A Synthesis of Research on ICT Adoption and Use by Medical Professionals in Sub-Saharan Africa

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ABSTRACT

Health care practitioners rely on access to relevant and up-to-date medical information in order to effectively treat their patients. One efficient, low-cost avenue for such information is online collections, but certain regions lack the information and communication technologies (ICT) necessary for widespread and reliable access to online resources. The characteristics of existing ICT infrastructure in many developing countries are not well understood. This research synthesis focuses on Sub-Saharan Africa (SSA), an area with low levels of ICT infrastructure. It presents a synthesis of statistical analyses and a review across disciplines of information published on the state of ICT and health information access in SSA. An overview of the existing knowledge allowed us to identify the salient features of this particular ICT environment, and informed the development of a survey for SSA healthcare professionals. The synthesis and preliminary results from our survey suggest that Internet connectivity remains highly unreliable in Sub-Saharan Africa and that mobile devices provide the most reliable technology for health care providers to carry out their work.

Categories and Subject Descriptors

H.3.7 [**Digital Libraries**]: Dissemination.

General Terms

Measurement, Documentation, Design, Reliability, Languages.

Keywords

Mobile phones, digital libraries, e-health, wireless, Sub-Saharan Africa

1. INTRODUCTION

Providing effective access to health information resources presents many complexities that deserve increased examination. While information resources such as health digital libraries have been rapidly emerging in recent years, they still lack comprehensive dissemination in developing countries, which have a great need for health information. A health information digital resource created specifically for developing countries could serve as a replicable model for other projects; together, such resources would fill a vital need for accurate and current medical information in areas with poor information and communication technology (ICT) infrastructures.

Around 50 million people die every year from infectious disease, two-thirds of which could be saved by better health information [7]. The United Nation's Millennium Development Goals [50] include the need to "develop a global partnership for development" and, "in cooperation with the private sector, to make available the benefits of new technologies, especially information and communications technologies." In economically developing areas of the world, up-to-date medical information is often scarce due to a lack of financial resources and technological infrastructure. Such information would help healthcare professionals in areas such as Sub-Saharan Africa (SSA) to better serve patients. As it is currently infeasible for many poor countries to build more physical infrastructures or to increase the number of workers devoted to healthcare, it is crucial for the international community to seek out other ways of contributing to the long-term improvement of health in these areas through low-cost technological innovation. One area of focus is to provide access to medical knowledge via ICT. The challenge is to develop effective strategies for providing this knowledge in a form that is accessible given the ICT that is currently available.

Prior studies and projects have focused on free access to journal databases and innovative technologies to facilitate discussion among medical personnel [28, 30, 39, 41, 52]. Such efforts have helped increase both scholarly and collegial communication among the global medical community. However, few overall reviews have been conducted to synthesize various types of research on how to make medical information resources available in ICT-poor areas. Current models to increase medical information access exist primarily in contexts where electricity and high-speed Internet connectivity are available and reliable. Further work is needed to discover how to better serve healthcare personnel who have limited infrastructure support.

In order to address the most effective ways for disseminating health information in SSA, we have: 1) analyzed existing statistics available on ICT and medical information access in SSA to determine relevant technological requirements and constraints; 2) synthesized research on providing access to health information in low-ICT areas across the disciplines of public policy, technology, and public health; and 3) developed a survey that was distributed to healthcare professionals in SSA and elsewhere to obtain a more specific and current understanding of the requirements and constraints of providing low-ICT-appropriate access to health information. We present preliminary recommendations for how digital health information can be most effectively deployed in areas where both information resources and ICT are scarce.

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Prior digital library projects have suggested possible solutions for regions with limited ICT access such as combinations of online and offline (CD-ROMs, downloaded text) materials, and most recently, mobile health technologies. Questions remain, however, regarding how to negotiate the intersection between existing technological capabilities in SSA and the informational needs of healthcare professionals. In order to determine how best to disseminate information via digital libraries in technologically developing areas, we address the following questions:

- How can existing digital library technologies and designs be used to bridge the gaps between medical information needs and the available ICT infrastructure in SSA?
    - What is the current overall state of ICT infrastructure in SSA?
    - What are the medical information needs of healthcare professionals in SSA?
    - How are the available technologies and designs helping meet these needs?
- What digital library designs, which utilize the current ICT infrastructure, would be appropriate to meet the medical information needs in SSA?
    - What types of health-related online resources do healthcare professionals need?
    - What types of cost-effective technology can bring website resources such as digital libraries to SSA, given the limitations of the infrastructure?
    - What multi-lingual considerations will affect the design of a medical information digital library?

2. RELATED WORK

Analyses of mobile tools as both catalysts and indicators of development in SSA point out the role of health practitioners as leaders in developing novel applications of the technologies [2]. Clearly the intersection of networked technologies and health in the developing world is an area of serious interest. While a number of projects involving the use of mobile technologies to support health services (m-health) have been launched in recent years, the results are mixed and little comprehensive evaluation is available. In order to support evaluation, researchers and practitioners need to begin by deciding on the appropriate outcome measures, such as health outcomes, economic outcomes, and overall sustainability of these projects [21]. A review of the broader category of e-health projects (using any kind of ICT application) also shows a number of promising results, but shows little consistency among the evaluations. Project evaluations tend to be mostly descriptive and done locally, with few performed by larger funding organizations implementing rigorous processes for evaluating outcomes. [4]. Well-designed systems supported by strategic partnerships with international organizations who have the means and motivation to perform follow-up and rigorous evaluation are consistently recommended [4, 21].

The Health InterNetwork Access to Research Initiative (HINARI) is a project supported by a number of medical journal publishers that works to provide free online access to medical journals for healthcare providers in developing nations [7]. HINARI is one of the largest WHO-supported projects for the distribution of electronic medical information and has been largely successful. At present, efforts to provide hospitals, medical universities, and health science libraries with free or inexpensive access to online medical databases include HINARI, Program for the Enhancement of Research Information (PERI), and the Ptolemy Project. These projects offer free access to databases such as PubMed/Medline and are a key resource for up-to-date medical information for practitioners.

Digital libraries are increasingly recognized as a cost-effective resource for sharing knowledge. In the developing world, journal access initiatives such as HINARI and PERI have proven useful in supplementing institutions' limited collections budgets, although the infrastructure issues for digital access need to be addressed [22]. However, many such databases are primarily designed with the technological capabilities of more developed areas in mind.

Other adaptation efforts focused on modifying the Greenstone digital library software to provide access to resources online and offline. These projects met with some success and some limitations. The Greenstone design was chosen for its suitability in low-ICT environments, specifically areas with unreliable or nonexistent network connectivity. In order to address this issue, Greenstone contains functionality to allow both the content and digital library software to be burned to a CD-ROM for offline distribution. Witten [53] discusses the necessity of offline access for low-ICT areas and the applicability of CD-ROMs for use in libraries. CD-ROMs are suitable because many libraries in SSA have CD-ROM facilities. However, this limits access to information outside of libraries since home computers with CD-ROM drives are not common [36].

Further efforts have been made to extend Greenstone beyond CD-ROMs to more readily available technologies. Another study allowed users to customize their interface to Greenstone to fit on small-screen HTML browsers on PDAs [40]. A project involving user-contributed content in rural villages allowed users to create story content using media phones and then upload it to a Greenstone library running on a central kiosk in the village [20]. The content could then be downloaded from the kiosk to media phones or iPods for viewing and sharing with others. Additionally, paper representations of the stories could be generated to be shared offline.

Digital libraries for the web might also consider using offline access to information downloaded from an online resource. The RuralCafe project, for example, also used a local caching system synchronized with network servers to address the bandwidth and connectivity issues in low-ICT areas [8]. In this project, users' machines were connected to a local intelligent proxy that cached search results and queries the user had made. This allowed users to refine their queries using this cached data and to specify the richness of the search results.

3. METHODOLOGY

The goal of our research is to construct a comprehensive picture of the state of healthcare information needs, digital libraries, and ICT resources available in SSA so that we can make suitable recommendations for digital health information resources. We synthesized information obtained from multiple types of analysis, combining both quantitative and qualitative information in a three-stage approach to achieve a richer understanding of the state of ICT in SSA with respect to healthcare. Our baseline was a descriptive statistical analysis of development indicator data. This provided a quantitative dataset specifically focused on the state of ICT in SSA. The quantitative data analysis was augmented with a multidisciplinary research synthesis, which combined qualitative

and quantitative data from published papers and reports. This research synthesis fills in the gaps in our knowledge of ICT where comprehensive quantitative data was not available.

After the review of available published information on ICT in SSA, there were still some unanswered questions about our specific case of digital libraries for healthcare professionals. In order to obtain information about ICT resources specific to our case, we developed a survey to be answered by healthcare professionals in SSA regarding their health information needs and access to ICT resources. This allows us to corroborate, in a limited and preliminary way, the results obtained from our synthesis**.**

3.1 Quantitative analysis of development indicators

First, a series of quantitative analyses were conducted to achieve a better overall picture of the existing telecommunication infrastructure in SSA. This baseline informed us of the types of technologies, design strategies, and accessibility issues to focus on. We initially compiled descriptive statistics on ICT data from the World Bank's 2009 World Development Indicators (WDI). The WDI dataset is primarily from the International Telecommunication Union, a United Nations agency whose main activity is to collect statistics from government agencies and through market research [54].

In SSA, there are 48 nations, all of which have differing ICT considerations, which include electricity costs, frequencies of electrical outages, penetration of mobile phone and personal computer ownership. Therefore, it was necessary to determine ICT profiles for individual countries, as well as for the whole of SSA. Other goals were producing descriptive statistics on these indicators and looking at longitudinal shifts. We then noted socio-economic trends in technology and communication such as the trend towards mobile devices.

The second half of the WDI analysis involved a series of inferential statistics measuring and describing the relationships between different variables. For this study, we examined the relationship between types of ICT, costs, and ownership. While causation cannot be determined through such analysis and is not within the scope of this study, correlated results factor into our decisions.

3.2 Synthesis of research

The statistical sources provided an excellent framework for beginning to understand the challenges in providing ICT-based information services in SSA, but there were some limits to the usefulness of the data. The multi-disciplinary nature of the project and the emergent and varied features of technology access and use in the developing world suggested the need for an extended review of both quantitative and qualitative data from prior research and projects. There were features of the environment of ICT access and health information access in SSA that could not be easily captured by the dataset. For example, there is the question of why certain policy approaches have been more successful than others. Additionally, the most recent on-the-ground descriptions of the rapid growth of mobile device usage indicate that it may have outpaced the statistics, making them somewhat out of date. Therefore, we included a second stage in our research: a research synthesis aimed at providing additional information that was lacking in the WDI data.

Our research synthesis stage is essentially a review of published literature containing information on topics relating to healthcare and ICT topics in SSA and other developing countries. We did not limit the research synthesis to only peer-reviewed articles in the field of information studies. Health information research has generally been a "boundary area" for many disciplines, incorporating tools, techniques, and researchers from a variety of fields [9]. Therefore, we felt it necessary from the outset to include in our literature search materials published in areas of public health, international relations, economics, and computer science, in addition to studies published in the information science field.

We organized our synthesis into three main categories. The first relates to public health and medicine such as the problem of infectious disease, and information for healthcare workers, especially those who are mobile. The second is technology and infrastructure such as Internet access, mobile device use, and computing technology generally. The last category is economics and policy such as costs of Internet, government projects, and communication.

3.3 Survey design and dissemination

In order to corroborate results from our synthesis, we conducted a survey of healthcare professionals in SSA. It consisted of open-ended and Likert-scale opinion questions, descriptive questions about available hardware and software, medical information use, and demographic questions.

Twenty-five healthcare professionals in SSA responded to the survey via email with or as a text attachment. The latter negated the need for constant Internet connectivity. The survey was offered in English and French. Participants were recruited through listservs and forwarded by people working with healthcare workers. Because of this snowball sampling method, it was not possible to calculate a response rate.

We conducted a pilot study of the survey with seven University of Texas at Austin graduate students to identify confusing questions and other issues. We included demographic questions to identify important aspects about our respondents. For example, we included questions to identify gender, age, and country since these factors have been determined to be possible predictors of Internet use [32].

4. RESULTS

The results are divided first into three descriptive sections from our research synthesis: public health and medicine, technology and infrastructure, and economics and public policy. The final results section describes how our synthesis suggested directions for our survey and includes some initial survey responses.

4.1 Public health and medicine

The health status of Africans remains perilous, according to recent comprehensive surveys. A WHO report [55] discusses how the region's geography and climate, combined with the most pernicious poverty on the planet, make communicable diseases an extraordinary burden on Africans, with diseases such as malaria being more intractable there than anywhere else in the world. Malaria, diarrheal diseases, and acute respiratory diseases combined account for 51% of all deaths. The current continent-wide life expectancy is around 47 years [55]. According to Gordon [15], health indicators have deteriorated since the 1960s and continue to deteriorate in the lowest-developing countries, particularly in Africa, even when government spending has increased. For instance, in Ghana, infant mortality rates continue

to worsen, despite "about 400 percent increase in government budget allocation to the health sector over the last three to four years," [43].

While 90% of the world's health funding goes to 10% of the areas of the world, the remaining 90% of the world, the developing world, has to make do with 10% of global funds [14, 7]. This "90-10 problem" is widely invoked as a motivating force for improving access to healthcare information. In Sub-Saharan Africa, the ratio of doctors to patients is low compared to more industrialized areas. The average government expenditure on public health in SSA has remained constant at between 9 and 10% of total government expenditure for 2002-2006 [54]. Meanwhile, the U.S. government's expenditures on public health during the same period were between 19 and 20%. The World Bank's WDI data indicates that the average amount spent per capita in the U.S. was $6,400, which is more than 100 times the average for SSA, at around $63 per person. These figures suggest that SSA countries have only kept pace with inflation in their public health expenditures, and what is being spent is on the very low end of the spectrum.

Deficits in medical infrastructure are a problem in developing countries. With a significant fraction of national income fighting infectious diseases such as malaria, there are insufficient funds to buy expensive medical equipment priced in US dollars [46]. This lack of equipment is of particular concern because the general trend in medicine is moving away from direct examination of patients by doctors and towards image-based lab diagnostics, which require specialized equipment. Since the infrastructure to support lab work, especially the maintenance and the transporting of samples and communication between the lab and rural areas, remains challenging for healthcare workers, there has been an effort by global health organizations to develop rugged on-site diagnostic tools [44].

Healthcare workers are chronically in short supply in SSA. There are about 10 doctors per 100,000 people in Africa, compared to 549 doctors per 100,000 people in the U.S. [39]. This deficit of doctors makes it crucial to have efficient ways for medical personnel (including nurses and medical aid workers) to communicate with one another and to gain access to medical information that can be used as a diagnostic and teaching tool. Out-migration of doctors is also recognized as a problem. Many countries are developing approaches to deal with this problem by training lower-skilled health workers to take on some medical tasks, such as the regular administration of anti-retroviral therapies (ARVs) to HIV/AIDS patients [54]. Medical salaries are low throughout the region although it is difficult to know how low. Data gathering is complicated by the combination of public and private funding sources, multiple methods of compensation, and the fact that many healthcare workers earn additional income through second jobs [33]. Data collected in 2005 from Ghana and Zambia found an average monthly income for doctors at around US$1,200; other healthcare workers averaged around US$400.

Efforts to improve healthcare in Africa suggest a pragmatic trend that recognizes the limits of infrastructure and the persistent problem of poverty. Solutions are found in approaches that bypass traditional high-cost, high-specialization, infrastructure-intensive healthcare in favor of an integrated, flexible system. Mobile healthcare workers are deployed in rural areas where access to established facilities is limited. They may work as part of a coordinated effort to address underlying causes of infectious disease by providing tools and training on proper sanitation and improving access to clean water supplies [1]. In South Africa, a healthcare train visits rural areas, providing health care to over 500,000 people and working to train community-based volunteer home healthcare workers [55]. Community home-based care programs (CHBCs) and community health workers (CHWs) are important parts of many efforts to cope with long-term care needs of individuals suffering from HIV/AIDS [49] by delivering medicines as well as food to patients.

Information needs among healthcare workers in SSA are difficult to categorize because of the vast differences within the region. Cultural practices, relative isolation, and lack of relevant materials can combine to make understanding of information needs more complex [14]. If healthcare workers are not accustomed to using or finding materials relevant to them, then they will have had little experience in requesting or evaluating information sources. Successful health information projects have applied a flexible, pragmatic approach and worked to incorporate existing community information networks. Issues such as copyright protections and technology for accessing the materials remain much more likely to be challenges in the developing world.

One persistent barrier to health information dissemination in SSA is the translation of medical terminology. This is an ongoing issue in international medicine with efforts to standardize medical terminology to standards such the International Classification of Diseases (ICD), the Systematized Nomenclature of Medicine (SNOMED), the Current Procedural Terminology (CPT), and the National Library of Medicine's Medical Subject Headings (MeSH) and their international affiliates. However, according to Kanter et al. [23], standardization of terminology may be insufficient for successful implementation of health information initiatives in Africa. Although Africa has official national language groups such as English, French, and Portuguese, numerous linguistic differences also exist both at the national and local levels. Therefore, different names of specific disease entities, medications, and laboratory tests persist. In order to solve this problem, the Millennium Global Village Network (MVP-Net) has organized a centralized Terminology Service Bureau (TSB) which maintains a database of translations from the SNOMED CT reference terminology to local terms provided by clinicians in participating countries.

A number of research projects and health information initiatives have recognized the need for coordinated efforts to improve access to healthcare information in developing countries. Madon, Sahay, and Sudan [29] describe a large-scale networked data gathering and distribution system in the state of Andhra Pradesh, India, which was designed to report and share local information about diseases and other health issues from local clinics in the region. The distribution of computing technology was complicated by problems with an irregular power supply and the delivery of computers without first ascertaining if the clinic could house the machine (many structures were not weather-proof, for example). Issues of language and basic infrastructure can prove to be complications if not considered at all stages of a health information distribution project.

Two major ongoing deficiencies persist in information access projects such as HINARI and PERI that make those projects unable to be fully utilized: geographically appropriate design and proper training for personnel. Many of the current digital library projects aimed at supporting developing areas are not fully functional in low-ICT environments. The infrastructure for Internet service in Sub-Saharan Africa remains unreliable and costly. In parts of Africa, Internet service can cost around $50 per month, while the annual salary is often less than $1,000 [39].

Access points such as HINARI require a bandwidth of 56k or higher [41], but electronic medical resource studies in Ghana [28], Nigeria [52], and Kenya [22] have shown that slow connectivity and electricity outages continue to negatively affect information retrieval and communication via the Internet. Sulimani and Katsekpor's [47] study of Ghanaian faculty information needs indicates that while the faculty would prefer to use online resources, they tend not to use the Internet because access points are too far away for easy access and the connection is both too slow and often interrupted.

Also, several studies [47, 22] point to the problem of medical personnel and researchers lacking the training to make the best use of available electronic resources. Networked health information is a particularly potent boundary object between government agencies, non-profit organizations, and commercial and technological enterprises in the developing world. Many working in this research area perceive a need for education and resources that are not controlled by government [24].

4.2 Technology and infrastructure

Mobile phones are the fastest growing technology in SSA (Fig. 1) because of several reasons. First, the physical device is both portable and component-oriented, which makes it easy to transport and replace. Second, the mobile industry has taken off in Africa within the last decade due to a number of economic factors [2]. While expensive fixed telephony projects have been stalled by transnational and institutional disagreements, mobile telecommunication policies have been liberalizing the industry [17]. Rather than state-controlled monopolies, the mobile sector is competitive and privatized. This has resulted in network-sharing among mobile service providers and lower prices for consumers. Mobile phones are particularly popular among lower income groups because of the ability to acquire prepaid and pay-as-you-go phones, which are relatively small investments compared to purchasing fixed lines. In fact, there is a trend of mobile phones replacing landlines, rather than just supplementing them [16]. Many mobile companies are offering dynamic tariff systems, which allow consumers to make inexpensive calls during off-peak hours, and borderless roaming between neighboring African nations.

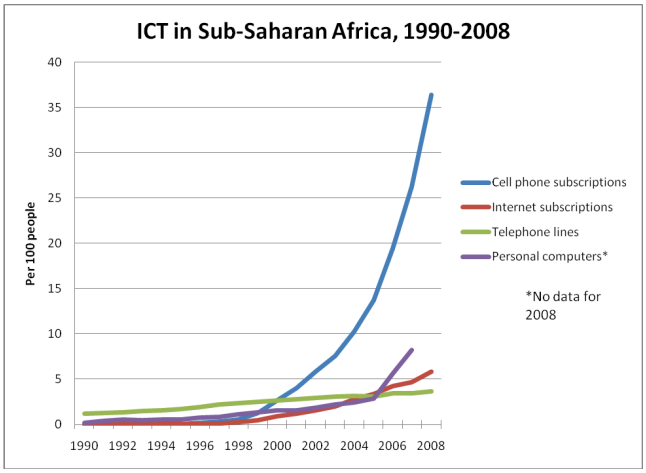

Fig. 1: Rapid growth of mobile subscriptions in Sub-Saharan Africa.

The increasing popularity of mobiles in SSA likely results from innovations being developed for this type of communication; inventive technological designs that take advantage of the existing technology in order to improve the everyday lives of people are particularly valuable, both socially and economically, in developing areas such as SSA. Currently, texting services are the most widespread and popular feature of mobile phones. In the health arena, SMS is being used to provide health information to the public. Examples of this type of service include the Grameen Foundation's Clinic Finder and Health Tips services [51]. M-Pesa, which originated in Kenya, is a service provided by the company Safaricom that allows people to transfer money using their mobile phones. In agriculture, several projects such as Farmer's Friend, Reuters Market Lite, and TradeNet have resulted in ways for farmers to use their phones to buy, sell, and trade stock and crops. In medicine, a service called ePharmacyNet has been testing its mobile presence in Benin by allowing doctors and patients to order drugs through SMS and a call center, as well as through a website. It was found that "mobile phones are appropriate means of network communication to process an order" [13].

While not universal, mobile coverage in SSA is rapidly increasing. Several countries have achieved or are near 100% mobile teledensity, which means statistically, there is a mobile or SIM for every person (but in reality some people own more than one while others own none). These countries include Ghana, Kenya, and Tanzania [12]. Mobile phone penetration in South Africa is equivalent to the US, and double the world average at 71.6% [32]. Kelly and Biggs [25] note that there has been a recent growth of Third Generation (3G) networks (CDMA 1x, CDMA+EV-DO, WCDMA, WCDMA+HSDPA) in Africa, from one in 2003, to 17 in 2006. The growth of 3G networks allows those with 3G-capable phones and computer with compatible modems to send and receive data at higher rates. While second generation (2G) mobiles can access Internet via the General Packet Radio Service (GPRS) or Enhanced Data rates for GSM Evolution (EDGE) standard, third generation mobiles can access Internet at much faster speeds via Universal Mobile Telecommunications System (UMTS) or the High-Speed Downlink Packet Access (HSDPA) standards [42].

Meanwhile, broadband Internet is slowly growing in SSA. The African Development Indicators for 2008-9 show decreasing prices for Internet, which currently costs an average of $42.10/month. However, prices are not evenly distributed, as "some universities in Africa are spending as much as the equivalent of 20 full-time faculty salaries for a 2-megabit Internet connection that is then distributed to 500 to 600 computers, resulting in a costly and slow connection for everyone" [35].

There has been a sharp increase in both the international Internet bandwidth in SSA and the number of secure Internet servers, the latter with more than 2,000 in 2008 [54]. The majority of those servers are in South Africa, which leads Africa in Internet use and infrastructure as well as mobile use. In a survey of Internet usage among doctors in South Africa, it was determined that the prevalence and usage patterns are equivalent to international averages [32]. While only 9% of the general population of South Africa uses the Internet, 89% of sampled doctors had access and 74% said that it improved their medical practice. Access was common from both work and home, with email being the primary use but web access also being common. Home usage was unexpectedly high because, "the prime method of access from work is through a 56kb dialup connection. In South Africa, where local calls are charged per minute, this is both expensive and inefficient. This poor access probably encourages doctors to have home access" [32]. There has also been an acceleration of Internet

growth among other SSA countries [54]. However, the growth of wireless Internet has been slowed by lacking and inconsistent regulation and licensing of the wireless spectrum by countries in SSA [38].

Furthermore, the problem of rolling blackouts continues to affect Africa [11]. In South Africa, these blackouts are hurting every economic sector including mining operations and healthcare facilities. South Africa's electricity supplier, Eskom, is a state-owned monopoly. Eskom also supplies Zimbabwe, Namibia, and Botswana, and cuts them off during shortage crises [19]. There are not enough power plants, and until more are built, there is a continued need for electricity conservation because demand is outpacing production. According to the World Health Organization, "the typical server [in Africa] is online only about six hours per day and has frequent disconnects lasting days or weeks" [35]. Since South Africa, the most developed SSA country, still has insufficient and erratic electricity, projects cannot rely on uninterrupted Internet connectivity as the primary means of accessing the digital library.

Some success dealing with unreliable Internet connectivity has been had with using advanced, adaptive file transfers protocols such as BitTorrent [16]. A project to distribute and update a large bioinformatics database to researchers in developing countries in the Asia-Pacific region found limited success with traditional FTP file transfers, but had good results using BitTorrent. The BitTorrent protocol simultaneously downloads from multiple sources, finds the fastest and most geographically nearby peers, and automatically resumes broken connections. Downloads of the database were found to be more likely to complete and downloaded three times faster than FTP. While these results were derived from tests in the Asia-Pacific region, there does seem to be some BitTorrent use already in Africa, with 1.74% (roughly 220,000 per month) of visitors to uTorrent.com, the website of one of the most popular BitTorrent clients, coming from Africa.

Another option for Internet access, particularly in rural areas, is telecenters. According to Lucas [27], "For the great majority of households, direct access to health-related ITC services, where it exists, will be via a local company, government body or non-profit organization that provides such services to the general public, typically charging a time-dependent fee. The majority of these 'telecenters' are small scale, private sector enterprises." They have also been invested in by governments and donors, with particular growth in mobile phone based telecenters, with the primary objective being to "establish centres in relatively remote rural areas with the specific intention of using ITC to advance economic and social development objectives." However, their primary usage seems to be social; there is no evidence that healthcare professionals use these telecenters to obtain access to health information.

Digital libraries are increasingly recognized as a cost-effective knowledge sharing resource. In the developing world, journal access initiatives such as HINARI and PERI have proven useful in supplementing institutions' limited collections budgets, although the infrastructure issues for digital access need to be addressed [22]. Other projects, like GIDEON, a subscriber-based infectious disease database, could be useful [43]. However, many such databases are primarily designed with the technological capabilities of more developed areas in mind, and would benefit from a model for providing resources in low-ICT areas. These existing digital libraries provide a supplemental source of information, but still may not be used as often as their more expensive paper counterparts due to low accessibility in SSA.

Looking at the potential for accessing digital libraries on mobile phones, Alvarez-Cavazos et al. [3] defined the following challenges for mobile digital library usage: connection adaptation (unstable bandwidth), limitations on the processor speed and memory capacity of mobile devices, mobility (the location of the mobile unit and the possible lack of service), and security of both the wireless mobile environment and portable devices themselves. A digital library for health information that uses a mobile environment as a platform must consider these issues, especially in terms of bandwidth requirements for visual resources. Marshall and Ruotolo [31] studied the reading habits of students, teaching assistants, and professors involved in two college courses where all of the reading materials for the course were accessed through a digital library on a hand-held PocketPC computer. In the 2002 study users preferred to access shorter documents on the hand-held readers, and successfully utilized the search and annotation features, two functions that are found in almost every digital library. Buchanan et al. [5] also found search to be an important function for mobile digital libraries when studying the usage of a Greenstone digital library displayed on a small screen, and reported that users found browsing to be problematic. They found that giving broad outlines of available data and categorizing data into thematic categories made accessing information more efficient on the small screen.

Other adaptation efforts focused on modifying the Greenstone digital library software to provide access to resources online and offline. These projects met with some success and limitations. The Greenstone design was chosen for its suitability in low-ICT environments, specifically areas with unreliable or nonexistent network connectivity. In order to address this issue, Greenstone contains functionality to allow both the content and digital library software to be burned to a CD-ROM for offline distribution. Witten [53] discusses the necessity of offline access for low-ICT areas and the applicability of CD-ROMs for use in libraries. CD-ROMs are suitable because many libraries in SSA have CD-ROM facilities. However, this limits access to information outside of libraries since home computers with CD-ROM drives are not common [36].

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Digital libraries for the web might also consider using offline access to information downloaded from an online resource. The RuralCafe project, for example, also used a local caching system synchronized with network servers to address the bandwidth and connectivity issues in low-ICT areas [8]. In this project, users' machines were connected to a local intelligent proxy that cached search results and queries the user had made. This allowed users to refine their queries using this data and to specify the "richness" of the search results.

4.3 Economics and public policy

Recent recommendations from both academia [19, 6, 26) and policy professionals [45] have highlighted the need for health

information system development to better include a bottom-up approach that embraces collaborative participation from community stakeholders. Privately-funded care programs frequently focus on a particular health area (HIV/AIDS or malaria, for example) to the exclusion of an integrated healthcare approach, and often leave with the data and expertise when the program is over. Academic research and projects in developing nations also may tend to focus on the interests of the researchers and their need for certain results in order to satisfy funders, often minimizing the channels for community input and insufficiently disseminating data resulting from the project within its host country. It is clear that an effective and ethical health information program in the developing world needs to prioritize the broadest possible access to its resources and find a way to support and integrate existing communities of practice and information.

A related critique of technological interventions in developing countries is that they may not be cost-effective and sustainable in the long term. This effectiveness may also be overstated by parties with a vested interest such as private companies and donors, downplaying the costs of scaling, maintenance, and upgrades. For instance, the Uganda Health Information Network (UHIN) Project distributed 200 PDAs to health workers linked to infrared connection points at 20 health facilities allowing communication over the local GSM mobile phone network [27]. While a cost-effectiveness study showed that the PDA system provided 25% more benefits over the original system, there were numerous scalability, maintenance, and upgrade problems. The infrared connection points proved to be inadequate and had to be upgraded to a more expensive system, charging the batteries proved to be a problem, and cellular data connections proved to be more expensive than having doctors physically travel between facilities. Additionally, expanding the program to cover all districts would cost an estimated US$5 million a year out of an overall national health budget of US$150 million.

Health-related technology programs in SSA cannot rely upon economic support of those nations. In their longitudinal policy study of South Africa's public healthcare systems, Coovadia et al. [10] note that the country – the wealthiest in SSA – currently suffers from a lack of stewardship and effective implementation in its healthcare system. As a result, community involvement, which is one of the "fundamental facets of primary health care," has not become a fully realized component. This lack of community involvement is noted elsewhere, as the authors pointed out that data gathered from a series interviews of health policy makers in Kenya did not contain any mention of "grassroots advocacy groups" as providing inputs for health policy formation [26]. Rising costs of treatment are a result of the private sector's fee-for-service model, rather than because of any new technology use.

Overall, a review of existing research indicates that Sub-Saharan Africa suffers from infrastructure limitations such as electricity outages and cost of access to basic Internet service. Additionally, the overlapping and oftentimes contradictory goals of actors in the health policy space, while problematic in most countries, are particularly challenging for developing nations in Africa. Recommendations for improved projects include such efforts as better identification of stakeholders, greater support for collaborative processes among all stakeholders, and a recognition that different communication strategies may be needed to fully engage potential participants [26],

4.4 Survey

Since our research showed the burgeoning potential for digital library access via mobile technology, a significant portion of the survey's content focused on available mobile capabilities. The survey also addresses the availability and consistency of ICT access in a medical facility context.

Our survey results illustrated that the ICT deficiency is not as much a matter of not having access to devices, but rather not having fast, affordable, reliable Internet connectivity. We found that healthcare practitioners in SSA had access to ICT devices such as mobile phones in proportions that more or less reflect the global rate of adoption. The majority of survey respondents had Nokia phones running the Symbian operating system, with iPhones and Android phones being less common. The healthcare workers surveyed also reported using online health information resources such as databases and online journals. However, participants cited Internet connectivity as a major problem in their access to these resources.

5. DISCUSSION

The options for healthcare information resources in Sub-Saharan Africa are limited by the constraints on the information resources imposed by the available ICT infrastructure. The move towards image-based diagnostic tests in healthcare means that healthcare information resources are going to move towards containing databases of images. This means that simple SMS text messaging is insufficient to access these resources. Similarly, traditional phones with small, low-resolution screens are not a viable platform for disseminating this type of information, despite their popularity in SSA. However, trends such as cellular network-based telecenters may mean that the cellular network connections to non-phone devices such as desktop and laptop computers may be an option. Another constraint on health information resources for healthcare professionals is the need to keep them up–to-date. Healthcare workers need up-to-date information and health information resources change often, sometimes daily. Distribution by offline mediums, such as CD-ROM, are therefore not appropriate unless there is also a mechanism to send frequent offline updates.

The potential user base may vary widely in terms of their specific occupation within the healthcare field (doctor, nurse, researcher, community health worker), their affiliation with governmental or non-governmental institutions, and their access to and familiarity with ICT tools, and particularly ICT tools within healthcare settings. The trends emerging from health interventions (and many other areas of human activity) in SSA suggest that tools that "leapfrog" over large bureaucracies and intractable infrastructure problems are being quickly adopted and deployed [37].

Healthcare workers in SSA are frequently non-doctor, community-based individuals who may already be integrated into care systems for ongoing problems such as malaria and HIV/AIDS. Determining how best to support a lightweight system while leveraging its unique strength as a community-based and embedded arrangement will be an ongoing process. A flexible project should also respond the needs of doctors and researchers at more established facilities, recognizing their importance as stakeholders and potential contributors to the knowledge base of infectious disease information.

In terms of ICT infrastructure, Internet use is growing and in some cases, particularly South Africa, healthcare professionals do have Internet access. However, constant connectivity cannot be

assumed as both Internet and electrical service are unreliable. Two approaches have been used successfully to deal with unreliable connectivity. The first is to have a locally cached copy of the resources which can be accessed offline and sometimes even by other computers on the local network. This can take the form of an entirely offline collection such as eGranary [34] or a collection which is updated when Internet is available. The second approach, which has been used for non-interactive information resources such as databases, is to use an advanced file transfer protocol such as BitTorrent to download the collection more quickly and reliably. The most robust approach is to create a system which can be used offline and which can receive updates by the most convenient method, whether it is BitTorrent or delivery on physical media such as a flash drive or a CD-ROM. However updates are delivered, it is important that the user interface for the resource displays information about which version is being used and when it was last updated.

Another key issue for packaging information resources in SSA is that of translation. There are thousands of spoken languages throughout Africa. In addition to the colonial-based languages such as English and French, other national languages include Swahili and Arabic. Furthermore, there is the separate issue of the translation of medical terminology. Medical terminology translation is a particularly difficult issue because it requires translators that know both written languages as well as both sets of medical terminology. An alternative approach is to use automated machine translation for the medical terminology, for instance using the MVP-Net TSB database of localized medical terminology. For this to be possible, medical terms, such as the names of diseases, tests, and procedures, would need to be identified in the text of the information resource, for instance using semantic markup. Terms used in the text would be linked to terms in a reference terminology such as SNOMED CT and then the terms could be automatically replaced with localized terms.

An important economic consideration is the sustainability and hidden costs of a solution. Will the components need to be upgraded over time? How much will it cost to scale it from a small pilot deployment to national use? Does the system require workers to have additional training? Are there increased variable costs such as bandwidth costs? Ideally, information resources will work within the existing technological infrastructure without requiring upgrades and be self-contained so that additional training is not necessary to configure or use them. If the system is going to receive updates over the Internet, these need to be carefully regulated so that the user can control the updates, as this is a hidden cost which might be significant if bandwidth is scarce and priced based on usage.

Mobile phones are prevalent as a hardware platform, but many are not suitable for displaying necessary high quality digital images. If digital libraries have long documents available, to facilitate dissemination in low-ICT areas, they may want to break these resources up into multiple smaller pieces suitable for reading on the small screens of mobile devices. Desktop computers are a capable hardware platform, but suffer from electrical outages. PDAs have been used, but in previous research there were issues with the cost of providing PDAs for all healthcare workers and the need to frequently charge the batteries was problematic. More information is necessary on the prevalence of devices that are robust against electrical outages such as laptops, netbooks, smartphones and tablets. Additionally, information is needed on whether electrical service unreliability is as much of an issue for healthcare professionals as it is for the general public. In order to integrate with the existing technological system, we need to know how healthcare workers use computers and mobile devices in their work now and how they deal with issues of unreliability.

5.1 Limitations

The quantitative analysis of our study was restricted to data from the World Bank's World Development Indicators, and does not consider alternative comprehensive ICT data sources for SSA. The multi-disciplinary research synthesis was primarily dependent upon published literature, which often typically is part of a multi-year research process and may not represent the very latest information from the region. Published literature may also be reflective of biases within the academic fields and within funding sources in the non-profit community, and has traditionally represented more "first-world" perspectives than researchers and authors from the developing world itself. Inter- and intra-governmental and organizational politics are implicit in this type of study, and while this issue should be considered, it does not preclude the useful application of the data.

Since the survey was distributed to healthcare professionals via email, those without access to the Internet were excluded. It is beyond the scope of this study to consider digital library dissemination methods to those without any current Internet access. The sample size was not sufficient to be representative. The numbers and affiliations (e.g., institution, specific geographic location) of those on the mailing lists will remain anonymous due to privacy considerations. The sample population was self-selected through the initial email and any subsequent snowball distributing to additional healthcare professionals. Those who were not able to read English or French were necessarily excluded from the survey.

6. CONCLUSION

The low-ICT environment of Sub-Saharan Africa poses particular problems for online distribution of health information resources in areas that may have a particular need for those very resources. The primary deficiency in ICT that we identified in our research is not lack of hardware, but rather lack of affordable and reliable connectivity. Users are likely to be offline frequently and so information resources need to be accessible while offline. Additionally, health information resources are updated frequently and so the means of distributing updates must be considered. Mobile devices are the primary way that users in SSA obtain connectivity. However, there is a diversity of mobile options, from Symbian to Android to iPhone. A comprehensive solution must work across mobile platforms. Finally, any project implemented in SSA should pursue proper community input, marketing, and training in order to inform the participants that those resources are available, and how it is possible to access and contribute to them.

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