TECHNOLOGICAL CULTURAL DISCONNECTS, IMPACTS ON EQUALITY: USA LEGAL DISCOURSE

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Key words: law and technology, policy, teaching, inequality, culture, critical race theory

Abstract
Advancements in technology may be seen as holding the greatest importance for societal development and progress. But, cultural values and notions of equality are, at least, of equal importance. The thesis of this paper is that if the focus in policy making is solely or primarily on advancing technology, technology will generally be advanced in a way that increases inequalities already predominant in a society. To avoid the furtherance and magnification of inequalities, policies for the advancement of technology, thus, must be shaped with an eye for, and in the spirit of, furthering greater equality, in order to avoid the advancements with the built in automatic furtherance of inequality. This paper will consider the cultural disconnect in technological advancements. It will use as examples, several conversations taking place in American legal discourse. These examples will be discussed using a critical race analysis that is used to identify the perpetuation of underlying racial inequalities even when the legal discourse seems neutral. This same type analysis, also situated in the use of narrative, will inform this paper's questioning of the cultural disconnects in the advancement of technology and how rectifying these disconnects can both further advancement and help eliminate automatic inequalities.

INTRODUCTION

This paper is informed by the author's teaching about race and its implications in the law, including in mainstream courses [1], and by some of her scholarship [2] which is closely aligned with the critical race scholarship movement [3]. As a law teacher, the author regularly asks her students whether they think the law should direct individuals' conceptions of equality, or whether they believe basic notions of equality should direct the shaping of the law. In her scholarship, she seeks to critique the hidden inequalities that are present in the norm of legal discourse, which thus requires a more critical analysis beneath the face of the law. The author believes in the potential value of the law, and consistently applied rules, to enhance cultural values of the people and to elevate experiences of equality for all.

A law or policy may seem neutral on its face. On its face a rule or policy may appear to be fair, or fairly constructed to engender equal rights or equal access. A more careful inspection, though, of many laws and policies may reveal hidden biases or potential biases in application that continue long held inequities in the legal system. So while the law can lead and uplift society to be better, to do better, and to focus more on basic rights of dignity and equality for all, the law can also accomplish quite the opposite.

Of course some policies may be intentionally constructed to maintain systems of racial, or gender, or cultural privilege. Other policies may cause the same inequalities, inherently or through shortsightedness. A critical inspection of laws and policies can reveal, then, inequalities present beneath the surface.

A similar critical query is related to this International Conference on Appropriate Technology. The author must note at the beginning, however, that though she has concerns about inequities in some technological advancement, she favors many advances in technology. Borrowing from the use of narrative in the critical race movement, the author's own story, simply as a citizen and a beneficiary of technological progress, reflects the esteem to which she holds the advancement of technology and science.

The author was raised in the segregated Deep South of America [4]. Many of her summers were spent visiting her grandparents in rural communities who for many years lacked indoor plumbing, or electricity or phones or access to motor transportations or other conveniences routinely enjoyed in America today. With technological advancements in these communities, also came some opportunities for Blacks, especially those with higher education, to participate in the continued educational and technological development that can inure to the benefit of the community and future generations.

Such advancements can also, unfortunately, leave a particular community behind and can also further values visibly and invisibly hostile to the cultural values of a people or of an underprivileged community. Many of these cultural values are rich and deeply embedded. Considering the importance of these community and cultural values could indeed enrich technological progress and societal progress.

Thus, while technological advancement can lift a community and a people, advancement without consideration of imbedded inequality can further more inequality. Advancement without careful policy attention to the cultural values of non-dominant cultures can devalue the culture of those who should instead be enriched and who could enrich the whole with the wealth of the cultural virtue that could be brought to advancement.

A number of scholars in the United States are conversing on these broader problems. These conversations, to be reported on in this paper, center on questions which implicate policy directions. These conversations ask questions such as the following: Should informational technologies continue at a great pace for many, while the historically underrepresented groups' abilities to participate in the communication are further diminished? Should potential injury to cultural values be of concern when risk assessment is made of advanced technological techniques? Must the cultural values at risk be ones widely shared for the potential damage to them to become a major factor in technological risk assessment? Does technological development create a new advanced culture deserving of more respect than past and present cultural communities? Should policies for the advancement of technology consider the impact of those policies on how future generations will look, live, or experience life?

The root inquiry of all of these questions relates to the need for examination of the cost of certain advancements. Consider: what if certain advancement necessarily triggered inequalities for the privileged, do you think that advancement would be actually pursued at all? Likely, it would not. Likely that technology would not be further explored at all if the technology endangered privileged groups of whites, or of males, or of the economically privileged. If the advancement did more forward, it would be with definite consternation of the injuries to the privileged group. So, what if certain advancement necessarily triggers racial, gender, ethnic, cultural continued inequalities, should that advancement be pursued at all without carefully addressing whether the advancement causes an exponential perpetuation of inequality? The answers to the two questions should be the same, if all groups and

cultures are highly and equally valued. Likely, they are not. An awareness of this inequality ought to be a core consideration in formulating technological advancement policies.

Conversations about the Need for Critical Technological Policy Examination

Technological advancements, without scrutiny, may further inequality and disregard for cultural values in multiple ways. A number of those ways, and the reported critique of legal scholars, will be discussed below.

A. Should informational technologies continue at a great pace for many, while the historically underrepresented groups' abilities to participate in the communication are further diminished?

Many scholars have addressed the gender and racial gap among technology professionals. As this divide limits the participation of women and minorities in technology, failure to rectify it will mean that in coming years a large majority of the population could be left out of the advances and unable to compete [5].

Another problem with the gender and racial divide prevails, though. With the majority of the population left out even in the planning and policy making stages, a majority of the perspectives may be left out of the conversation, too. With the majority of perspectives, backgrounds, and lives restricted from access to the initial policy planning, likely embedded inequality will continue to prevail.

These omitted perspectives could be invaluable in helping to shape technological advancement in a way that benefits a larger sector of our society and more cultures than what may be regarded as the technological norm. All women are not the same, nor are all non-whites. However, many may have had different and rich experiences that could help to shape a future of advancement with a firmer connection to norms of equality.

Disregarding the inequalities that lead to fewer voices of women and minorities at the policymaking level could very well lead to a continuation of the same types of policies that led to the present gap. As stated by one scholar:

> Information technology is the governance structure of the twenty-first century and embodies the values of its makers, the information technology professionals who create it. Without working to create a more representative body . . . information technology . . . increasingly runs the risk of acting in opposition to, rather than in accordance with, the wishes of a majority of those governed . . . . . As we commence the second decade of information technology law and policy, we are faced with a fundamental decision regarding the nature of information technology: will it become the ultimate cultural tool of equality or the ultimate cultural tool of exclusion [6].

Evaluating the implications of technological advancement could also be more critically examined through a greater exchange of the related ideas. The author of one article congratulates scientific communities for the extensive peer review and criticism that precede and accompany broad efforts [7]. Still, this review leaves out critical segments: the general public with relatively lesser education about science and technology. Often the public is left out as a result of the lack of education afforded to the general public about science in general. More specifically:

> Modern societies' increasing dependence on science has proceeded hand in hand with developments that disable most citizens, even the most technically expert, from selectively addressing the larger set of questions: Is it good science; what is it good for; and is it good enough? Science has not only become infused with multiple social and political interests, it is also in danger of escaping effective critical control [8].

While the lack of knowledge about science and technology impedes the contributions that many in the public could make in evaluating policy implications for advancement, the lack of knowledge about other cultures and groups also impedes progress. Technology professionals, who lack cultural or racial understanding of the various groups impacted by certain advancement, may actually further harm these groups through stereotyping, generalizations, and not allowing the affected people "to determine whether the technology is truly compatible with their spiritual, cultural, and environmental values" [9].

In addition, if technology professionals have a lack of cultural understanding of the affected groups, then engagement with the group will be further hindered. Misunderstanding will abound. Opportunities to help technological advancement to be transformative for the privileged and the underprivileged, together, will be lost.

Lack of cultural and racial education by skilled technological professionals therefore impedes effective and inclusive collaboration [10]. For this collaboration to flow more freely requires multicultural education and sensitivity with critical openness.

B. Should potential injury to cultural values be of concern when risk assessment is made of advanced technological techniques?

Without scrutiny, present advancement may hold certain lives as more worthwhile than others, a continuation of present inequalities. A pivotal question here is should technological advancement dictate prevailing cultural norms, or should cultural and ethical values effect (or even restrict) technological advancement? One constitutional law scholar describes an increasing quandary of "inattention to the ways in which technologies and legal arrangements may *express* and not simply *implement* existing values" and also the ways "technological and legal choices we make may *alter* those values and transform the very metric by which we assess the 'costs' or 'benefits' of what we have done" [11]. He also questions whether technological advancements with cloning, human interface with computer systems, and manipulation of genetic materials may actually change what it means, and how law and society regards what it means, to be an individual with constitutional rights [12].

An expansion of this question is related to whether technology should shape how life is valued or the worth of various lives. If technological advancement creates "better lives" without considering the inequalities in present systems already as to which lives are better or worth more than other lives, technology then has contributed to inequities rather than serving the populace.

Without scrutiny present advancement may hold and pursue certain values for advancement and wealth as higher values than, perhaps, non-economically based cultural values of other groups. One example is found in the United States and the relationship of the policies of the country in contradiction to Native American cultural belief in the sacredness of land. The

sacredness and respect of land is central to the Native American worldview. Throughout history, some American policies exploited Indian holdings. Also tribal needs for economic development for the survival of the tribe today place these cultural values of land sacredness in jeopardy [13]. Even environmental justice emphases in economic or technological development may ignore the great cultural harm caused to Native Americans when their land is sacrificed for the economic or technological successes of the majority [14].

Thus policies for technological advancement must explore what cultural values are at stake, which requires cultural education and engagement with those who are different. If the advancement is based solely on what is familiar, then inequalities will be automatically imbedded.

C. Should policies for the advancement of technology consider the impact of those policies on how future generations will look, live, or experience life?

Advancement in technologies may also directly and indirectly impact how the generations to come will experience life and culture. For example, errors and technological mistakes in the growing area of test tube fertilization for child conception may lead to increased need to consider what it means to be a parent or raise legal questions of who is entitled to raise and rear children, posing biological connections against other connections [15].

To raise such questions does not necessarily suggest that such technological advancements should be halted. Rather, the potential for error and the resulting effect on families, family psychology and sociology, and reproductive and family law should be a part of the planning and policy constructions for technological advancement. Moreover, advancement for the sake of advancement, or at the quickest speed possible, could actually create changes in society that the laws or various cultures or educational institutions are ill equipped to maintain or tolerate.

Conclusion

When this paper was first contemplated, the author was meeting with a law student who has an extensive background in technology. The author asked the student: Should technological advancements be restricted if they intrude on cultural values or perpetuate inequality? The student readily answered, "No." He argued that growth in technology should be more unrestricted and it will shape or determine the future culture and what cultural values endure.

Obviously, this author is in disagreement with her student. Technology is not a culture itself, but is an avenue for expression of cultural and ethical values. Technology is not a picture of equality; rather it can be used to intentionally forge greater equity and equality. It is this author's position that this forging of equality will become a part of technological advancement only if intentionally considered and embedded.

Technology professionals and policymakers can effectuate better growth and equitable progress for us all by asking: Who is left out of the policy planning and how can the voices left out be included? What cultural education is missing in the educations of those who forge expansions of technology? What cultural values are inherently advanced by present developments, and which ones could better be represented? And, if certain advancements affect future landscapes of life, what policy considerations are demanded?

One critical race scholar, reflecting on a quote by Dr. Martin Luther King, Jr. that "There is a sort of poverty of the spirit which stands in glaring contrast to our scientific and technological abundance," urges that "the terrible gap between our technological achievements and our moral and spiritual values is as intractable today as it was in King's time" [16]. This author agrees.

Further, not only is there a gap between technological advancements and progress in our spiritual or cultural values, there is also a gap within these technological advancements where an intentionality of a focus on equality is lacking.

Acknowledgements
The author would like to acknowledge the intellectual support and encouragement in her advancement provided by Dr. Loretta A. Moore, Associate Vice President for Research and Scholarly Engagement and Principal Investigator of the *JSUAdvance* National Science Foundation funded grant, at Jackson State University, Jackson, Mississippi.

The author would also like to acknowledge the support of her home institution, Mississippi College School of Law, for its summer research grant and post-publication grant that support her scholarly agenda and scholarship of all faculty members.

The author also appreciates her home school and Dean Jim Rosenblatt, for the financial support through faculty travel funding that encourages and funds faculty in international and national presentations and collaborations.

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ENABLING ICT TECHNOLOGY FOR ZIMBABWEAN SCHOOLS: A CONTINUOUS EFFORT BY THE MINISTRY OF EDUCATION

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Keywords: Information Communication technology, appropriate technology

Abstract

Teachers and staff need to be continuously trained and developed to improve their performance in effectively guiding students to master new ICT technologies in the classroom. They need to be well equipped with appropriate ICT technologies for continuous support of student learning. Students also need to be introduced to ICT technologies at a young age and therefore, policies should be put in place to ensure that schools provide the necessary technologies for ICT education. Resident Zimbabweans can network with those in the diaspora over the internet in order to tap into their experiences and resources to promote appropriate technology development. These networks can significantly promote areas of research, technology transfers, information exchange and training. The creation of knowledge society blocks in which experts in the core of ICT abroad can collaborate with experts at home to promote ICT development in the country is vital.

1. Introduction

Information Communication Technologies (ICT) has been adopted by many countries over the years due to the perceived economic benefits associated with being technologically advanced [8]. The education sectors of nations bear the responsibility to prepare society for these changing technologies. Government policies usually steer the direction of education and to ensure a comprehensive dissemination of ICT technologies to all members of the society, a broadening of education is required with respect to the extent to which ICT literacy is fulfilled in schools.

1.1 Background

ICT penetrated into government structures in Zimbabwe starting from 1972 with the inauguration of the Central Computing Services, later spreading to all government ministries and departments [6]. A variety of government documents and statutory instruments have been developed culminating in the National ICT Policy Framework of 2007 and the establishment of the Ministry of ICT (MICT) in 2009. The ICT Bill of 2011 addressed concerns about possible paralysis of the ICT Policy due to the existence of three government ministries purportedly running ICT matters independently [7]. The ICT Policy review to align it with current technological developments resulted in education being afforded centre-stage in ICT technology development and adoption. The Minister of ICT, Nelson Chamisa, was quoted as saying that government was "*moving forward to capacitate schools and tertiary institutions with adequately trained staff and the requisite technologies*". The ability of communities to enjoy the benefits of ICT depends on two things; the availability of appropriate ICT resources and the requisite technological literacy.

The strategic plan of the MICT for 2010-2014 has provisions for transforming the nation into a knowledge society by making ICT resources available and affordable to Zimbabwean all over the country [6]. The plan's Strategic Goal 3.3 guarantees ICT curricular at all levels of Education and this noble goal needs to be supported by appropriate ICT resources and properly trained teachers. ICT can also provide teachers with tools that can 'open up new possibilities in the classrooms' Vassilou in Eurydice [2] but only if the teachers and students have sufficient ICT competencies. However, many policies die at implementation stage due to the absence of ICT resources [13]; *[10]*. According to Rouse [11] "it is feared that unless less technologically advanced areas have a chance to catch up, the increasing technological advances in developed nations will only serve to exacerbate the already-existing economic and technological gaps."

High mobile penetration rates of around 78% [4] and increased broadband internet usage have transformed the way people obtain and disseminate information in Zimbabwe. Most government ministries are also now online and the MICT has indicated that the government is committed to building community awareness on the important role of ICT in today's constantly evolving world. In 2010, the ICT Achievers Awards to acknowledge and honour ICT innovators and major contributors in society were launched. This thrust for excellence and use of ICTs in improving people's lifestyles and business operations has seen the programme celebrated annually. Local ICT professionals and industry are encouraged to "develop 21st century world class innovative and creative ICT solutions which will uplift the image of Zimbabwe's ICT sector both locally and internationally".

The President of Zimbabwe has also noted that all educational institutions should benefit from the e-learning initiative that has been launched in the country. Education is given the responsibility to ensure that society is educated and can adapt to new technologies. The 21st Century education incorporates technologies in the classroom to engage students in ways not previously possible by creating new learning and teaching prospects that enhance achievement and interactions with local and global communities [5]. Goal as cited by Mceetya [5] indicated that once students learn these technologies, they will be confident, creative and productive users of new technologies".

Universities, technical colleges and teachers colleges, which are critical for ICT training in society, have, however, produced only a small proportion of graduates [3] due to several constraints. Most European Union (EU) countries have made strides in funding ICT projects in schools and universities. They have also advanced ICT policies in schools, leveling changes to ICT practices, strategies, content evaluation and processes. Vassiliou in Eurydice [2] mentioned that ICTs are evolving extremely rapidly and becoming extremely complex and thus require teachers and staff to be trained and developed. Universities and colleges can provide a platform for teachers to gain ICT skills and literacy so that they can be able to impart the needed knowledge to students. In developing countries, the serious brain drain of the few skilled professionals in the field is a major limiting factor [12]. Other impeding factors include lack of funding to support the purchase of the technology [9]. More so infrastructural development and resource availability further compound the problem of improving the teacher's quality. In Zimbabwe the access to ICT is not equally distributed as most of the ICT facilities are mainly concentrated in urban centres. In most parts of the rural areas there is hardly any relevant equipment which can be of benefit to both students and teachers. Universities are tasked with the major responsibility of offering courses that provide professional development of teachers in ICT but enrolment levels are still very low due to the

absence of readily available ICT resources. The cost of ICT technologies is a huge impediment and developing country governments should further explore options to reduce the costs to the ordinary person.

1.2 Problem Statement

Zimbabwe has put in place policies to promote ICT education in schools, colleges and Universities. This formal setting has been advanced to build capabilities and empower people from different sectors of the economy with ICT skills for national development. Observations are that policy implementations of this nature require necessary resources and funding. The question that needs answering is whether ICT investment matches investment in education. It is the endeavour of this study to establish the current policies and standards as regards ICT in schools as well as the level of computerization and how knowledgeable teachers are in ICT resources that support the educational process. Efforts by policy makers to support these ICT objectives will also be unveiled.

1.3 Objectives of the study

1 To establish how the Education sector has established ICT technologies in schools.
2 To assess how teachers are knowledgeable of ICT education.
3 To explore how the Ministry of Education enforces and supports ICT policies and standards.

3. Research Methodology

The study used the survey design. Information was collected from participants from a representative sample of 65 teachers (15% of the population) from a population of 407 teachers from 20 secondary schools in Bindura District of Mashonaland Central Province in Zimbabwe. Questionnaires, interview schedules, observations and documentary study were used to gather information. The questionnaire was the main research instrument. Permission to carry out the research in the District was sought from officials in the Ministry of Education, Sport and Culture. 65 questionnaires were administered to teachers and heads of schools after a visit was made to the schools where questionnaires were left, completed and returned in one week. Observations, interviews and discussions were also conducted in the same week. The data collected was coded and converted into tables for easy understanding so as to identify similarities and relationships to draw meaning out of the data.

4. Data Presentation, Analysis and Discussion

The results were discussed in relation to the research questions.

4.1 Biographical Data

Of the 65 respondents, 52 (80%) were males whilst 13 (20%) were females indicating that there are fewer female teachers in the District. From the age data, the majority of teachers (51%) were in the 41-50 age category followed by category 31-40 with 35% of the sample indicating mature participants. There is also an indication of a young generation in schools represented by 5 (8%). These are assumed to have a quicker understanding of ICT technologies. On the same note, there was also a relatively small portion of participants aged 51-6 of 4 (6%). The group is relatively old and presumed experienced enough to provide information for the study. All teachers interviewed had a cell phone. This is in support of the Minister of ICT's general observations that there was an increase in ICT usage particularly, the mobile cell phone.

The majority of teachers 46 (70%) had no email, an indication that this technology is still not very popular in schools. Five (25%) out of the 20 schools had a landlinetelephone indicating a likely shift towards emerging new technologies such as cell phones which every teacher was using. All teachers 65 (100%) indicated that their schools had no website. This shows that a lot of schools have not yet developed for internet usage. Most teachers 55 (85%) indicated that electricity was available on limited times ranging from 4 hours to 8 hours a day as a lot of load shedding was being experienced. This implies that there is a limitation of availability of electricity in schools which hinders the full use of electrical gadgets.

Policies and curriculum

Table 1 below presents findings on the extent to which teachers were knowledgeable of ICT policies and instruments.

Table 1: Knowledge ofICT Policies

	Conversant	%	Ignorant	%
A national ICT Policy	13	20	52	80
A national Strategy/plan	16	24	49	75
A set of regulatory procedures	55	84	10	15
A regulatory institution body	57	88	8	12

Most teachers (80%) were ignorant and not aware of ICT policies in schools, though (20%) teachers indicated that the country had policy provisions that promote ICT education. Seventy five (75%) teachers also had no knowledge of the nation's strategies /plans for ICT in schools. However, most teachers (88%) indicated that they were aware of the regulatory institution/body and (84%) teachers were aware of the regulatory procedures. It appears that teachers had a varied understanding of ICT guiding principles, yet they are the ones supposed to be on the driving seat to assist students but noticeably a lack of knowledge of the guiding principles prevailed.

To examine further the knowledge of ICT policies, teachers were asked to give examples of the four aspects mentioned above. The majority of teachers 55 (84%) failed to identify policies that are at play in the country, only 20 (31%) teachers managed to name the Ministry of ICT as a regulatory institutional body and 12 (18%) teachers named the Presidential computerization programme of donating computers to schools as the strategy. The President set a noble example that needs to be augmented to ensure that all schools are equipped with computers.

On ICT Curriculum and subjects offered, most teachers (48%) agreed that the curriculum included a basic computer subject. However, from the interviews carried out with teachers it was revealed that the basic computer studies being offered were piecemeal and not offered to all children thereby defeating the thrust by the Ministry of ICT of an ICT curricular for all children. All teachers (100%) indicated that ICT assisted instruction was not yet introduced in schools and that most subjects were still being taught using the traditional ways. This means a lot has to be done for its implementation in schools.

Provision of ICT resources

It was also important to assess the provision of ICT resources in schools. Out of the twenty schools, fifteen (75%) had no telephone communication facilities, 13 (65%) had no computers and computer laboratories and 18 (90%) had no computers connected to internet. This suggests that ICT support services were limited in schools. Only 7 (35%) schools had a

computer laboratory. Number of computers per laboratory varied from 5 to 30 depending on the size of the school. Only 7 (11%) teachers were teaching a basic computer subject, while 15 (23%) teachers indicated that they were trained to teach basic computer studies. Three (5%) teachers indicated that they were trained to teach using ICT facilities such as projectors and screens.

The majority of teachers 62 (95%) rated the computer equipment and resources found in the schools lowly. It was indicated that considering the large numbers of pupils per school, a laboratory with only few computers for the whole school did not auger well. As such, competition to get into the laboratories was common. Some teachers and students with less enthusiasm rendered the laboratories a no go area, thus defeating the announcement by government of ICT education for all. There is an indication that ICT standards can be raised by ensuring that schools are well equipped with enough equipment that is user friendly and of high quality. Together with this, qualified personnel should be deployed in schools.

Upon further enquiry on whether teachers were familiar with communication technologies, it was revealed that most teachers were able to use communication technologies such as Phone (100%), SMS (96%) and Social Network (64%). The most commonly used social network was Face book registering (58%).

What the government can do to improve ICT education in schools

It was suggested that the ICT curricula should be mandatory and that all children in all schools in the country be accorded time to study the subject area. To make this possible it was indicated that computers should be provided in all schools. The teachers needed also to be trained so that they use ICT in the teaching of all subjects. In some areas electricity is not available hence the need to ensure electricity supplies at these schools as well as ZESA to address and solve faults timely. Government can also promote solar powered computers and this requires researchers, educationists to come together to develop cheaper and affordable solar gadgets that can aid ICT in schools. Econet Mobile Company has been commended for providing solar lights and chargers to rural teachers and there is need to encourage more innovations for the 21st century.

There was an outcry that teachers need to be trained so that they are realigned to become computer literate. The teachers can be empowered through the provision of laptops and computers at subsidized prices and affordable terms. Computer literacy was a prerequisite for many teachers who wanted computers to be available in each and every school for them to have access.

Improving Standards on ICT Education

It was urged that school authorities and parents should raise funds to build secure computer laboratories and procure more computer resources for schools as well as service existing ones. Funds could also be sourced through special levies as well as availing credit terms to schools to enable them to purchase textbooks and ICT equipment. It was also suggested that schools can have a budget provision for ICT equipment which can be augmented by government and donors so that every school has a computer laboratory and up to date computer equipment. Many laboratories needed to be created at every school so as to increase access as the current state of just one laboratory per school with at least 20 computers was not sufficient, particularly with enrolment levels of about 4000 pupils in most schools. There was need to approach donors and local stakeholders to donate equipment to schools so as to compliment government efforts to improve computer resources in schools. Zimbabweans in

the diaspora could be approached to assist in the development of ICT in the country as the knowledge they are gaining in the global world can be made use of to promote development of appropriate ICT technologies for the country.

Due to the rapid changes in technology, teachers needed to be continuously staff developed to improve and enhance their performance in order to effectively guide students to master the new ICT technologies in the classroom. They needed to be well equipped with ICT technologies for continuous support of students learning. The need to ensure that teachers continuously revive themselves to keep abreast with new technologies for the benefit of students and society as a whole was vital. Universities and teachers colleges must therefore provide a curricular that aims at improving the teachers' quality in ICT technologies. The teachers also needed to be educated on computer use through seminars and workshops linking education and research so that they are informed of new trends in technology. Research and intellectual expositions done by universities needed also to encourage researches in ICT.

Teachers also felt that if there are departmental provisions of computers connected to internet, it would enable both teachers and pupils to carry out research on the subject matter. This was thought to be a better solution rather than crowding at computer laboratories with limited human resources. It was indicated that students would get assistance from departments as soon as possible.

Teachers' role in Advancing ICT Education in schools

Programmes are being offered in Universities and Colleges of Education for teachers to enhance their ICT skills so that they are able to assist students from various back grounds to benefit from ICT technologies. However, teachers expressed concern over time off from work to go and study, which was difficult to get for some. The initiative to ensure that disadvantaged children benefit and become experts in the world of ICT was crucial. Teachers appreciated the role that they were to tap the interest of students and to motivate them to study the subject area. In their teaching they indicated that they would impart the knowledge necessary to ensure that every child is capable of using the 21st century gadgets and equipment. However this was their ideal classroom, since they were incapacitated due to lack of resources in most schools. Some of the teachers were also not conversant with the technologies of the day, except the cell phone which almost every teacher had.

Recommendations on improving ICT standards

1. All teachers enjoyed the cell phone technology which can be tapped to provide social networking of teacher to teacher, student to teacher, teacher to student and student to student networks. Most teachers indicated that they used Facebook. This can be developed into a network that can be used by students and teachers to share educational information and notes. Mxit is being used in South Africa by students with difficulties in certain subject areas such as Mathematics to get help from online tutors. The networks for teachers and lecturers can be of significant importance in promoting areas of research, technology transfers, information exchange and training.

2. Policy makers should mandate stakeholders to implement ICT programmes in schools to all pupils with the necessary support such as human and material resources.

3. It is suggested that Zimbabweans in the diaspora be included to assist in ICT development in the country. These can be networked through the internet and tapped to promote development.

4. There is also need to create knowledge society blocks in which experts in the core of ICT abroad can collaborate with experts at home to promote knowledge sharing and development of ICT equipment and accessories in the country. These should also include networks of institutions of research, development and collaborative programmes.

5. The Ministry of Education should initiate and mobilize funds and resources so that all the disadvantaged pupils especially in the rural areas have access to ICT through provision of ICT equipment in schools and Rural ICT centres. The need for zero tolerance of substandard ICT products is called for and thus the Standard Association of Zimbabwe is tasked to ensure that importers and suppliers of ICT equipment comply.

6. Zimbabwe Revenue Authority should waiver tax on imports of ICT equipment. This is to ensure that ICT equipment is abundant on the market and that it is affordable to many.

Conclusion

The study revealed that ICT education is still in its infant stage as most schools are just offering basic computer studies to a limited number of students. The study also noted that ICT education was limited due to a number of factors such as funding and resource availability. For example some rural school teachers indicated the lack of electricity. Teachers are critical agents of change and that they need to have information at their fingertips to be able to assist who ever calls for their service. They need to become relevant in this time and age so that they master the 21st century technological innovations. An ICT culture needs to be propagated if Zimbabwe is to withstand challenges of the 21st century.

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SURVIVAL ETHICS IN THE REAL WORLD: A GLOBAL MODEL FOR EXPERIMENTAL ETHICS

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Key words: community, development, education, ethics, sustainability, survival, checklist

Abstract
We model a framework for academic, agency, community, and other stakeholder groups using an ethical decision-making approach to foster ethical and sustainable development in Africa. The essay's first part develops a model for the interaction between ethics and science. The essay's second part models a set of interacting centers focused on addressing pervasive issues amenable to appropriate solutions developed jointly with affected communities. Best practices, as evidenced by real world outcomes, will be shared among participating centers and then exported to other Global South locations.

Introduction

Our earlier essay, "Introducing Survival Ethics into Engineering Education and Practice," established a model for a triage ethics applicable to the implementation of appropriate technologies [1]. Survival ethics focuses first on the human requirements for clean air and water, food, shelter and clothing, healthcare and education. Survival ethics defines a foundation of conditions critical to survival upon which may then be layered those conditions critical to flourishing, such as rationality, community bonding and freedom.

Survival incorporates the ethical components embedded in the United Nations Universal Declaration of Human Rights. Article 25, Section 1 states the basic conditions for survival: **"**Everyone has the right to a standard of living adequate for the health and well-being of himself and of his family, including food, clothing, housing and medical care and necessary social services, and the right to security in the event of unemployment, sickness, disability, widowhood, old age or other lack of livelihood in circumstances beyond his control" [2]. Article 26, Section 1 states the right to a basic education: "Everyone has the right to education. Education shall be free, at least in the elementary and fundamental stages" [2].

Article 26, Section 2 expresses the right to an education that promotes flourishing in the entire human community: "Education shall be directed to the full development of the human personality and to the strengthening of respect for human rights and fundamental freedoms. It shall promote understanding, tolerance and friendship among all nations, racial or religious groups, and shall further the activities of the United Nations for the maintenance of peace" [2]. Principles fostering survival and flourishing define the basic philosophy of the UN Millennium Development Goals [3].

Recent explications of human eusociality provide a foundation for claiming universal rights to these social goods. Eusocial organisms exhibit reproductive division of labor, have overlapping generations, and show cooperative care of young. Like other eusocial

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species, humans may dedicate themselves to the well-being of their groups, though the costs to their individual fitness may be substantial. Eusociality is believed to account for the expansion of the human population from a small number some 200,000 years ago to over seven billion strong today. Stephen Pinker's *Better Angels of our Nature* delineates humanity's record of moral progress [4]. Edward O.Wilson's *Social Conquest of the Earth* offers an evolutionary explanation of this progress [5].

The essay's first part proposes a model for the interaction between ethics as a prescriptive discipline and science as a descriptive discipline. Ethics states what *should* happen and sciences states what *does* happen and *how* it can happen. We examine the question of how the two disciplines may be fused together to work toward sustainable development, grounded in universal rights to survival and flourishing. Can a global consensus on ethics be derived while acknowledging differences in cultural and environmental circumstances? The essay offers a mechanism that researchers may use to engage the survival ethics protocol with a multi-disciplinary approach to problems of development.

The essay's second section describes the practical application of survival ethics theory through an emerging network of international centers dedicated to sustainable development grounded in social justice. The objective of the network is to demonstrate the following: 1) ethical development can achieve sustainable results; and 2) an ethical framework is necessary for sustainable development. We will demonstrate this through collaborative multi-disciplinary efforts focused on the implementation and evaluation of appropriate technology development projects. The model provides the flexibility to address challenges arising from the changing nature of the international development landscape. It also speaks to global trends in environment, demographics, urbanization, economics, connectivity, healthcare, science and technology. One issue in development is the difficulty in isolating causal factors that affect the success of projects. We offer here a program to determine what works and what does not in this regard.

Part I: The Consortium of Science and Ethics: A Model

This section examines the prospects for reaching global consensus on ethical prescriptions for human development. Science appears to offer a model using objectivity, while philosophy and ethics appear to offer a model based in subjectivity. We believe that ethics and science are compatible, and that ethics informs the processes that lead to effective and sustainable human development through the applications of science and technology. To what degree are ethical decisions subject to scientific analysis? While some researchers claim that ethics may be reduced to principles of evolutionary psychology [6], it is clear that the foundational principles of ethics must lie within the boundaries of philosophy.

Against some philosophers who claim that the subject of ethics, the good, must transcend empirical analysis, survival ethics traces the source of value to desire— the fulfillment of basic needs. Ultimate desires are not yet subject to rational analysis. The desire to survive must appear as a brute fact that cannot—and perhaps need not—be given a justification. Theorists like Joyce furnish explanations of such desires through evolutionary theory [7]. A scientific theory may explain why we come to have basic desires. If such desires are not fulfilled, individuals do not survive and do not pass their genes to future generations. Unfortunately, such a theory cannot judge whether such desires are *desirable* in some innate, universal sense. We can argue, for example, that the ethical goods required for flourishing—community bonding, rationality, creativity and the like—are themselves justified through their utility to survival.

However, we acknowledge that survival cannot be an ethical good that serves as the foundation for all other goods. We admire those who have given up their lives for what they take to be higher goods—defense of their communities or struggles for justice, for example. Freedom, pleasure, religious conviction may trump survival. In the end, the bottom line is that these basic desires have worked for past generations. That many of us share the same desires is a fact that neither legitimates those desires nor mandates that they will continue to work in the future. The only justification of desire is desire itself. That we come to have certain desires by reason of causal chains involving evolutionary theory is a matter for investigation. While science may not necessarily determine the legitimacy of desires, it can provide a mechanism aiding in the achievement of them.

Suppose we say categorically that life is good. We make no qualifications. It is good simply because we desire to live. However, if we say that air is good because it supports our lives, then we can make room for empirical investigation. The experiment—depriving ourselves of air—will necessarily be brief, but its results will be conclusive. The province of science is to investigate hypothetical commands: if you wish to live, then make sure that you are well supplied with pure air, temperature control, clean water, nutritious food, minimal healthcare and education. If the quality of these goods is degraded, then the quality of life must also degenerate.

To generalize, we might say that what is good is what is desirable. We cannot argue about the legitimacy of our most basic desires. We can and often do argue about the best means to achieve those desires. If you desire x because you think it will secure y, your desire for x can be refuted if you come to believe—empirically—that x will not produce y. You may desire x intensely, but you do so only because of your belief that it will produce y. If your belief is wrong, then x is desired but not desirable.

Scientific investigation can exert powerful traction in testing judgments about the desirability of goods and actions. We can say that drinking water that has trace amounts of contamination is good if there is no evidence that the contaminants cause disease or genetic damage. We can also conduct an empirical investigation to find out whether in this case absence of evidence means evidence of absence.

We require a new approach fusing the disciplines of ethics and the sciences. If we can agree on basic ethical goods such as survival, then the best means for securing survival for the greatest number of people is through scientific investigation. Science cannot declare that securing survival for the greatest number of people is unreservedly good. That is a matter for ethical decision. However, if one can claim that the survival of the greatest number of people will serve a greater good, then that claim can become a matter for empirical investigation. We claim that survival is best ensured through flourishing, and we judge whether a community is flourishing by analysis of its numbers, the strength of its binding principles, and the excellence of its members.

If our intuition about the importance of numbers is correct and if our intuition about the correlation of survival and flourishing is correct, then we can safely say that the survival of the greatest number of people is unreservedly good. Unfortunately, empirical testing of the hypothesis, "there's strength in numbers," may not be possible since the hypothesis is so general as to be interpreted in any way that best fits the available evidence. Are humans best divided into small or large groups? Should the human footprint on the planet be enlarged or reduced? Once the objective is well defined, empirical investigation can follow.

Due to the complexity of human behavior, analysis of the ethicality of means/ends relationships requires interdisciplinary research. If we say that x is good because it will produce y, then the context of the claim dictates the kind of research needed to substantiate the claim. If we say that a development project will guarantee the survival and enhance the quality of life of a community, the complexity of the project will dictate the numbers and professional competencies of the team assigned to evaluate the project in terms of the survival ethics checklists [1, 12].

Even a simple act like digging a well calls for a broad range of expert knowledge. What is the expectation for the quality of water from the well? What levels of arsenic or salt are found in the water table? What is the projected depth of the well? Does the community have the resources to cover the cost of the well? Will the well be an excessive burden on an already stressed water table? Will the well displace the workers who make their living by carrying water from more distant sites? What is the projected life of the well? What effect will the well have on the social fabric of the community? What will the impact of the well be on surrounding communities?

> Exemplar: Bunker Roy's assistant Ramniwas tells the story of his first encounter with the Barefoot College [8] mission in Rajasthan, India. A Barefoot College well-drilling team saw the greatest need for a well in Ramniwas' village, an outcaste community situated near a higher status village. Those higher status residents fiercely protested the well's being drilled in the poor village. Both parties saw the issue as one of justice. The higher status villagers believed that their caste privileged themselves over outcastes. The Barefoot College drillers believed that the well would increase the morale and economic viability of the poorest residents of the area. Their vision of justice triumphed, but a better resolution of the conflict might have come from a survival ethics team approach.

A survival ethics team forms itself around a constellation of research questions. For the technical aspects of such a project, geologists, chemists, engineers and technologists would all have roles in decision and evaluation processes. For the humanistic aspects, economists, political scientists, psychologists and anthropologists would join the conversation. In the interest of increased objectivity, NGOs (Non-Governmental Organizations) would also add their expertise. Pursuing sustainability for the project could include participation of SMEs (Small and Medium Enterprises) that would advise community members on forming a corporation for the maintenance of the well and for replacement wells in the long run. Most important would be the participation of community members, both as individuals and as members of CBOs (Community Based Organizations). Here students would be called upon to exercise service-learning initiatives. In collaboration with community members in rural areas and university experts, all-inclusive societies would strive to achieve culturally sensitive and ethical solutions to development challenges.

Part II: A Global Network for Survival Ethics

We are formulating a working model for development based on the concept of survival ethics. Research on its compatibility with ethical systems of traditional cultures in the Global South is critical to the success of this model. Howard University researchers and colleagues from African institutions are drawing upon mutual global expertise in addressing the long-standing failures of global development projects. The Howard model builds on a network of university-based centers for ethical and sustainable development with an initial focus on

Africa. Due to the high rates of poverty and development challenges throughout Africa, strategic and economic development is critical for this region.

Grounded in the concept of survival ethics, the Howard model establishes a set of relationships between United States and African universities to address development, democracy, sustainability, and defense issues. Howard University has established partnerships with a cross-section of African universities in developing nations to leverage expertise in areas congruent with the core objectives of international development agencies [9]. Virtual networks of indigenous and international experts collaboratively address challenges identified by communities and defined through assessment of collected data in targeted areas. Taking into account poverty indicators that define the most vulnerable communities is critical to the survival ethics protocol. The uniqueness of this approach is the establishment of ethical, community-inclusive partnerships that are data-driven, evidence-based, and tied to the use of appropriate technologies. The model empowers communities to address self-prioritized needs, improve quality of life and raise standards of living.

This model partners communities with academia, NGOs, SMEs and CBOs. It also engages students from Howard University and African institutions under the guidance of faculty and professionals in science, engineering and technology (STEM) disciplines. Working with NGOs, SMEs, CBOs and impoverished community members, the survival ethics model harnesses the enthusiasm of youth in the US and developing countries. It directs the passions and focus of these team members in a framework with expert guidance and mentorship from academics and practitioners. It also serves to bring people together to implement innovative and sustainable solutions to community-identified problems. The approach addresses community-delineated issues within an ethical, social and culturally aware decision-making framework that involves all affected groups and promotes gender equity. Full participation of team members and assessment and evaluation at all phases is also part of the model.

The survival ethics model includes the following:

- A core of faculty trained in social and ethical concept and component inclusion in science and engineering education.
- Faculty who recognize the potential of their students to promote community capacity-building.
- Networking among NGOs, SMEs, CBOs, community member partners, and governmental agencies engaged in specific development projects – a synergistic outcome of the faculty exchange and mentoring.
- Revisions and inclusion of service-learning courses in technology curricula. Curricular offerings focus on: 1) ethics and the philosophy of technology and engineering; 2) appropriate technology for developing communities with focus on water, sanitation, and environment; 3) alternative and renewable energy solutions in developing communities; 4) pharmaceutical manufacturing; 5) cultural and historical context, facilitation, and working with community members; and 6) data collection , evaluation, assessment, and monitoring..
- A new generation of students trained in socially and ethically responsible engineering. The students gain real world experience in development through their mandatory curricular engineering service-learning projects.
- All teams learn from and work in tandem with the communities they hope to help.

In the preliminary efforts to execute the survival ethics model, community-based projects are designed, developed and implemented in partnership with NGOs, SMEs, CBOs and the inclusion of communities at all phases. The potential for sustainability of these projects will be significantly higher, since monitoring and evaluation will be conducted on a long-term, on-going basis with community participation.

> Exemplar: At the request of the St. Luke Foundation in Moshi, Tanzania, Howard and Purdue University researchers and African partners established an Industrial Pharmacy Training Unit at the Kilimanjaro School of Pharmacy / St. Luke Foundation in Moshi. The Unit teaches the fundamentals of drug development, regulation, and quality-assured drug production. World-class experts in drug discovery and development produced this curriculum. Contributors from the pharmaceutical industry, drug regulation (US FDA), patents (law firms) and academics have further tailored the program for the needs of African pharmaceutical professionals. This program utilizes intensive classroom training, team exercises and hands-on product development in a laboratory that has been designed and built for this purpose. At the end of the program, participants are able to develop new drug products and processes, as well as meaningful tests and specifications to assure drug quality. Participants are also able to utilize their learned skills to detect substandard and counterfeit medicines. Participants also understand how to meet International standards for Quality Assurance and are, therefore, prepared to sell their products to International Donor Agencies as one path for economic development. These operations are governed by a Quality Management System that includes roughly 400 Standard Operating Procedures to assure proper oversight of desired ethnical principles and congruence with international standards of quality assurance practice [10].

Howard's partnerships with institutions in Ethiopia, The Gambia, Ghana, Kenya, Senegal, South Africa, and Tanzania serve as foci for testing the survival ethics model. Each partnership focuses on incorporation of social and ethical engineering education and practices to make critical and sustainable impacts on development challenges. They employ the proposed model of community partnerships with engineering students and faculty, along with NGOs and SMEs to create and implement development solutions. Our expectation is that the successful execution of the project will provide development agencies with a clear ethical framework for the determination of aid needs and priorities. Anticipating success, we will then extend the model to the rest of the world, particularly the Caribbean, Latin America and impoverished regions of Asia and Oceania.

Critical to the success of the survival ethics protocol are effective measures of assessment. The global model focuses on four areas of assessment: 1) the ethics-based checklist model [1, 12], 2) the integration of faculty and students in engineering programs with NGOs, SMEs, and CBOs, 3) environmental impacts and 4) gender impacts [11].

Partnerships in development projects are assessed by the rate and efficiency of their establishment, their relationships with NGOs, SMEs, CBOs, and their collaboration with targeted communities. Evaluation of community-based projects examines the inclusion of the community in all phases of the project from conceptualization and prioritization of needs to project design and implementation. The potential for sustainability of these projects is determined through effective monitoring and evaluation. In addition, the effectiveness of knowledge and technology transfer is examined with respect to the degree of informed community engagement, discussion and approval, quality of community outreach, education,

capacity building, extension beyond the community, and evidence of government and multilateral aid agency support.

In particular, one aspect of success is measured by our initiatives to establish gender equity. The survival ethics model stresses the importance of gender equality and female empowerment. Addressing the needs of both genders, our strategy entails: 1) advocacy and female mentorship pairings; 2) participatory appraisals and social impact assessments that engage both genders; 3) facilitating leadership roles for both women and men; and 4) development of gender appropriate training and educational tools. Underlying each initiative is an ethical core that necessitates the trust of both genders and building rapport. The foundation of ethical development relies on confidentiality, consent, and risk disclosure. To do this, we obtain consent from participants and facilitate environments that guard their confidentiality. We include both genders in the decision-making process. In addition to all-inclusive community meetings, we meet separately with women and men to encourage further input. Assessment, performance evaluations, and documentation of communication challenges will gauge our abilities to engage both genders [11].

Another aspect of a successful development model involves a focused commitment to the environment. Our dedication to environmental sustainability is woven into all activities through: 1) assessment, mitigation, and monitoring, 2) coordination of experts, 3) explicit protocols, 4) community-based initiatives, and 5) teaching, training, and outreach. Projects are developed with a holistic approach to ensure that environmental hazards are not generated, and if they are, that they are handled in accordance with appropriate regulations, guidelines, and criteria. Environmental sustainability will be ensured through data-driven initiatives. Archaeological, soil, water, botanical and faunal data are collected from communities to build an environmental database, identify resources, and pinpoint harmful activity areas. We identify disposal patterns, ecological relationships, and impacts through surveys, interviews, excavations, maps, and ethnographies. Aerial photography, archaeological data, and the use of GIS allow us to analyze long-term impacts on a landscape, chart environmental changes, and create visual tools and maps to devise resource management strategies.

Conclusion

Survival ethics teams have the expertise to document environmental features, plot landscape transformations, identify pollutants, predict impacts, and devise effective mitigation policies. We have the equipment to conduct soil and bone chemistry analysis, water quality assessments, tests for food-borne illnesses caused by natural resources, and investigations of air quality. Environmental education and outreach are an integral component of all projects. We train students and communities, consult with NGOs and SMEs, and raise awareness of environmental control technologies. Standard Operating Procedures are used to manage key personnel who handle waste products or engage in practices that impact the environment. Partners and communities are educated about potential dangers and contaminants and made aware of the benefits of a clean and safe environment.

Overall, an ethical model of sustainable development is grounded in a multi-disciplinary framework. It leverages the expertise of academics, SMEs, and NGOs, while it relies on the energies and talents of young students. Most importantly, it is community-driven and recognizes the importance of empowering communities that are able to maintain their own solutions.

Two open questions remain in this philosophical approach to ethical, sustainable development. First, will long-range assessment of ethics-based development strategies demonstrate their superiority to other models? And second, is it possible to scale ethics-based development to global applications? Atul Gawande with others is a proponent of a "checklist model" to ensure quality care, decreased costs, and constant innovation of hospital care [12]. Successful experimental results with similar models [10] encourage the authors to pursue broader application of the survival ethics checklist model [13, 14].

Acknowledgements
The authors wish to acknowledge the work of our African partners who have made this project possible.

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LINKING RESEARCH STRATEGIES WITH POLICY MAKING AND SOCIAL ACTION: AN ANALYSIS OF PROJECT DESIGN TO DEVELOP AN mHEALTH SERVICE DELIVERY PACKAGE[1]

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Keywords: Mobile Technology, Health System Strengthening, Community Development

Abstract:
Mobile telephony penetration in Sudan, as in other low and middle income countries, has dramatically increased in the past few years. It is also a country that faces significant humanitarian challenges, has the largest internally displaced population in Africa [2], in addition to infrastructural (and in places security or geography) challenges that limit access of citizens living outside urban centers to public services. The appropriateness of this proposed package is situated within the growing worldwide momentum and enthusiasm to capitalize on improvements in telecommunications and the rapid uptake of mobile technologies to support the achievement of global, national, district, community, and individual level health priorities. The value of the project is drawn from addressing knowledge gaps that exist in our understanding of which technologies works best and in what context. This paper describes the design of the project and examines the relationships between the selected research strategies with outcome indicators such as health system strengthening and community empowerment.

Introduction

The Sudan, classified as a lower income country [6], is also undergoing rapid change, political unrest, active conflict, which put additional barriers for 'access to public services' and new meanings for 'far to reach communities' to include security when examining coverage or availability of service and considering displacement as a factor that affect accessibility of services. The proposed package examines whether mobile technology solutions can improve access of the dispersed, unsafe, or excluded, from the reach of the public health system. Sudan has a varied set of far-to-reach communities, a large civil society, three telecommunication service providers and boasts population coverage of 85% and over 10 million subscribers in 2008 (not considering multiple ownership of SIM card) [1], which are factors that open space for the ideas in this proposal.

Though the mHealth (mobile health), which utilizes mobile technologies such as SMS for healthcare services such as disease surveillance, is still in its early stages, there are indications that it has the potential to extend the reach of health systems to remote populations and to promote a shift toward citizen-centered health care and well-being. Global reports indicate gaps in our understanding of what works and what does not, and country initiatives are yet to give evidence in terms of cost benefit and health outcomes. The WHO 2009 global survey found that 83% of member states have at least one mHealth initiative.

[1] This working paper examines various ideas being developed into a grant proposal by Author.

While Africa reported the least activity, there were notable examples on the uses of mobile technologies for emergency and disaster situations, health call centers for specific diseases, SMS and voice for treatment compliance and health promotion [3]. UNICEF's Technology

and Innovation Lab teams produced a wide variety of open source mHealth software as well as piloted projects in a number of African countries [4]. The main barriers for mHealth initiatives however involve difficulties in demonstrating the cost effectiveness of these initiatives; in defining the mobile application's architecture and platforms; and in devising policies that encourage their use [5]. There are also legitimate concerns about their effectiveness in areas with severe shortages in services or drug supply, the security of citizen information by applications using mobile health technologies, and the inherent limitations of SMS in terms of size, privacy, and utility for multilingual and multi-ownership contexts.

This proposed project aims to address some of these knowledge gaps by conducting a 3-year controlled study to design and implement an integrated mHealth package that coordinate elements of treatment compliance, data management, emergency response, health education and consultation to be administered by local health workers and community volunteers and linked to existing health services. The controlled study approach increases the reliability of project results (scientific method) and the publish-ability of its research, which are often considered the 'weakest link' in the scholarship of South (or aid-receiving) countries whose role in the development project is defined by the "*cultural mindset of donor agencies*". The project framework also sets out to critically examine and disambiguate the semantics of phrases such as 'technology appropriateness' and 'community empowerment' when defining outcome indicators to avoid the pitfalls of "*development-speak*" [7].

The remainder of the paper describes the proposed methodology in Section 2. Section 3 discusses the relationships between the selected methodologies with indicators and expected outcomes which are followed by final remarks in Section 4.

Research Framework

The project is envisaged as a partnership between the *Epidemiological Laboratory*, which is highly experienced in turning research into policy and practice where the project builds on their past relevant project experiences e.g. TB Reach and Triage-Plus, as well as their extensive work on health promotion; and *Asmaa Society for Development*, which brings their experience in community development and empowerment, in particular their work on literacy using REFLECT tools and civil rights concepts in a number of regions in the country. REFLECT was originally developed for adult literacy and combines Freire's thematic approach with participatory tools linking learning to empowerment. It is based on the involvement of learners in identifying learning (generative) themes and producing own learning materials where the traditional teacher role is replaced by a facilitator of learning.

Research Hypothesis and Objectives

The hypothesis of the research is that the 'proposed package will increase access of hard-to-reach populations to healthcare and health-related information, as well as improve adherence to treatment levels and the ability of local health workers to diagnose, treat and track diseases in a timely and cost effectively manner.' Its objectives include:

1. Design and implement an integrated and generic health delivery package using appropriate mhealth solutions to provide the following services:
    a) Adherence to Treatment
    b) Data Collection and Disease Surveillance
    c) Health Information Systems and Point-of-Care Support
    d) Health Promotion and Disease Prevention
    e) Emergency Medical Response
2. Assess the effectiveness of the package in terms of:
    a) Health outcomes and Cost
    b) Usability and Technology Appropriateness
    c) Community Need and Demand
3. Build capacity of project researchers in developing and tailoring open source mobile applications; and of project partners (such as local health workers, community volunteers, Community-based organizations) in the uses of mobile technologies for healthcare.

Box 1: Research Objectives

Research Design and Methodology

The project methodology combines parallel group randomized controlled studies and participatory research methods. The controlled study approach is meant to improve the reliability of evidence obtained while participatory approaches are sought to facilitate the engagement of study participants throughout the project. Quantitative and qualitative methods are used to define and measure project indicators in terms of health outcomes, cost effectiveness and package acceptance and relevance, as well as indicators on community need and demand for package services. By applying a knowledge management approach to capture and represent project knowledge, the package will be formalized and documented, and its effectiveness assessed in terms of defined health outcomes, return on investment and technology appropriateness, as well as in terms of community need and demand. The significance of considering 'effectiveness' from the perspective of the community, as well as the health system, is that it opens alternative (community-led) diffusion and sustainability strategies to institutionalization which is an ideal output for evidence-based studies. Ethical considerations will examine areas of concern in controlled studies and appropriate technology projects as well as follow national and global guidelines and best practice. A key feature of this project is the early and genuine involvement of the targeted population and stakeholders in project design, implementation and evaluation processes which aims to empower communities in identifying problems and possible solutions as well as to ensure relevance and appropriateness of package for context. Social and gender equity considerations will be incorporated into the analysis, formulation, and monitoring of project strategies and activities. The following subsections examine specific design aspects of the project. First, the project frame work is described as a set of phases, activities and milestones; second, ethical considerations and social and gender equity concerns are discussed; and third, the expected project outcome is defined.

Phases, Activities and Milestones

There are two project activities that run throughout the 36-month project: (1) capacity building of project team and (2) project management. Quality assurance will involve the

appraisal of quarterly/yearly reviews and project knowledge production processes. The project is divided into 4 iterative phases each involving several activities and yielding various milestones as summarized in Table 1:

Phase & Milestones	***Main Activities***
1. Preparation and situation analysis ***Milestones***: • Establishment of local community and project advisor structures • Baseline survey report	• Studying relevant country experiences and alternative mHeath technologies • Assessing and defining ethical aspects of study • Identifying required skills of team members/staff; research questions for uptake at B.Sc. and M.Sc. levels • Collecting data and information from available national datasets and case studies • Identifying potential project locations • Liaising with and appraising community and local health authority perceptions on project objectives • Identifying possible community members/structures for the different package user roles • Determining selection/evaluation criteria, surveillance/monitoring data and sample size • Identifying long-term sustainability options • Recruiting intervention and control groups • Conducting baseline survey
2. Package design and testing ***Milestones***: • Established project evaluation criteria • Operation and training manuals • Package ready for piloting • Project hardware equipment procured	• Conducting community-wide discussion sessions to inform package design and identify feasible sustainability options • Selecting appropriate technologies and establishing information flows • Designing and developing system components • Integrating and testing package (includes user acceptance testing) • Documenting design and producing manuals for operation and training
3. Training and implementation ***Milestone***: • Finalized package • Completed training program • Established monitoring and quality assurance mechanisms	• Defining package implementation strategy • Training of selected community health providers (operators) • Conducting community-wide educational meetings • Piloting and verifying package functionality with operators/community • Finalizing/implementing package
4. Evaluation and recommendations ***Milestone***: • Process, cost effectiveness, package acceptance evaluations • Recommendations on roll-out options • Community decisions and plans on way forward • Research report on capacity building needs, new research inquiries/projects, publications, etc.	• Assessing impact based on health outcomes, cost effectiveness , usability/appropriateness of selected technologies and interface, community indicators on need and demand • Conducting community-wide meetings to disseminate and validate findings • Formulating research project recommendations • Establishing community governance body and sustainability mechanism

Table 1: Project Phases, Activities and Milestones

Ethical and Equity Considerations

The main principles guiding this project is providing access to health services for the larger and less advantaged portion of the population by utilizing what already exists (low end mobile phones) and building on what is free (open source software). There is a flow of

citizens from affected areas from the three active conflicts areas to urban centers, especially Khartoum. The lack of hosting services or established camps as well as the recent sharp decrease in numbers of INGOs in Sudan; have further complicated the status of IDPs at this point in time. The skills required to operate and maintain the system will be transferred to a selected group of trainer-of-trainers that is representative of the different categories of community members, with focus on those who are less mobile like women and elders.

The fundamental condition for the project to commence is the willingness of participating communities. The project will set up a local governance structure and conduct regular community-wide educational meetings to ensure active engagement in decision making and transparency of research process and outcome. The research and package design will undergo ethical analysis and review to obtain ethics approvals by the national review body, as well as through periodic reviews on project procedures and data management by project consultants. These analyses will review considerations that are relevant to controlled studies such as transparency of the randomization process, and others related to appropriate technologies such as developing tools that extend human labor and skills. Using participatory approaches for package design and the selection of services provides the project with knowledge on local need and demand. The target population (internally displaced persons) is considered among the socially excluded and vulnerable groups in Sudan – a country marked by conflict and instability. The project aims to address inequities in healthcare provision by capitalizing on the most commonly available and used technology (mobile phones). Social and gender equity concerns are considered in the analysis, formulation, and monitoring of project strategies and activities using awareness sessions and gender sensitivity analysis. This analysis aims to identify contextual social/gender-related objectives/outcomes and facilitate mainstreaming gender in package design and implementation strategy. The package's generic solution component will be examined to suggest its potential application for different essential public services, like education, and other categories of vulnerable or hard-to-reach groups.

Expected Outcomes

The expected outcomes of this study are four fold. Firstly, *"strengthening health system"* by assessing health outcomes using indicators on community access to health information and adherence to treatment, morbidity and mortality rates, as well as on information flows between community and local health services. The project will be piloted in two internally displaced population locations in Khartoum State to represent control and intervention groups. Sample sizes have been computed to obtain 95% confidence level.

Secondly "*contributing to knowledge-base"* by assessing knowledge disseminated by the projects in terms of the number of public seminars, conference participations, scholarly and popular publications; and knowledge gained by each of the partnering organizations in terms of technical and innovative capacities of project team members that feed into the partnering organizations existing efforts. Of particular relevance is the work of the Epidemiological Laboratory on pro-poor healthcare approaches (e.g. Triage Plus project), and the literacy project of Asmaa Society. The systematic approach offered by knowledge management for recognizing and creating organizational knowledge that carries high potential of application, is of paramount importance for measuring the project's intellectual contribution.

Thirdly in terms of *technology appropriateness* by examining the 'ethicality' of the decisions made on the selection of technologies for package implementation. This evaluation will utilize a checklist on the seven core values of survival ethics that proposes a set of values for

ethical practice in the engineering/technology-based projects. [8] The checklist will indicate 'practical ethics' values such as burden on community resources, relevance to context, tools adaptability and flexibility, as well as levels of community ownership of project and extension of local labor.

Fourthly, in terms of *empowering community* which will consider the project researchers as part of the 'beneficiary' community where their 'empowerment' or 'struggle for social justice' use the number of new linkages/projects a researcher forms/initiates with private sector or academia as indicator. The participatory approach, based theoretically on 'empowering' educational philosophy rural development practice (Paulo Freire and Robert Chambers), provide tools "*to incorporate the knowledge and opinion of rural people in the planning and management of development projects and programmes*[2]" but whether the project brings about an 'empowered community that can *transform* their lives' is a fundamental question. Constructing indicators for such a concept essentially a process itself (transformation), is not simple and is the least developed among the project outcome indicators. The literacy tools developed by Asmaa's that are based on REFLECT will be utilized to support the community to model own conceptual understanding and expected outcomes of becoming 'empowered' – noting here the critique of the vagueness of the use of the word and the need "*to build a new language in which to frame our vision and strategies for social transformation at the local, national, or global level.*" [7 ibid]

The following section discusses further some of these outcome indicators and their underlying theories and processes that lead to them, and how they merge the perspectives of system and user to influence policy making or project 'sustainability' (another contentious term at the intersection of science and politics to be disambiguated with sister 'empowerment').

Linking Research Strategies with Policy and Action

The project proposes the combined set of approaches as a framework for linking project knowledge and community actors, with "evidence and empowerment" as mechanisms for influencing policy making. The quantitative nature of the first two indicators dealing with providing evidence of support to Sudan's health system and monitoring the intellectual contribution of the project facilitate statistical analysis, while the other two sets of indicators are much more challenging to 'control' and require critical analysis and further questioning. The following diagram (Figure 1) is a conceptual map[3] depicting the project's framework.

The map shows the relationships between the selected research strategies, outcome indicators and how they attempt at changing the World view and influence policy. It can be read (as sentences) starting at a selected method or specific approach and following the arrows. For example, a *controlled study* which belong to the *positivist* worldview, determine *hypotheses* of *research* that examine *indicator* to test *hypothesis* which produce an *intellectual contribution* and inform *practice*. *System strengthening* indicators change this particular World view (a verification process to adopt *policy*). *Participatory approaches* view the World as socially constructed and generate *hypotheses* by interpreting *practice*. Selected tools like *REFLECT*, a *participatory approach* but also belong to an *advocacy* World view, focus on *empowerment* and influence policy through *activism* (a transformation process).

[2] Wikipedia

[3] Concept mapping is a technique for visualizing relationships among different concepts. Map was developed using IHMC CmapTools (http://cmap.ihmc.us/).

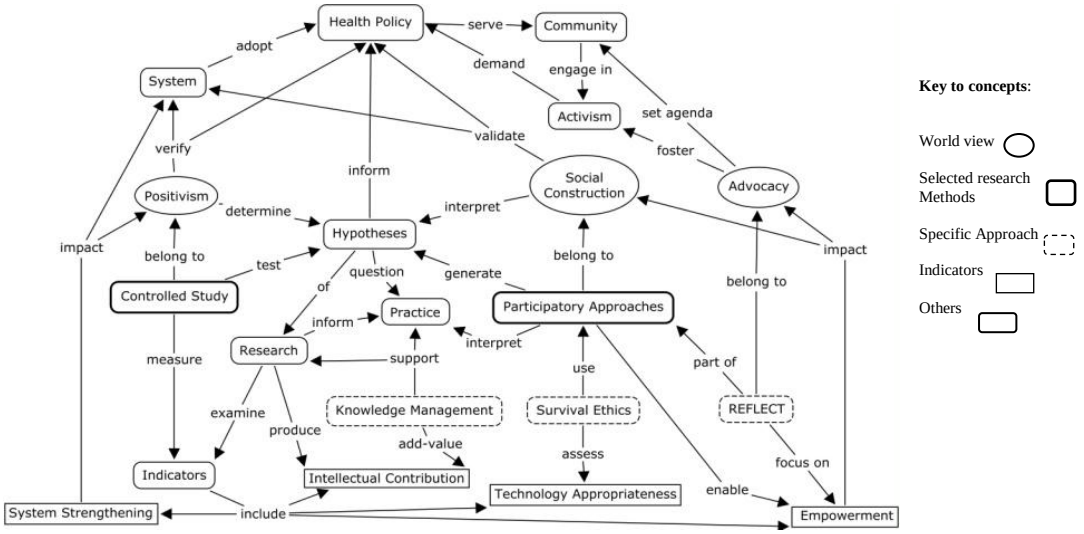

Figure 1: A Concept Map depicting "*How research strategies influence our views of the world?***"**

Lower level maps can be drawn to examine relationships between method and outcome. This exercise, especially for qualitative indicators, help pin words like empowerment to specific meanings which can be argued as useful, not for measurement as an outcome per se, but as a tool to critically examine research design and refine our assumptions and planning.

Concluding Remarks

This working paper examined strategies that are proposed for a research and development project on utilizing mobile technologies for health service provision. The analysis aimed at mapping the relationships of selected strategies to expected project outcomes in terms of their associated indicators (evidence) as well as social change (World view). This exercise is argued as an approach for discussing the ideas and argument of the research, but also for assessing the nature of the expected impacts and revisit project strategies and assumptions. The concept mapping tool forces intent in the process of naming concept's relationships to construct meaningful phrases; therefore it enables the examination of the constructed logic and expected value of the project.

By and large, the value of this project will be drawn from its research intellectual input and evidence of support for Sudan's health system; it can also come through improved innovative capacities of system and people to cope with the richness in the set of hard-to-reach communities. While the first value set can be measured, the second can only be critiqued and aspired to. For example, this project assumes that the use of appropriate technology and meaningful learning would empower: (1) Participant community with technology skills that they can utilize for different information-based initiatives such as in mLearning or mCommerce and with organizing tools to transform own lives; (2) Researchers to apply knowledge gained for other hard-to-reach communities such as in regions where there is active conflict or nomadic population (both of relevance to Sudan's political situation and demographic characteristics); and (3) to each use what they know to impact policy. While this latter value cannot be measured, the paper argues that it can be self-critiqued through a cycle of deconstruction and refinement of what we believe will transpire from our intended project actions.

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A Head-Driven Algorithm for Analysis of Low Pressure Water Distribution Networks

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Key Words: Hydraulic Models; Water Distribution; Demand Driven Approach; Head Driven Approach.

Abstract
Hydraulic models for water distribution networks have, in the past decades, become synonymous with management of water supply. For networks prone to low pressures, the concept of pressure dependency of withdrawals is widely appreciated and in this regard, head-driven analysis of water distribution networks has, in recent years, received growing attention as a viable alternative to the traditional demand-driven approach. This is due to its very attractive capabilities of determining the amount of water that can be supplied at various pressures, and thereby reflecting the actual status of a network. Unfortunately, tools for modelling pressure-dependent demand are still in a developmental phase and are not yet commercially available for use to the wider population. In this paper, a head-driven analysis model built on the relationship between nodal heads and flows is developed in MATLAB and its outputs compared against outputs from the Demand-Driven Available-Demand-Fraction (DD ADF) model. Results reveal good agreement between the outputs of the two models. Results also show that the model can accurately determine flows that can be enabled by prevailing nodal pressures in a network.

INTRODUCTION
Most cities rely on networks of pressurised water supply systems for conveyance of potable water. Thus, networks are designed to operate under a pressurised flow regime. However, in practice, there can exist periods with shortfalls in pressure and this affects the quantity of water that can be supplied. In addition, water distribution models in current use consider full time sufficiently pressurized networks, with an assumption that analysis is based on a demand driven (DDA) rationale whereby demand is independent of pressure. In this approach, it is taken for granted that pressures are available to satisfy demands defined at nodes, thus allowing nodal hydraulic heads and pipe flows to be determined by solving a set of quasi-linear equations [1]. This formulation is well developed and valid for scenarios in which pressures in a system are adequate for delivering the required nodal demands. However, the models produce unrealistic results during pressure shortfalls, when the required demands are shown to be satisfied in all circumstances, including periods of inadequate pressure. This is the basic weakness of the demand-driven approach to water distribution network modelling.

The pressure dependency of withdrawals from water distribution systems under conditions of abnormal stress is well accepted [2], [3], [4]. From a head-driven analysis (HDA) perspective, the problem that needs to be addressed is to determine available flows at prevailing pressures, which requires formulation of a relationship between pressure and discharge. In a water distribution modelling process, constitutive equations for flow in water supply networks have to simultaneously satisfy nodal flow continuity and conservation of energy applied to each loop or path. Thus, in HDA, primacy is given to pressures and a node is supplied with its demand fully only if a minimum required supply pressure is satisfied at that node. If the minimum pressure requirement cannot be met, then a fraction of the nodal demand satisfied is determined by recognition of a relationship between nodal head and nodal

outflow. Typically, the relationship utilises fixed demands above a critical pressure value, zero demand below a given minimum pressure and some relationship between pressure and demand for intermediate pressures [5- 8].

The minimum pressure threshold below which no supply is feasible is junction-specific and also depends on demand, elevation as well as the type of service connection and type of development in the area served by that junction [9]. This value is usually the minimum of outlet elevations in the locality served by the junction. In the absence of such data, it can be taken as the elevation of the junction itself. The Office of Water Services in England specifies a minimum acceptable static pressure of 7 mwc (68.5 kPa) below which customers may be entitled to compensation for less than satisfactory service [9]. In general, nodal heads of 15 mwc to 25 mwc will guarantee satisfactory service at all related top taps in a distribution system [10].

In this paper, a head-driven analysis model built on the relationship between nodal heads and flows is developed in MATLAB and its outputs compared against outputs from the Demand-Driven Available-Demand-Fraction (DD ADF) model. Results reveal good agreement between the outputs of the two models. Results also show that the model can accurately determine flows that can be enabled by prevailing nodal pressures in a network.

METHODS

The methodology comprised of the following major steps: development of HDA model (development and programming of pressure-flow relationship); construction of network model of Kampala Water Supply Network, Uganda; application of DD-ADF model; and comparison of model outputs with DD-ADF model outputs

Step 1: Development of HDA model

Typically the relationship between pressure and discharge is expressed as follows:

$$\Delta h = KQ^n, \qquad \Delta h = h - h_{\min} \tag{1}$$

where Δh represents a change in pressure at the node, with h being the head at the node and h_{min} being the minimum head, usually zero. K denotes a resistance constant of the pipe. The pressure drop is usually related to flow in the pipe by a characteristic power n. Using the Hazen-Williams method, the value of n depends on the type of liquid in the system. For water it is set at 1.852 and

$$K = \frac{K_1 L}{C^{1.852} D^{4.8704}} \tag{2}$$

where: K_1 is a constant (10.675 for SI units) and C is referred to as the Hazen-Williams coefficient. In this model we use the Hazen-Williams headloss equation with C = 140 for plastic and steel pipes.

At zero pressure, no flow is enabled at the node. For pressure above a critical value (reference head), flow is maximum, since there is a practical limit to withdrawals due to consumption capacity. For pressure values between zero and the reference point, the flow varies in direct proportionality with change in pressure. This argument is summarized in Table 1.

Table 1

Pressure h (mwc)	Discharge Q
$h \le h_{\min}$	0
$h_{\min} \le h \le h_{\max}$	$0 \le Q \le Q_{\max}$
$h > h_{\max}$	$Q = Q_{\max}$

The conditions in Table 1 were programmed in MATLAB with the following pseudocode:

Determine maximum demand at node $Q_{\max}$

Set minimum gauge pressure at a node $h_{\min} = 0$

Set reference gauge pressure at the node $h_{ref} = 10$

Get gauge pressure at the node h

Workout pressure difference at the node $\Delta h = h - h_{\min}$

Set $n = 1.852$, ***Set*** $K_1 = 10.675$, ***Set*** $C = 140$

L= ('give value of length of pipe in metres')

D=('give value of internal diameter of pipe in metres')

Determine pipe resistance constant $K = \dfrac{K_1 L}{c^{1.852} D^{4.8704}}$

If $h < h_{\min}$ ***, not possible***

else if $h = h_{\min}$, $Q = 0$

else if $h_{\min} < h \le h_{ref}$, $Q = \left(\dfrac{\Delta h}{K}\right)^{\frac{1}{n}}$ ***from*** $\Delta h = KQ^n$

else $Q = Q_{\max}$

Step 2: Development of network model of Kampala Water Supply Network.

A case study of the network for the Rubaga subsystem of the Kampala Water Supply Network was modelled in DDA and subjected to a high demand loading that identified nodes whose pressures were insufficient to fully satisfy their demands [11]. The Rubaga subsystem was modelled to comprise of 22 pipes and one 4000 m^3 reservoir. A model of the Rubaga subsystem showing nodes with their elevations (masl) and Identification Numbers (ID) as well as pipe diameters (mm) is shown in Figure 1.

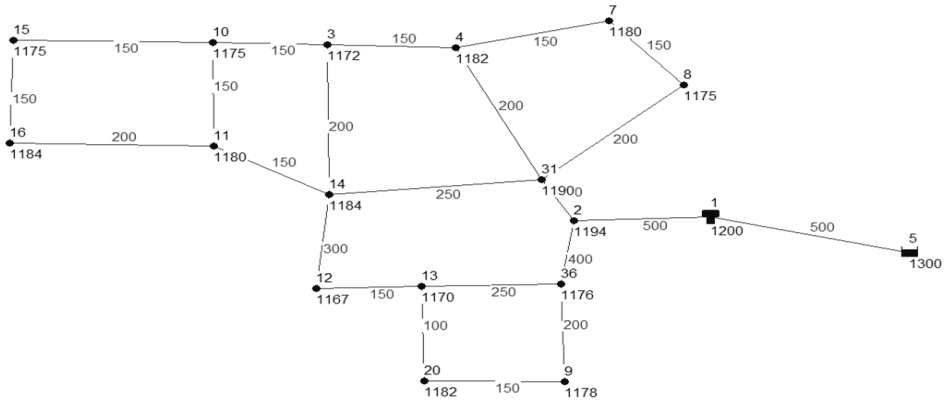

Figure 1: Model of Rubaga Subsystem showing Node Elevations, IDs and Pipe Diameter

Two broad scenarios were considered as follows:

i. Normal operating systems in which pressures are sufficient to meet the demand throughout the network. This scenario involved monitoring the response and performance of the model during ideal flow conditions i.e. periods and sections when pressures are sufficient, in order to find out system behaviour and pressures, heads and flows at various sections. This provided a control and benchmark to the subsequent scenarios.

ii. A constrained system which was created by imposing excessive demand loadings, insufficient supply and inadequate pipe sizes.

Step 3: Application of DD-ADF model

Having carried out demand driven analysis (DDA), nodes at which pressures were insufficient to fully supply their demands were identified. At this point, a semi-pressure driven technique developed by [12] and [13], called the Demand-Driven Available-Demand-Fraction (DD ADF) method was employed to identify what supply would be enabled at the prevailing pressures. This iterative method based on HDA, adjusts both demand and pressure in order to yield an optimum solution (pressure and flow values) that represents equilibrium of a water distribution network and certainly, the reality on the ground.

As already discussed, since demands are fixed under DDA while pressures vary, a nodal pressure value was considered insufficient if it was lower than the pressure threshold, a situation that would result in a lower outflow than is required. The threshold value for each node can be approximated by the expected maximum outlet level in the locality served by that node represented by the height of the tallest building that can be agreeably supplied by the service provider without extra pumping. When lower nodal pressures are obtained then only a fraction of the original demand is met.

Demand at every pressure-deficient junction was treated as an unknown value while a pressure threshold was imposed through the following modifications:

i. Elevation of the node was increased by the value of the threshold pressure head ultimately making the node pressure zero and disabling supply, necessitating the substitution of the original node demand value with zero.

ii. An outlet to the node was provided through a virtual reservoir installed at the same new elevation and connected through a pipe that was infinitesimally short in order to minimise head losses which would reduce discharge to the virtual reservoir when the model was run. It should be noted that the new node elevation does not enable any supply but the discharge into the virtual tank logically reflects the supply that can be made (i.e. the proportion of the original demand met) if the original nodal elevation were to hold.

With these modifications, demand at each pressure-deficient function was treated as an unknown while a pressure threshold was imposed. If one or more artificial reservoirs received more water than their nodes demanded, those artificial reservoirs would be removed from the network and the original elevations and demand at the corresponding nodes would be restored. This procedure was carried out in an iterative manner until acceptable demand values that corresponded to the available pressures were obtained.

Step 4: Comparison of model outputs with DD-ADF model outputs

Outputs from the DD ADF model were compared with those from the developed program.

RESULTS AND DISCUSSION

For the following set of variable theoretical inputs in Table 2, the developed program generated Figure 2 which demonstrates that the higher the pressure at the node the higher the supply enabled.

Table 2: Model Inputs

Parameter	Value
Demand at node (cumecs)	0.0375
Minimum gauge pressure at node (mwc)	0
Reference gauge pressure at node (mwc)	8
Pipe diameter (m)	0.3
Pipe length (m)	110

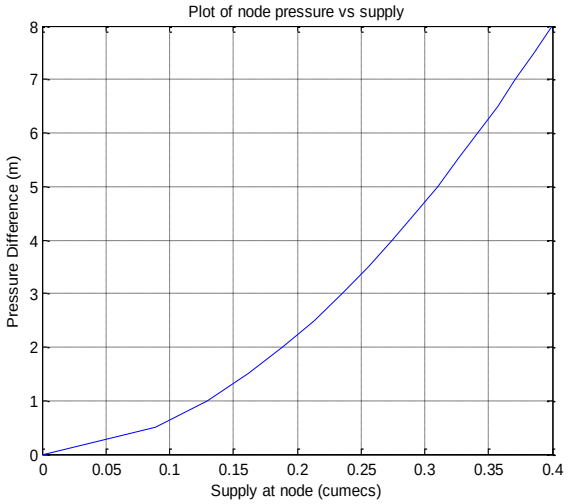

Figure 2: Plot of node pressure vs supply

Table 3 shows the loading that the Rubaga network was subjected to. The Table shows the initial node demand and corresponding pressure values at 16 00 hours (peak period). It can be observed that subsequent loading was heavier than initial loading, to the point of producing negative pressures at node 16 (refer to Figure 1 for node ID). Figure 3 shows initial pressures at 16 00 hours (peak demand hour) and Figure 4 shows pressures after higher demand loadings are made. It can be observed, as is expected of demand-driven analysis, that lower pressures arise from higher demand loadings. It is particularly observed that negative pressures developed at junction 16 (node ID in Figure 1) highlighted in Figure 4, which implies an inability to meet the demand at that node.

At junction 16 the pressure required to satisfy a demand of 37.5 l/s is negative which is logically interpreted to mean that at this demand value no supply is possible at this node. This is a computational result however in reality some water will come out of this node at a discharge less than 37.5 l/s, in proportion to the prevailing pressure at the node and this further underlies the chief weakness of demand-driven analysis for water distribution networks. Using head-driven analysis however, it can be worked out that the demand that can be met at node 16 is 9.73 l/s at midnight and 0.4 l/s at the peak hour.

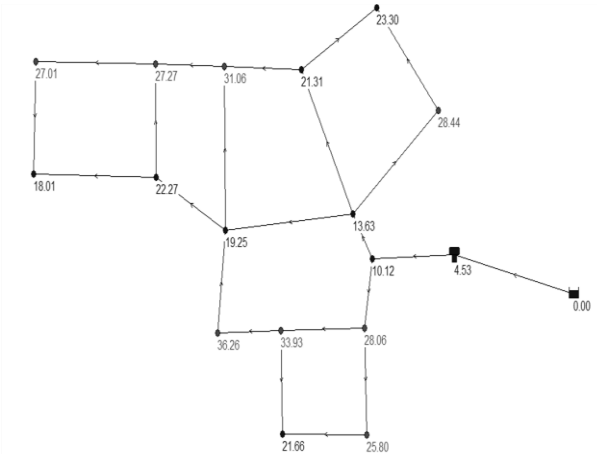

Figure 3: Initial pressures (mwc) at 16 00 hours

Figure 5 illustrates the variation of available outflow with pressure at Node 16 in the model at 16 00 hours after the application of the DD ADF technique. It can be seen that nodal supply increases with increasing pressure at the node and reduces with declining nodal pressures. When pressure is the determining factor of system performance, then the higher the pressure in the system the more the water supplied. It can also be seen that the maximum demand of 37.5 l/s (Table 2) is met at 8 m thus, realistically the reference pressure should be 8 m and this value was used to test the developed HDA model.

Comparison of outputs from the developed model shows good agreement with results of the DD ADF approach. For example, the maximum demand 37.5 l/s at node 16 as shown in Table 2 is satisfied at a pressure 7.2 mwc in the developed model, while using DD ADF, the demand is met at about 8 m. Similarly, 27 l/s are supplied at 4 m in the developed model, while it is supplied at about 4.5 m under DD ADF. These differences represent an average deviation of 10 %, which is relatively small. It should also be noted that while the variation of pressure vs supply from the developed model is non-linear, the nature of the variation from DD-ADF is linear. This is because the developed model utilizes head loss equations which are non-linear while DD ADF does not.

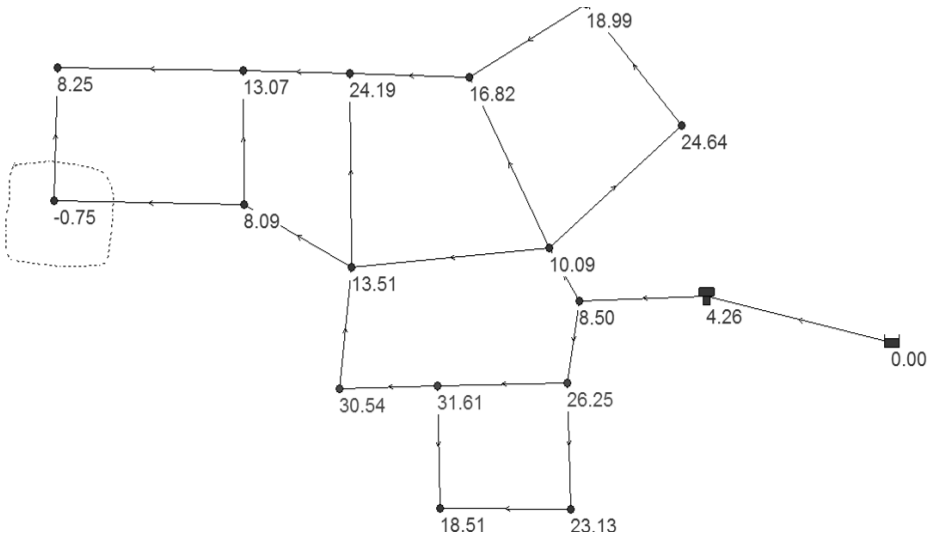

Figure 4: Pressures (mwc) after higher demand loadings are made

The differences can also be explained by the difficulty in establishing a pressure-flow relationship at every node, which would require extensive field data collection and calibration. Moreover, models are schematized and some features are lost; secondary networks have variable head losses and outlet elevations which would require all the more data to collect [12], [13], [14]. Worse still, resulting equations have no computational methods to solve them. These shortcomings present real difficulties in application of head-driven analysis. As [7] states, this explains why there are no commercial hydraulic solvers using HDA. In order to circumvent the aforementioned challenges, ailing networks are identified using DDA as was done in this study before invoking HDA application. Nevertheless, head-driven analysis has demonstrated superior advantages over demand-driven models inasfaras establishment of supply at pressure-deficient nodes is concerned. This becomes an important tool for management of pressure-deficient networks.

Table 3: Initial and subsequent pressure and demand values at 16 00 hours

	Initial Conditions		Subsequent Conditions	
Node ID	**Demand (l/s)**	**Pressure (mwc)**	**Demand (l/s)**	**Pressure (mwc)**
2	8.5	10.12	8.5	8.5
14	8.75	19.25	17.5	13.51
20	8.25	21.66	17.5	18.51
31	8.5	13.63	17.5	10.09
36	8.25	28.06	8.25	26.25
12	8.75	36.26	17.5	30.54
13	8.75	33.93	17.5	31.61
3	8.75	31.06	17.5	24.19
4	8.25	21.31	17.5	16.82
7	8	23.3	8	18.99
8	8	28.44	8	24.64
9	8.25	25.8	17.5	23.13
10	8.75	27.27	17.5	13.07
11	8.75	22.27	17.5	8.09
15	8.25	27.01	37.5	8.25
16	8.75	18.01	37.5	-0.75
Tank 5	-584.97	0	-585.82	0
Tank 1	449.47	4.53	303.07	4.26

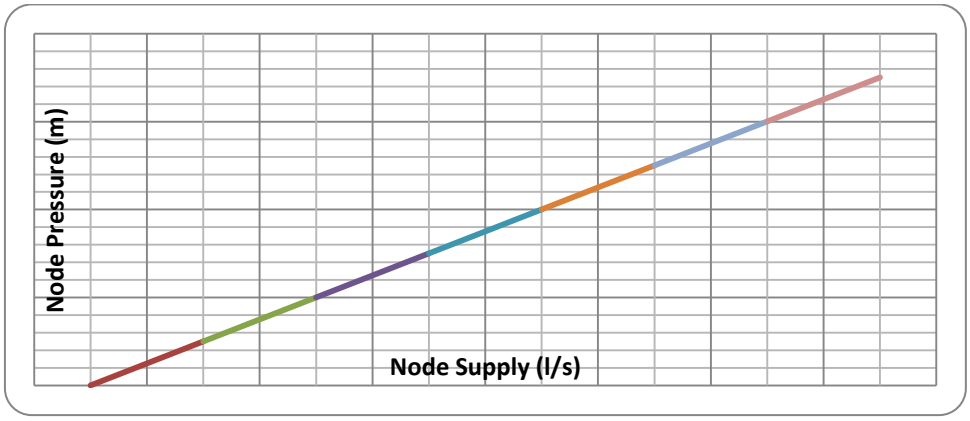

Figure 5: Variation of node pressure (mwc) with supply (l/s)

CONCLUSION AND RECOMMENDATION

A model that accurately predicts supply that is available at a node, depending on the pressure at the node, has been developed from sound technical and practical considerations. Further studies should investigate how the developed model can be applied simultaneously to all the nodes in the network, especially pressure-deficient nodes in order to enable a systems analysis effect that will inform its overall impact throughout the network.

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SURFACE AND SUBSURFACE ASSESSMENT OF URBAN HAND DUG WELLS IN AKURE, NIGERIA

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Abstract
Hand dug wells which are self-supply systems are still the most common technique of ground water exploitation in developing countries. The aim of this research work is the statistical assessment of the state of the art and technology in hand dug water supply well design, construction and maintenance in a developing country like Nigeria. The overall statistics of the study shows that 74% of the wells in the area of case study are provided with lining (masonry or concrete), 68% have an apron and 78% of the wells are located 15 m and farther away from soak-away pit. Depth to water table ranged from 2.5 m to 20.0 m, with an average depth to water table of 7.0 m for the 200 sample wells. The local lithologic units identified in the study area are the charnokites, pegmatites, migmatite – gneiss, biotite gneiss and granites. The water level for most of the wells occur within the partially weathered rock zone and fractured/weathered rock as expected for the basement complex rock geology of the study area. This is usually preceded by lateritic/sandy clay soil strata which portends some level of protection for the underground water formation.

Keywords: Hand-dug well features, growing urban area, statistical appraisal, lithologic units

1. INTRODUCTION

The implementation of good hand-dug well-design criteria can have a global effect on water supply management and public health [1]. In developing countries more than 6 people in 10 lack ready access to improved water, while nearly 4 in 10 lack sanitary toilets, contributing to both disease and malnourishment. The World Health Organization's Global Burden of Disease database provides some striking findings on the repercussions of environmental factors, including that unclean water and inadequate sanitation and hygiene are among the 10 leading causes of disease worldwide. Each year environment-related diseases, including acute respiratory infections and diarrhoea, kill at least 3 million children under age 5—more than the entire under-five populations of Austria, Belgium, the Netherlands, Portugal and Switzerland combined[2]. The availability of cheap, easily-applied water supply technologies can make a significant contribution to the development of solutions in a multi-disciplinary approach to the improvement of living standards in developing countries. Hand-dug wells provide a cheap, low-technology solution to the challenges of rural water supply [3]. There is now an urgent need to scientifically harness both human and material resources in order to meet the target 10 (Halve, by 2015, the proportion of people without sustainable access to safe drinking water and basic sanitation) of the pertinent Millennium Development Goal (Goal 7 – Ensure Environmental Sustainability). Akure, a growing urban area within latitudes 7° 10'N and 7° 20'N and between longitudes 5° 07'E and 5° 17'E in Ondo State, Southwestern Nigeria was chosen for this research work because it is one of the few towns in Africa and the only one in Nigeria selected as a millennium city by the United Nations Millennium Development Initiative [4]. Hand dug well features can be divided into three parts: intake, shaft and well head (Figure 1). The intake is the bottom section of the well that taps into the aquifer, support the exposed section of the aquifer and permit water to flow in while

preventing solids from entering into the well. In stable geological formation (e.g. in sandstone or fissured rock) it is possible to eliminate this component, but in conditions where the aquifer is made of sand or gravel, it is necessary for the functioning of the well [5]. The shaft is the middle section of the well. The lining of the shaft serves to retain the well wall in place, prevent inflow of potentially contaminated water near the surface, and provide a foundation for the well head. Even if a well is sunk into self – supporting rock, the top few meters should be lined and made water tight to avoid the risk of collapse at the top of the well. The well head is the top section of the well which is a seal to the well and prevents foreign objects from entering the well. Several studies exist on design of hand-dug wells in many parts of the world [6, 7 and 8]. However, there is little work on the standard specification for the design of hand-dug wells in developing countries. Poor understanding of soil subsurface profile, aquifer characteristics and lithologic units also limits the efficiency of groundwater resource exploitation in Nigeria.

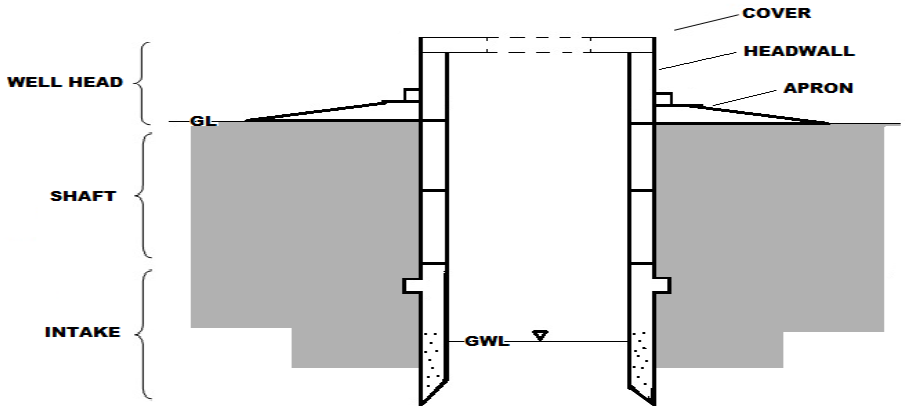

Figure 1: Hand dug water supply well features

2. MATERIALS AND METHODS

This section is subdivided into the description of the study area together with Data collection and analysis.

2.1. Description of Study Area

2.1.1. Topography and Geographical location, and Population

Akure the study area covers about 78.2 square kilometers and lies between latitude 7° 10'N and 7° 20'N and longitude 5°07'E and 5°17'E. The city is located on gently undulating terrain surrounded by isolated hills and inselbergs. The eastern part of Akure is hilly whereas the central part where the settlement is concentrated is undulating lowland. The northwestern part of the area is fairly hilly too. Rugged topography is dominant in the western and northern parts of Akure with an average elevation of 150m above sea level. To the south, the topography is gentle. The study area is drained by River Owena and River Ala and their tributaries. The increased relative political influence of Akure as a state capital since 1976 has greatly promoted its rapid growth and increased socio-economic activities resulting in its spatial expansion from an area of about 16 squares kilometers in 1980 to about 30 square kilometers in 2000. The city has a population of approximately 387,087 [9].

2.1.2. Geology of the study area

Geologically the area lies on the Pre-Cambrian basement complex of south-western Nigeria which is made up of migmatite-gneiss, gneisses and schists, granite gneisses, granites, charnockitic rocks, quartzites and unmetamorphosed dolerite dykes. A large part of the Akure

area is covered by migmatites which grade into banded gneisses, overlain by porphyritic biotite granites, charnockites and some quartzite bodies (Figure 2). The migmatite-gneiss covers more than half of the area and occurring in north-eastern and south eastern parts of the area. The biotite-granite occurs in several locations, mostly in the central part of the study area. The key to successful hydro-geological investigation is to get the geology right, since the geology controls the occurrence, distribution, movement and quality of groundwater [10, 11 and 12].

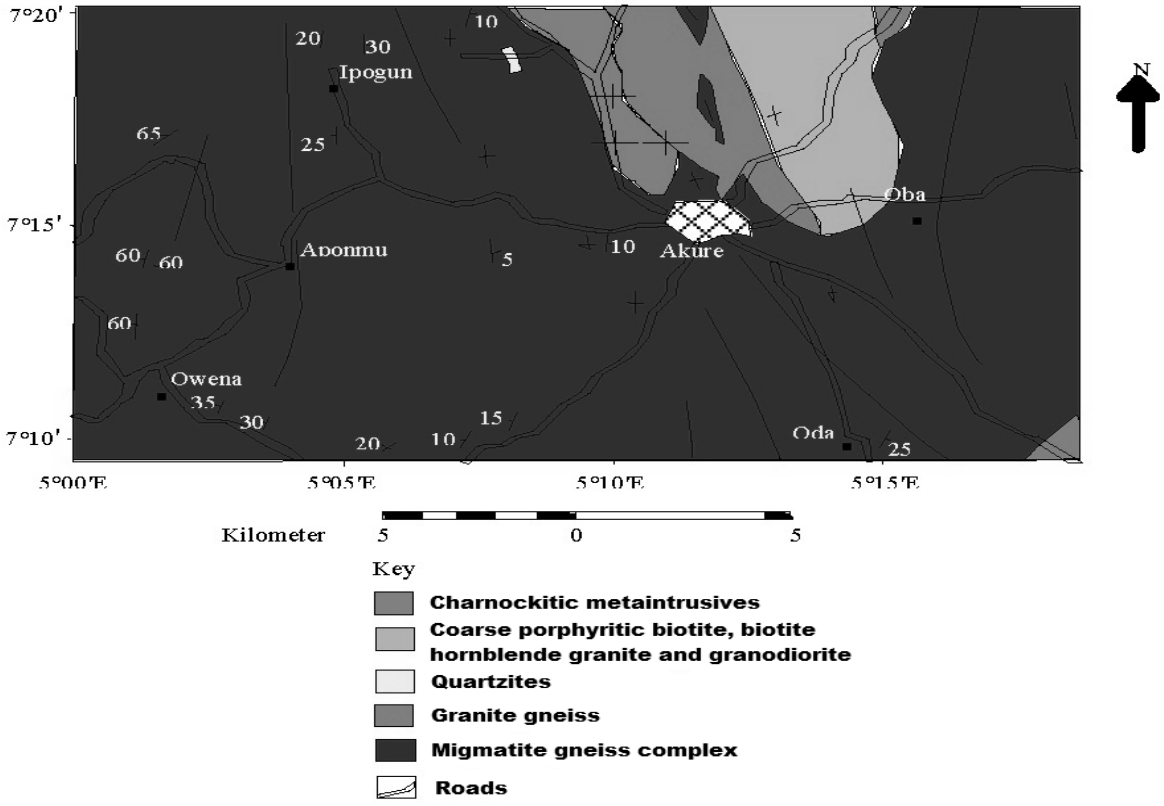

Figure 2**:** Geological map of Akure (Source: [12])

2.2. Data Collection and Analysis

Data collected for this research was carried out through desk top study, technical field survey, interview of householders and the use of questionnaires. Analysis of data was carried out using descriptive statistical method and plotting of the well log data.

2.2.1. Hand Dug Well Feature Survey

The field survey entails the grouping of different locations within the town with hand-dug water supply wells with the aid of street guide map of the study area obtained from the Ministry of Works and Transport, Akure, Ondo State. The study was conducted by collecting a wide range of data relating to the hand-dug well design, construction and soil subsurface features in Akure. The assessment included inventory and appraisal of two hundred (200) wells from different locations in the town and these locations were grouped into thirteen (13) zones namely Hospital road, Ijoka road, Sijuade road, Oda road, Arakale road, Oke-Ijebu, Ijapo Estate, Ondo bye pass, Ondo Road, Ayedun Quarters, Isolo, Oke – Aro and Araromi. The assessed wells are indicated on the street guide map of Akure in Figure 3. The following

data were measured: Well diameter, Well depth, Depth to water table and Well distance from soak-away pit. Measurements were carried out using measuring tapes. Hand-dug wells were also assessed to determine the following features: Well shape, Provision of headwall and cover, Provision of apron, Method of lifting, well yield during dry season, frequency of disinfection and type of well lining.

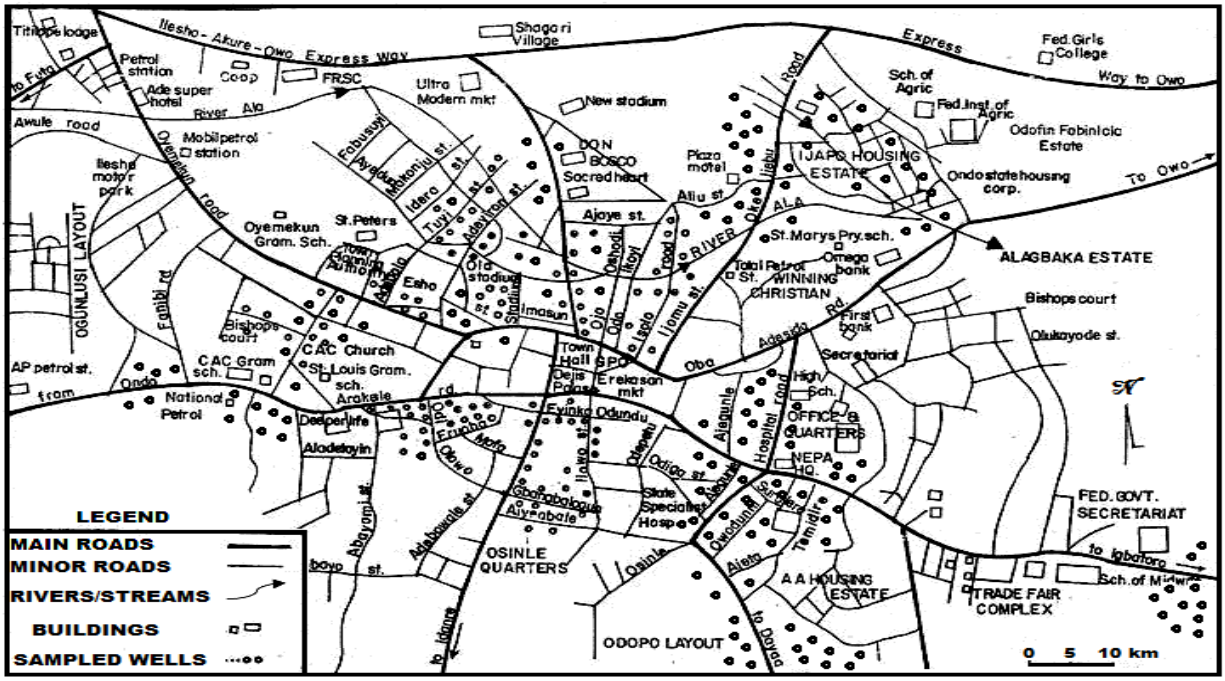

Figure 3: Street guide map of Akure metropolis showing sampled Hand dug well locations (Source: Ministry of Works and Transport, Akure, Ondo State)

2.2.2 Soil Subsurface Information Acquisition

The soil subsurface stratification for the thirteen different locations was achieved by compilation and plotting of well-log data obtained from the departments of Applied Geology and Applied Geophysics of the Federal University of Technology, Akure and the Ondo State UNICEF assisted Water and Sanitation office (WATSAN). This was crosschecked with visual soil inspection and identification on the field.

3. RESULTS AND DISCUSSION

The data collected were grouped according to the thirteen zones identified in section 2.2.1 (Table 1). The number of wells for each parameter assessed is indicated in Table 1.

The bar charts in Figure 4a and Figure 4b shows the visual representation of the various parameters in Table 1 based on percentages.

Table 1: Hand dug well features assessment for the thirteen zones

PARAMETERS	Ondo bye-pass	Ondo road	Ayedun quarters	Isolo	Oke-Aro	Araromi	Hospital road	Ijoka Road	Sijuade Road	Oda Road	Arakale	Oke- Ijebu	Ijapo Estate	TOTAL	
Apron	11	15	22	6	11	7	15	10	4	9	13	8	5	136	
No apron	0	4	8	4	9	3	8	6	4	8	3	5	2	64	200
Lining	8	18	23	8	17	10	14	13	1	9	14	8	7	150	
No lining	3	1	7	2	3	0	9	3	7	8	2	5	0	50	200
Disinfection	2	5	10	0	7	1	15	9	2	11	7	7	5	81	
No disinfection	9	14	20	10	13	9	8	7	6	6	9	6	2	119	200
> 15m from soak away	7	17	21	6	16	7	16	14	7	12	11	12	7	153	
< than 15m from soak away	4	2	9	4	4	3	7	2	1	5	5	1	0	47	200
Seasonal	1	2	8	4	2	1	10	6	4	3	7	4	4	56	
year round	10	17	22	6	18	9	13	10	4	14	9	9	3	144	200
Lifting method (pump)	3	4	0	1	1	1	1	1	1	0	0	0	5	18	
Lifting method (bailer)	13	22	17	16	11	11	22	15	7	17	16	13	2	182	200

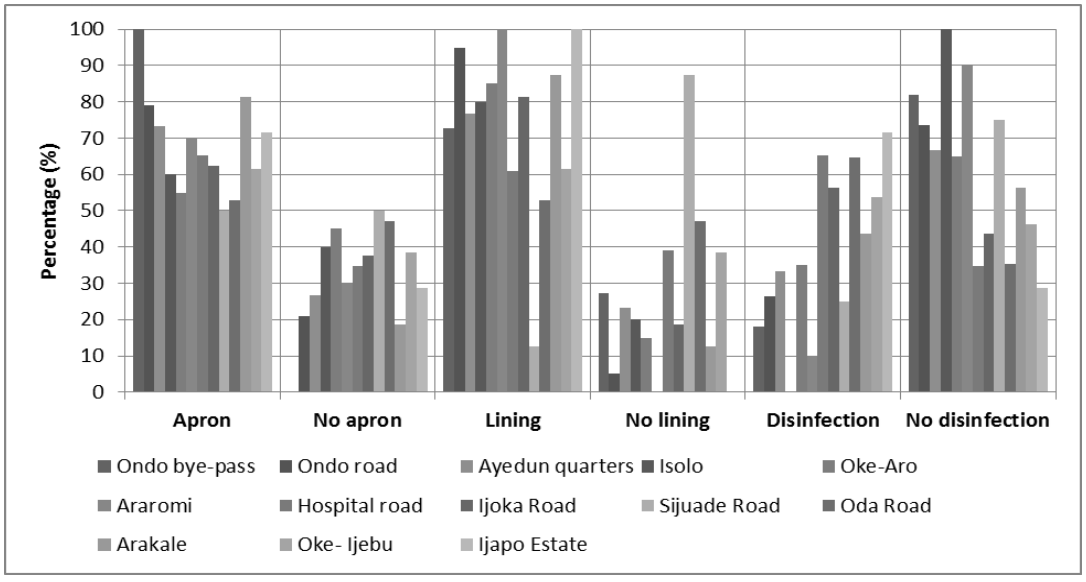

Figure 4a: Bar chart for the percentages of wells with provision of apron, lining and well disinfection

For the two hundred wells sampled an average of 68% of the hand dug wells were provided with aprons, and the range of those that provided aprons was between 50% and 100% in the thirteen zones. An average of 74% provided linings (masonry or concrete), and the range of those that provided lining was between 13% and 100% in the thirteen zones. An average of 39% disinfected their well regularly with chlorine compounds, and the range of those that disinfected their wells was between 29% and 100%. An average of 78% located their wells beyond 15 meters from soak away pit. Hand-dug wells that yield averagely/fully during the dry season were grouped as all- year round wells while those that yield none (empty)/low amount of water during dry season were grouped as seasonal wells. An average of 30% were seasonal wells, and the range of the low yield wells was between 9% and 57% for the various zones. An average of 13% use electrical pumps to lift water from the wells, and the range of those that used electrical pump lifting method was between 4% and 18%. The soil stratification for the thirteen zones was summarized into six well log groups described in Table 2 and plotted in Figure 5. The position of the water table is also shown in Figure 5. The overburden comprises mainly of topsoil, lateritic clayey sand, sandy clay and weathered rock. The subsoil examination for the well reveals that areas with thick overburden cover have higher well yields with full to average water volume during the dry season. A large part of the Akure area is covered by migmatite rocks. These have non-uniformity of weathering profiles of individual rock units which may have played a role in the variations of yields of the wells. The water level for most of the wells occur within the partially weathered rock and fractured/weathered rock zone as expected for the basement complex rock geology of the study area and the yield of water in the aquifer depends on the thickness of these zones. This is usually preceded by lateritic/ sandy clay soil strata which portends some level of protection for the underground water formation.

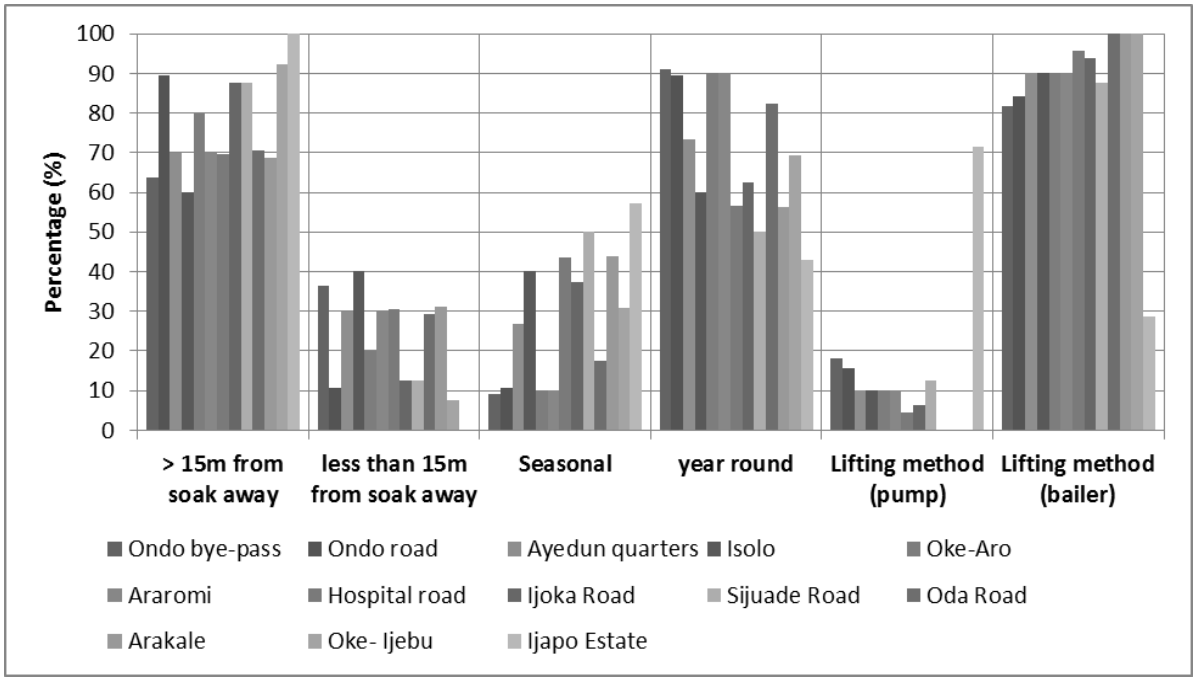

Figure 4b: Bar chart for the percentages of wells located beyond 15 meters from soak way pit, with high well yield and the use of electrical pump to lift water

Table 2: Soil Stratification groupings for the thirteen zones

Well 1- 30	Well 31 - 94	Well 95 - 160	Well 161 -176	Well 177 - 184	Well 185 - 200
Ondo Bye Pass, Ondo Rd.,	Hospital Road, Ijoka Rd., Sijuwade Rd., Oda Rd.,	Arakale Rd., Araromi St., Ayedun Qtrs.	Oke Ijebu Rd.,	Ijapo Rd Oke Aro	Isolo Rd.,

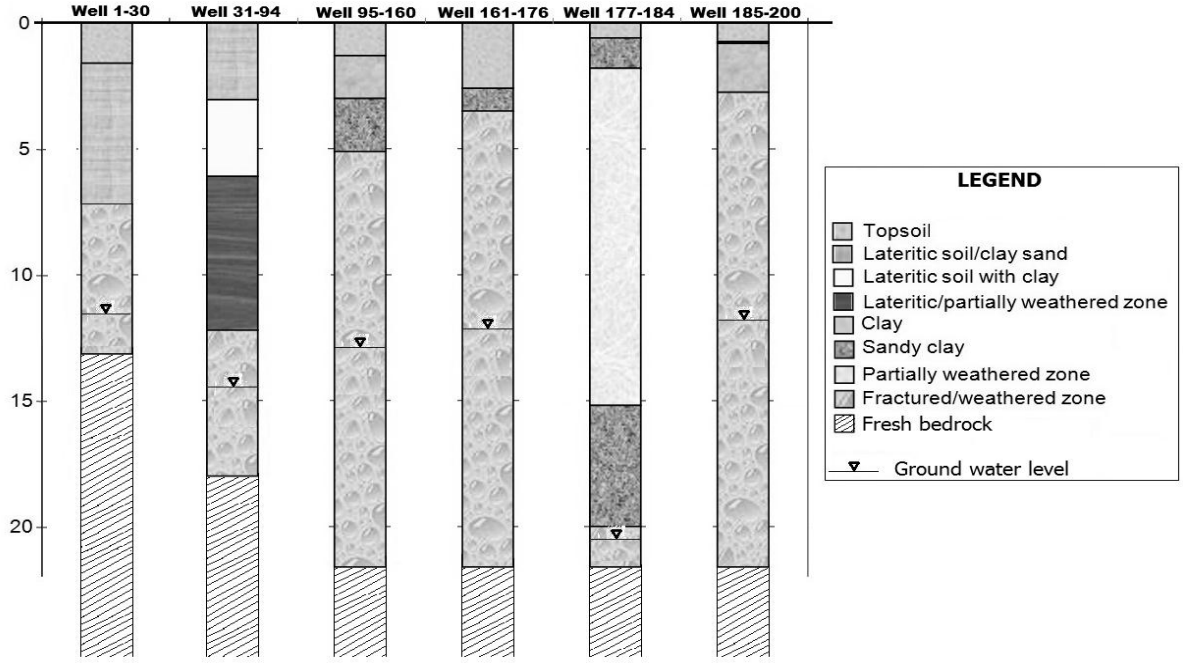

Figure 5: Summary of well logs for the hand dug wells in the various zones

4. CONCLUSIONS

Only an average of 39% of hand-dug well owners disinfects their wells regularly using chlorine compounds. An average of 30% were seasonal wells, and the range of the low yield wells was between 9% and 57% for the various zones. A low 13% use electrical pumps to lift water from the wells, and the range of those that used electrical pump lifting method was between 4% and 18%. The subsoil examination for the well reveals that areas with thick overburden cover have higher well yields with full to average water volume during the dry season. A large part of the Akure area is covered by migmatite rocks. These have non-uniformity of weathering profiles of individual rock units which may have played a role in the variations of yields of the wells. Given the wide range of well owners that provided standard protective features such as adequate apron and proper lining for their wells in the different zones and the low percentage of those that regularly disinfect their wells and use hygienic method of water abstraction from the wells, the state and local government authorities should provide a regulatory framework for the construction and maintenance of hand dug shallow wells. The headwall of hand-dug wells should not be less than one meter in height while the diameter of apron should be a minimum of two meters. In construction of the

apron, 8mm reinforcement bars or wire mesh should be used and a base footing of 750mm depth should be provided. The apron should have a gentle slope in order to drain away water. Also a permanent cover should be provided so as to prevent dirt from entry the well. The windlass method of lifting water should be adopted by people who cannot afford water pumping machine. This method is more hygienic compared to the bailer method because it prevents the bucket from being contaminated and also encourages the use of one bucket into the well. The hand-dug wells should be disinfected regularly, at least every 3 months or when there is noticeable change in the colour or taste of water using the brands of sodium hypochlorite sold most parts of Nigeria.

5. ACKNOWLEDGEMENT

The authors would like to acknowledge project students Daramola, B. G. and Akinseye, A for their involvement in data collection.

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Low Cost Remote Controlled Drip Irrigation Management System for Small Scale Farmers

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Keywords: drip irrigation management, sms

Abstract
Technological progress in the field of information handling, data storage, retrieval systems, networking, and importantly communication are the prime drivers of social and economic change. The invention of the cell phone has had dramatic impact on the way we live our lives Cell phone technology has led to leapfrogging, allowing villagers and farmers access to tools like the Internet without them ever having had access to ordinary landlines, or personal computers. Currently, just about every tradesman, shopkeeper, and farmer in the village has a cell phone or at least access to one. Despite having two of the longest rivers in the world, the problems of water shortage and conservation throughout the African continent have been well documented. The Nile River stretches a massive 64,000km and the Congo River which is the world's fifth longest river measures 4,000km, yet despite these facts the continent has twenty one of the world's most arid countries, in terms of water per person. The impact of water availability on agricultural produce of a nation highly affects the country's ability to feed its citizens. Drip irrigation is a highly encouraged form of irrigation especially in semi-arid sub Saharan Africa not only for its efficient plant water delivery, but also because it facilitates water conservation and minimal labour intensity. It is against this background that we present a solution for the remote management of small to medium scale drip irrigation systems. This will be achieved through the use of cell phone technology. It will involve the development of a system that has the ability to communicate with a cell phone using the short message service. The application will be able to switch the watering system on/off. It will also be able to gather statistics on the duration of watering and be able to turn off the watering when the right quantity of water has been delivered per individual plant.

1.0 Introduction

Agriculture is an important sector to most sub-Saharan African countries most of which have agro-based economies [1]. This sector faces major challenges in enhancing production in situations of dwindling natural resources, lack of financial support and under-utilization of some of the land. The growing demand for agricultural products, however, also offers opportunities for producers to sustain and improve their livelihoods. Zimbabwe's rainfall is seasonal from early November to late February and has become erratic with respect to the amount of water resulting from rainfall. Communal farmers rely on rainfall as the source of water for their agricultural activities, while small scale, medium scale and large scale farmers have to augment their water supply in order to carry out full scale farming throughout the year. This is usually through surface water in the form of dams, rivers or underground water. There is a cost associated with the movement of water from the source to the plant. This

movement has to be managed and controlled for effective production. There are generally two types of irrigation surface irrigation and local irrigation. In surface irrigation water is dispersed uniformly over a field such that each plant receives adequate water supply in order to produce to expectation e.g. sprinkler or flood irrigation. Local irrigation is where the plant has the water delivered straight to it under low pressure in a predetermined fashion. In Zimbabwe the predominant type of irrigation taking place is surface irrigation. The choice of irrigation type employed depends on several factors [2] namely natural conditions, type of crop, type of technology, previous experience with irrigation, required labour inputs and costs and benefits. Due to the lack of adequate water resources the most effective type of irrigation for arid regions like Zimbabwe is local irrigation i.e. dripping irrigation [3]. This type of irrigation is perceived to save water and reduce labour costs [1]. The problem of water management and conservation is not adequately addressed in the agricultural sector. Information and Communication Technologies (ICT) can play an important role in addressing these challenges and uplifting the livelihoods of the rural poor and newly resettled farmers. Increasing the efficiency, productivity and sustainability of small-scale farms is an area where ICT can make a significant contribution. The equipment involved in setting an irrigation scheme used to be expensive, but due to recent advancement in technology these costs have come down. Farming involves risks and uncertainties, with farmers facing many threats from poor soils, drought, erosion and pests. According to Ernst & Young since 2002, Africa has seen its number of cell phone subscribers climb by a compound annual growth rate (CAGR) of 49.3%. By 2013, market penetration in Africa can be expected to climb to more than 60%. Mobile phone penetration in Zimbabwe lies at 80% [4]. Farming in Zimbabwe is suffering from high prices of input costs, the government subsidies no longer exist and this has a major effect on production, particularly on the small-scale farmer. This paper proposes a Low Cost Remote Controlled Drip Irrigation Management System where a small scale farmer is able to remotely manage his/her drip irrigation system. It is important that any new assumed input in this case the ICT component be of low cost in order to maintain the viability of the farmer and avoid a negative perception towards the use of ICT as being costly. It is also important for African Governments to embrace the use of ICT in all sectors of the Government and economy by outlining specific objectives on how to directly impact the uptake of ICTes.

2.0 Related Work

The use of the short message service to remotely manage devices or applications is certainly not a new concept. In this area of drip irrigation a number of proprietary applications have been undertaken in other parts of the world that are also arid, Israel and India being case in points. The following were systems of interests to our research;

i) GSM Based Device ON-OFF Control Especially Designed For Agriculture

This system [7] is used to switch multiple devices located at a typical commercial farm. The system components are a GSM Controller, Microcontroller, and Motor Starter, Relays, Memory and a small liquid crystal display. In order to control devices an sms is sent and the system prompts the user for a password for authentication.

ii) Microcontroller based Drip Irrigation System

This application was presented (Ashok, 2010) as a proposal and is designed for large scale farming. The system as designed requires a dedicated individual to continually maintain the system due also to its size and complexity.

These solutions are viewed as not only being too expensive but also complex with respect to maintenance and results interpretation. Accessibility is also another challenge to the low scale African farmer. Another hindrance to the uptake of these types of solutions to the low scale African farmer is the acquisition costs.

3.0 Research Methodology

Oates [7] advocates a Design and Creation research methodology for Information Systems and Computing. This was the methodology adopted for this research and it involved five iterative steps defined as follows

1 Awareness – problem recognition and definition.
2 Potential Solutions – possible options of solving this problem
3 Development – implementation of a possible solution
4 Evaluation – evaluation of the implementation
5 Conclusion – conclusion on the suitability of the solution

The design and development of the application was carried out as outlined in the next section.

4.0 Development

The following assumptions were made.

- The user is competent in the use of their cell phone messaging system
- The service provider's standard rates shall apply for message charges
- A constant power supply is available for all points that need power.

System Functionality

.**Figure I** illustrates the flow of data from the sender to the receiving application.

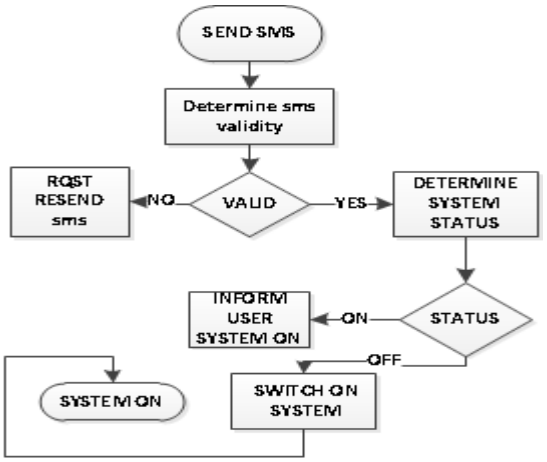

Figure I SMS Flow

Once deployed the system had the ability to facilitate the switching on or off of the drip watering system via a short message service (sms). The resident pc application monitors the duration of the watering which is calibrated according to plant requirements. The dripper has the ability to deliver a certain amount of water per hour. Depending on the settings configured on the application with respect to the amount of water to be delivered the system can be set to either automatically switch off after certain duration of time or inform the farmer that the desired amount of water has been delivered to each plant

Messaging

The farmer has the capability of sending the **ON/OFF** signal in the form of an sms message to the designated modem mobile phone number. There are types of messages that can be sent by the farmer a simple **<ON>** or **<OFF>** message or a duration based message <**ON> <2>** where the second format of the message has the duration in hours attached to the **ON** message. In this particular case the system will be switched on for 2 hours after which the application on the pc sends an **OFF** trigger to the interface box and watering is switched off.

Figure II illustrates the switching **"ON"** format of the sms and **Figure III** illustrates the switching **"OFF"** format. The system can interpret either uppercase or lowercase. This functionality is the standard sms functionality which is part of nearly all standard handsets.

Figure II. Switching ON **Figure III. Switch OFF**

PC Irrigation Management Application

Figure IV is an illustration of the Remote Irrigation Management application and the status of the different areas under irrigation if the field is partitioned. The irrigation application portal is serially connected to a general packet radio system (gprs) modem. The modem facilitates the receiving and sending of sms messages.

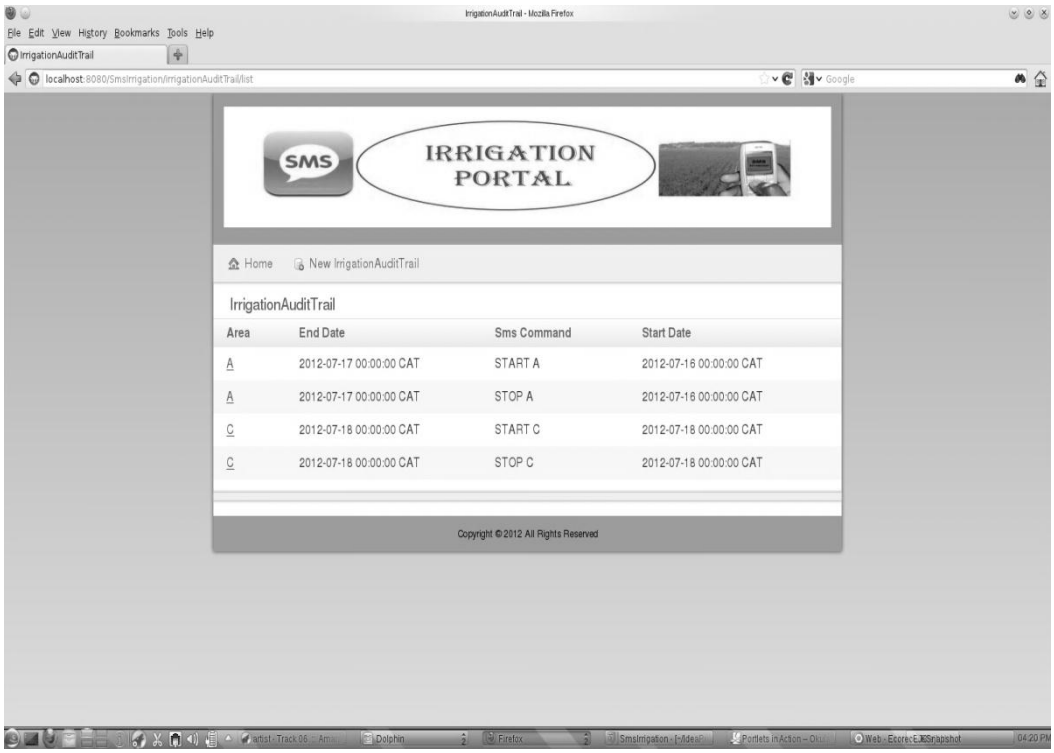

Figure IV. Irrigation Portal

The Irrigation management portal is web based for alternative accessibility through the internet should sms interface malfunction. MySql database was opted for as the data storage media. The com application is located in between the programmable interface controller and the farmer.

Programmable Interface Control Box (PICB)

The PICB contains the embedded system which consists mainly of the programmable interface controller 16F628 and the MAX232 for the pc serial connection. The PICB has a gate valve controller output. The PICB has 3 main functions; 1) receive **ON/OFF** instruction from the pc 2) sending an output to the gate valve relay and 3) receiving a signal from the sensors. **Figure V** is an outline of the connectivity between the pic16F628 and the MAX232.

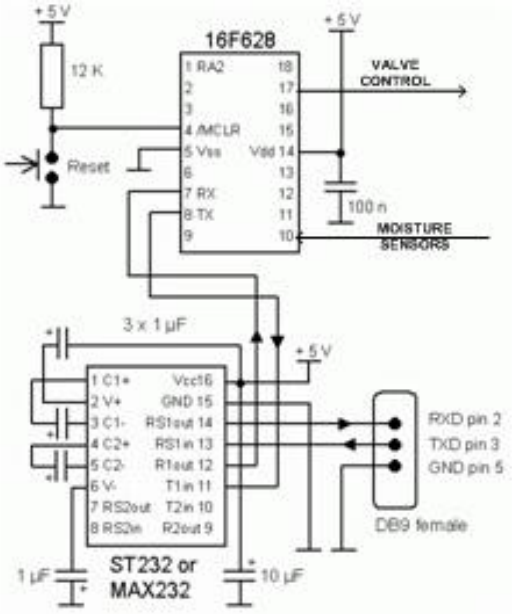

Figure V. PICB Component Diagram

5.0 Deployment Model Architecture

A prototype of the system was deployed on a test plot area measuring 15 meters by 15 meters, Ten 10 meter netfin drip lines with a hole separation of 0.2 meters were installed. Each drip hole had a drip rate of 1 hr/litre through gravitational force. The main pipe was connected to a reservoir tank through a digital gate valve which was to be controlled by the PICB through a relay. The water volume capacity of the tank was 2500 litres. The experiment was conducted over a period of 14 days where the **"ON"** and "**OFF"** signals were sent alternately every hour from 08:00 hrs to 16:00hrs for the duration of the 14 days. The second format of the message was also sent at alternate intervals with duration of 1 hour set. **Figure VI** is a conceptual overview of the desired system once deployed.

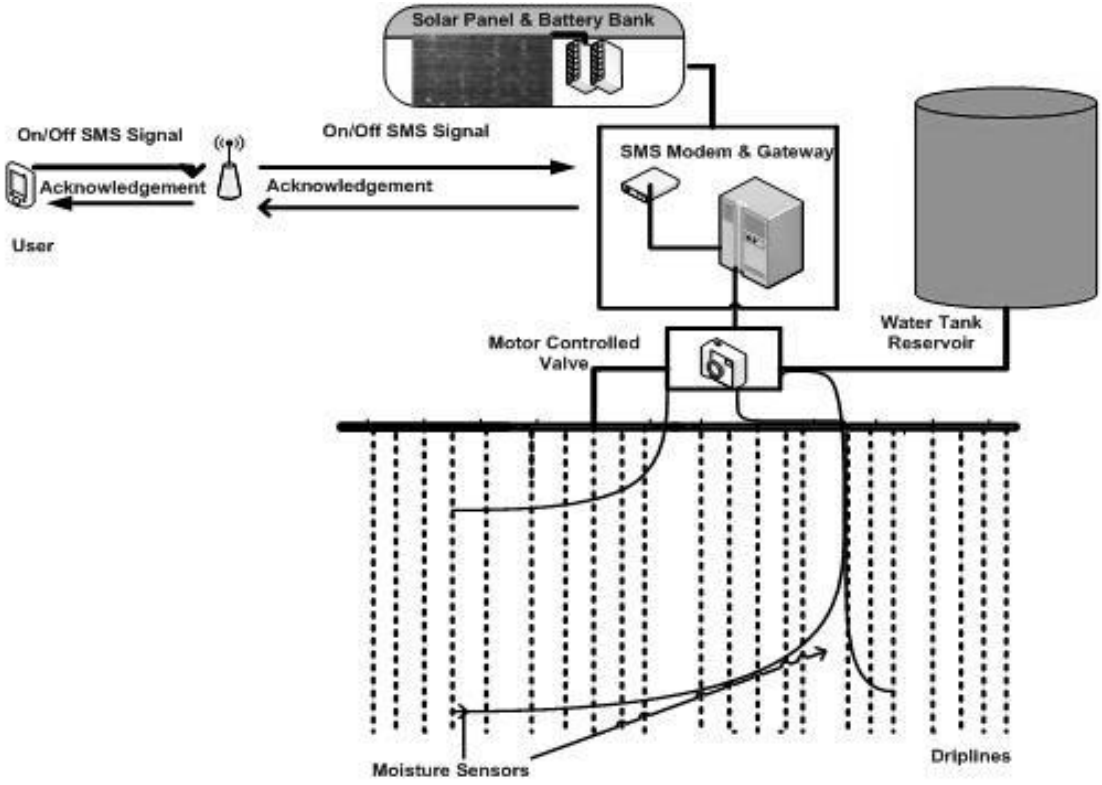

Figure VI. Conceptual System Architecture Overview

Prototype Equipment Cost

Equipment	**Specifications**	**Cost (USD)**
Personal Computer	Celeron G460, 1.8Ghz, 2G Ram, 750Gb	300.00
PCIB	PIC16F628,Max232	100.00
Valve Controller Relay	Panel Mount Relays, Hockey Puck Style (AD-SSR6 Series)	16.25
GPRS Modem	sim340RS232	89.90
Remote Controlled Application	Web based	50.00
Cell phone	sms capable	owned
Power Backup System	Solar Panel/Inverter System	optional
Total		**556.15**

Table 1 – Prototype System Cost Listing

Table 1 contains actual costing as relating to the values of the materials which would be used in system development.

6.0 Evaluation

System performance data was collected and outlined as follows

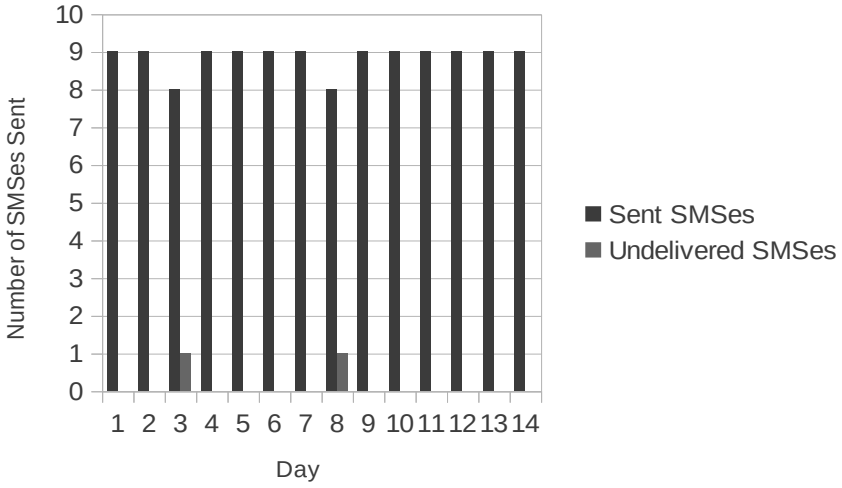

Table 2 Message Loss

Table 2 above illustrates the messages successfully sent and those that failed to be delivered. Of the 126 messages sent during the 14 days of testing only 2 messages failed to be delivered this was attributed to the service provider network conditions

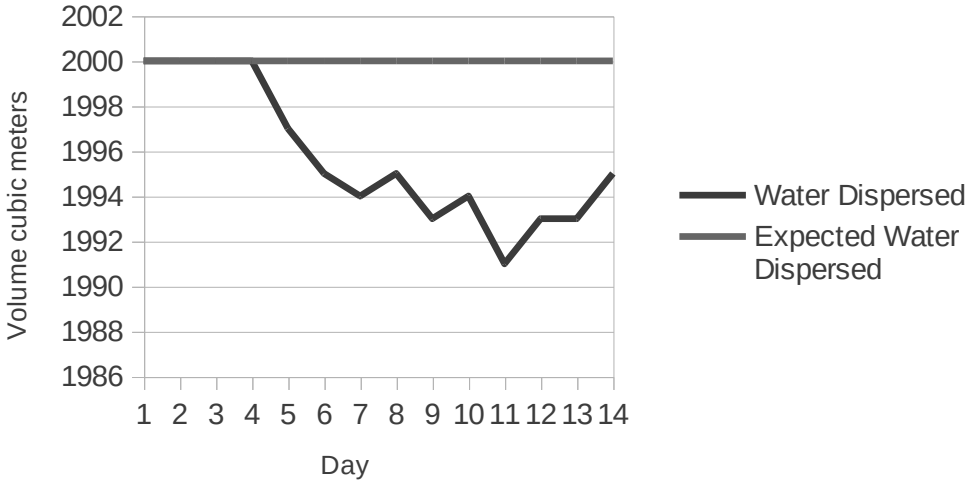

Table 3 Water Volumes Dispersal

Based on the theoretical dripping rate, in an hour the prototype test plot was expected to have dispersed 500 litres per hour and 2000 litres per day. **Table 3** depicts the expected water dispersal as well as the actual water dispersed. The prototype proved to be consistent and reliable however the moisture sensors require further testing as the test conditions practically kept the soil moist as water was delivered at shorter intervals of 1 hour.

System Limitations

Network congestion and delays in sms delivery may have an adverse effect on the watering, which may result in either over watering or under watering should the message delivery fail. It is therefore necessary to have an alternative or backup route to the system through the Internet web access. Currently the reports on water usage as available on the pc application are based on estimated water dispersal and not the actual water used. The water usage is calculated using watering duration and dripping rate. This does not provide an accurate water usage reading as indicated by **Table 3** to improve this metric a water flow monitoring system needs to be integrated to the system although this will increase the price of the system. The discrepancies in water dispersal can be attributed to environmental conditions and is not an impact of the system.

5.0 Conclusion

This automation will not only benefit the farmer in allowing flexibility in time management, but will also be important in gathering statistics which will allow for proper future planning. Small scale farmers tend to supplement their income through other means this system affords them time to deal with other issues while their fields are being watered. Affordability is a critical component of the system and we feel that at a cost of just under $600.00 the system is affordable. There is wide spread use of ICT in most sectors of the Zimbabwean economy but very limited in agriculture. We therefore feel this system will assist in the penetration of ICT in agriculture. In the Zimbabwean Government, ICT Policy Document [9] there is an e-Agriculture component which states that the government has a duty to promote and support the development of and access to affordable ICTs in land and water utilization. There is however no clear definition of how this objective will be achieved. Governments need to stipulate directly impacting policies as opposed to vague policies.

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