge infrastructures.

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