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International Journal of Computing and ICT Research

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Africa Can Greatly Benefit from Cloud Computing and Data Center Technologies – Part 1

*PROF. JOSEPH M. KIZZA**
Editor-in-Chief

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"Africa is virgin land, and they are adapting fast to new technologies and that is why we want to be there." Alexander Argov, Tikal's founder and CEO [Silverstein].

INTRODUCTION

Africa has made tremendous progress in the technology catch-up game in the last ten years. As I have been saying in my editorials in the last few issues of this journal, Africa was a late comer on the technological scene that has swept the rest of the world. However, because of the exuberance of her youth in embracing technology, the continent is making tremendous strides.

In this spirit I want to offer a few suggestions, as it concerns Africans, in which Africa can derive tremendous advantages and benefits in her development and technological trajectory, in the new technologies that are sweeping the rest of the world. These technologies are: Virtualization resulting in Cloud computing and Data Centers. In this part I of the article, I will focus on Cloud computing technologies and in part II I will deal with Data Centers.

According to Wikipedia (WIKIPEDIA), **Cloud computing** refers to the use and access of multiple server-based computational resources via a digital network like a Wide Area Network (WAN), Internet connection using the World Wide Web and others. This is in reality not a new technology as such. Indeed it is a revisit of an old technology developed during the days of the virtualization of operating system resources, services and technologies of the 1970s and 1980s. Back then, the technology part of time and resource-sharing where computing resources of the time residing on one mainframe were shared by hundreds of users from far of places connected to the mainframe using dump terminals. The mainframe was acting as a server, but it was not called a server. In today's environment, we have new terminologies and a new expended repertoire of computing services that almost make the environment new to the old timers and of course new to all the new brands of technology buffs.

Unlike in the old technologies of operating system resources virtualization where users accessed computing services from the mainframe using only dump terminals, today's Cloud users remotely access the server resources using a

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variety of devices including computers, netbooks, ipads, smart phones, or many other communication devices. And also different in the mainframe days gone by, but offered in cloud computing, is a large spectrum of computing services and applications provided and managed by the cloud server. In some cases, also data is stored remotely in the cloud configuration. However, similar to the computing of days gone by, in the Cloud, users do not download and install applications on their own device or computer; all processing and storage is maintained by the cloud server. The on-line services may be offered from a *cloud provider* like IBM, Microsoft and many others or by a private organization.

Like its cousin mainframe in the past, Cloud computing offers the users a model of computation that enables and creates a convenient, on-demand network access to a shared pool of configurable and expansive computing resources and services that are scalable, versatile and seemingly limitless to the users with minimal management effort or service provider interaction.

Africa with her computing environment and resources still in its infancy and with serious limited computing human capacity, modern computing equipment, services and management, but with expanding demand for human capacity in all areas, better computing equipment, faster computing environments and services and limited financial and human management resources may greatly benefit from this convenient, on-demand network access to a shared pool of configurable, expansive computing resources and services that are scalable versatile and seemingly limitless to the users with minimal management effort or service provider interaction provided by the Cloud.

Every aspect of the African institution and organization is bound to gain from Cloud computing. In particular, African institutions starting with governments, universities, both private and public organizations can benefit from the following list of services, resources and computing facilities that they would otherwise not have.

The following is a list of benefits Cloud computing technology offers to any computing environment makes a compelling case for African governments and institutions, if not already considering the technology, to start seriously thing about it [Wikipedia]:

- **Cost** – perhaps this is the most important of all Cloud benefits because of the limited African financial resources pool. For example one Cloud computing server can be used by the regional or country's universities all seamlessly sharing the needed resources. For businesses, this lowers the computing costs because the computing infrastructure is typically provided by a third-party and does not need to be purchased for one-time or infrequent intensive computing tasks. Because this is a shared pool of resources, pricing on a per unit utility computing is low hence requiring fewer and limited in-house IT skills for implementation.
- **Device and location independence** – This plays in the hands of developmentists who can now bring computing services and enable users in remote, difficult to access areas to access systems using a web browser regardless of their location or what device they are using for example a, PC, mobile phone or any other smart communication device.
- **Multi-tenancy** – the ability of the Cloud technology to enable sharing of resources nationally and regionally and allowing large pools of users to share these resources lowers the costs of shared computing for everyone thus allowing for better services for everyone.
- **Reliability** – because of the varying demands from users and to meet the expectations of users, Cloud technology brings into play more reliability through use of multiple redundant sites which in turn brings more confidence to the business community, improving the business environment and eventually attracting more foreign businesses into the region.
- **Performance** – along with improvement in reliability, performance improves and with improving performance, more demand and more improvement in performance leading to scalability to meet different customer needs.
- **Security** – to meet the expectation of the different categories of users, improved security is a must because of the centralization of data. So increased security-focused resources and operations, more and better trained personnel is a must.

- **Maintenance** – because computing resources are centralized, cloud computing applications and resources are easier to maintain. They are also easier to support and to improve, as the changes reach the clients instantly.

With all the benefits outlined above and a lot more not discussed here, the Cloud computing technology is probably one of the most suited new (but old) technology for Africa. It will tremendously improve the return on investment, create the needed computing and management human capacity and improve the business community confidence in the continent leading to new investments, new education opportunities and overall improvement in the individual welfare of the Africans themselves. This is a timey technology. Embrace it with hast!

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THE POOR AND THE MOBILE PHONE RELATED SPENDING

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Abstract

In this paper, we present work done to find out the challenges poor people in Kakamega east district in western Kenya face to maintain their mobile phones. It reports on findings from a study conducted to find out how the poor use their mobile phones, their means of acquisition, air time top up, battery recharge dynamics, and repair costs. Mobile phone maintenance costs visa-vi their earnings and spending were also analyzed. Results show that over 80% of the population own mobile phones and 61 % of all those who own and use mobile phones spend at least 10% of their disposable income on mobile phone. Some people at the bottom of the pyramid forego other important basic needs at the expense of maintaining their mobile phone. We conclude that, unless positive policy or interventions are put in place, economic leapfrogging is not likely to happen among the poor in developing countries even with the high uptake of ICTs, especially mobile phones.

KEY WORDS: LDCs, ICT, mobile phone, Poverty

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1. INTRODUCTION

In the past few decades, there have been many attempts and studies on the use of Information and Communication Technologies (ICTs) as a catalyst for socioeconomic development. The greatest challenge to many of these attempts has always been access and cost of ownership. The entrant of mobile phones in to the ICT ecology has greatly weakened access as a challenge. According to the International Telecommunication Union (ITU) - 2010, mobile

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cellular networks already cover close to 90 per cent of the world population and 80% of the population living in rural areas.

It also expects coverage to reach 100 per cent by 2015, eliminating the need for expensive infrastructure such as cabled networks. This extensive network has driven usage and subscription with over 3.8 billion mobile phones being in the developing world in 2010 and an expected 12% growth rate until 2015 [ITU, 2010]. Further, majority of these mobile phone users are said to be in rural Africa. The proportion of rural households with a mobile telephone has reached, or now exceeds, 50 per cent in many developing countries [ITU, 2010]. The increased usage in some ways may indicate systematic decrease in the cost of mobile communication. Mobile cellular services are much more affordable, with an average monthly cost of 15 purchasing power parity dollar (PPP\$) in developing countries compared to around 18 PPP\$ in developed countries [ITNEWSAFRICA, 2010]. In Africa alone, mobile phone subscriptions exceeded the 500 million mark by June 2010 implying that majority of the people now own these devices. [Allafrica.com, 2010] quoting from Informa Telecom and Media. The uptake of mobile phones from has its advantage, indeed studies have suggested that for every ten new mobile phones in 100 people population there is a 0.6% GDP growth [Sparks, 2008], this is good news to the developing countries that are badly in need of an economic boost.

However, within the same period that has seen an increase in mobile phone penetration, poverty is still on the increase. Studies show that poor people use up to a third of their household income on mobile phone related expenditures. There are statistics that compare the availability of clean water, food and even proper toilets to the number of mobile phones e.g. [The New York Times, 2010]. All these studies indicate that there are more mobile phones than basic human needs. Could there be a link to the two events? Could we be putting emphasis on the technology at a macro level and assuming its impact on the micro level? Finally are the perceived benefits really beneficial to all?

Assuming that on average a poor person earns Kshs 160 (US dollar 2) a day, it may be possible that the average spending (i.e. on food, clothing, technology etc) can be more than their daily earnings. We hypothesize that with no proper intervention, adoption and use of technology is likely to impoverish more. We therefore formed a hypothesis which states that: people at the bottom of the economic pyramid forego their basic needs at the expense of mobile phone technology. In order to test the hypothesis, we conducted a study to find out how the poor use their mobile phones, their means of acquisition, air time top up dynamics, battery recharge and repair costs. Mobile phone maintenance costs visa-vi their earnings and spending were also analyzed. Moreover, we sought to investigate how poor mobile phone users earn and spend their earnings.

The study was set up with the aim of finding out whether the perceived highly publicized mobile phone related growth matches the reality on the ground or not. Our main concern was to find out whether there is a direct relationship between increased mobile penetration rates, especially among the poor, and their economic growth. We draw our insights from a study we conducted in a rural village in Kakamega, Kenya on household income and expenditure. The study was inspired by the work of Abhijit V. Banerjee and Esther Duflo, the economic lives of the poor [Banerjee and Duflo, 2006] on how the poor use their earnings. Although their work was restricted to radio and television ICTs, it gave a good picture of how the poor distribute their income. Our expectation is that findings from this study and similar ones can inform ICT and economic policy makers make an informed and balanced view on the ability of the mobile phone as a preferred ICT choice in improving the lives of the poor.

In this paper, we describe the work done in Kenya, Kakamega east district. We report the findings of a research conducted to find out how people at the bottom of the pyramid (BOP), are affected by the technology with regard to forgoing their basic needs in place of mobile phone related expenditure. We show that although many people own and use mobile phones, direct economic gains are not as expected. However, we take into cognisance of the fact that even if there are no direct economic gains, there may be indirect gains that are as a result of social aspects. This is shown by examples where some people have reduced their travel expenses because they no longer need to do frequent visits when they need to communicate with friends or relatives; instead they call or send a message using short message service (SMS) technology.

The remaining part of this paper is organized as follows: Section two gives background information. In section three, methodology used is presented while section four has the results and discussions. We conclude in section five.

2. BACKGROUND INFORMATION

In 2009 Safaricom of Kenya posted over US dollars 125 Million net profit [Safaricom, 2009], Vodacom of South Africa US dollar 649.4 million [Businessweek, 2010] and MTN, South Africa US dollar 1.97 Billion [Total Telecom, 2010]. This shows that the mobile service provision is at its peak in Africa and service providers are having a field day in revenue collection. Could they be doing this at the expense of those below the poverty line?

These figures are contradictory to the realities on the ground. 320 million of the world's extreme poor – those living on less than US dollar 1 per day – call the African continent home [African Development Bank Group]. There is no place where extreme poverty is more evident than sub-Saharan Africa [Jeffrey Sachs et al, 2004; aDollar aDay, 2006;]. Almost 50% of the population are poor - the highest rate of extreme poverty in the world. They lack basic amenities, cannot afford proper health care and illiteracy is still a problem despite free and compulsory primary education many African and other developing world countries. In addition Infrastructural development in Africa is poor, there is low electricity penetration and poor roads network.

In these least developed countries (LDC) e.g. the sub-Saharan Africa, high mobile phone penetration in the last decade even among the poor has been reported. However, there has been very little to show for economic development except for cases where there have been interventions or where there was viable economic activities in place prior to introduction of mobile phones e.g. in cases such as those reported by [Abraham, 2007; and Donner, 2009;].

Airtime top up and mobile phone recharge

In this subsection, we highlight facts about the use of mobile phones and their related charges in Kenya. In the most preferred and widely used networks, a prepaid local SMS costs between Kshs 4 and Kshs 5.6 (US dollar 0.05 and 0.07) while a local call costs a minimum of Kshs 8.8 and a maximum of Kshs 16.8 (US dollar 0.11 and 0.21) per minute [The world factbook, 2010;]. 98.8% of all active SIM cards are prepaid in Kenya. The cost range depends on whether a call is within network or out of network. Average mobile monthly expenditure is Ksh 832.8 (US dollar 10.41) while disposable income is Kshs 1457.6 (US dollar 18.22) [Gillwald and Stork,2008;]. Apart from airtime costs and perennial mobile phone repair, rural mobile phone users pay for their mobile phone battery charging. It costs about Kshs 20 (US dollar 0.25) for every battery recharge. Depending on the mobile phone and its use, a recharged battery can last for a maximum of up to one week and a minimum of a day.

3. METHODOLOGY

The study was conducted in Kakamega east, a rural Kenyan district that is located approximately 400 KMs west of Nairobi. It is part of the larger Kakamega County which has a population of 1.6M people [Kenya National Bureau of statistics economic survey 2009]. Kakamega East district is a farming district with a population of 138 thousand people. The major source of income is small scale farming, where products are transported for subsistence consumption within the countries larger cities. According to the Kenyan Bureau of Statistics, the average house hold income in the district is approximately Kshs 160 (US dollar 2.0), the poverty level stands at over 50% and 85.1% of the population is literate. All of Kenya's four mobile service providers have a presence in the district, each with approximately 100% mobile network coverage. Usage of mobile phones among this population is both for personal and business purposes, with many users making use of the phone to contact relatives who are in the cities and other urban settings. The larger rural population airtime top up is done by relatives and friends based in urban areas by passing on credit through a technology referred to as '*sambaza*' in Kenya.

The sample size for this study was 597 respondents. This was a too large number for two people to administer questionnaires. Consequently, we saw the need to recruit and train research assistants. A total of seven research assistants were recruited and trained, specifically on how to administer questionnaires and more importantly on how to conduct interviews. When choosing our research assistants the local language and culture was important. They could all speak in Luhya, the local language, Swahili, the national language, and English, mainly used in Kenya as a writing language. Age was not an issue to us as we made an assumption that familiarity to the area under study

was enough. Education level was also taken into consideration. All our research assistants had a minimum education level of grade 12 with three of them being primary school teachers.

In order to have a somewhat convincing argument we adopted both qualitative and quantitative form of study. We used Descriptive research method [Mugenda and Mugenda, 1999], as we wanted to get information directly from the respondents about the problem. Descriptive studies basically deal with describing characteristics of particular individual or a group and in this case, it represented the rural population of Kakamega East district. Case study method utilizing Questionnaire and face to face interviews was employed during the survey. We chose Kakamega east district for a number of reasons, one was because we had an idea of the poverty index in the region, which was about 63% [Kenya National Bureau of statistics economic survey 2007]. The second reason was that there was an informal settlement area, commonly known as slums, around Kakamega Town, which in most cases are an indication of poverty ridden areas. Finally, Kakamega was an ideal location for us as we had an easy access to the community as well as the administration. One of the researchers originally hailed from Kakamega east and hence was familiar with the local language and culture. These provided the researchers a good working relation with both the community and the administration.

Based on a population of 138,000, a sample size of 597 was chosen for this study. This was arrived at by using a statistical calculator applying a statistical formula described in [Creative Research Systems]. With a confidence level of 95% and statistical margin error of 3%, a total of 600 questionnaires were distributed. The questionnaires were used to collect information on the demographic distribution, income level, phone ownership and subscribers' earnings. The information was then used to formulate interview guiding questions in a way that would not lead us into either asking leading questions or those questions that would generate redundant information.

The area under study had network coverage from the three major mobile operators in Kenya i.e. Safaricom¹, Zain² and Orange³. This means that service provision to the subscribers is competitive. Eighty percent of all the respondents had mobile phones. Geographically, over 80% of the western Kenya region has network coverage and in Kakamega east district, network coverage is nearing 100%.

Although informal interviews were encouraged, there were guiding questions aimed at giving information about: Income level per day per subscriber, with sub – questions such as the amount of earnings per day or per month depending on the type of work, whether contract or permanent. The second issue was on mobile phone ownership and usage, with the intention of knowing whether one owned a mobile phone or not and if yes, how do they use it. As a third issue, we collected information about ownership reasons; – whether for social or business use. In guiding question number four, the idea was to find out how the respondents maintain their phones. We defined maintenance as battery charging costs, mobile phone repair and airtime recharge costs. Any Social aspect that may be competing with mobile phone maintenance was the fifth guiding question. The concern here was to see if there is any social expenditure such as taking a friend for drinks, that compete with mobile phone expenditure and what is the apportioning like between the two? Perception questions on transport substitution, employment, social cultural factors were also asked. This question was informed by the argument that mobile phone adoption and use is not necessarily for economics gains only and hence the importance of picking out other benefits. For example we wanted to find out if it's true that mobile phone communication, whether business or social can reduce the number of trips to a certain place. Finally, the last question was what the respondents would like to see changed with regard to top regulatory intervention for adoption and universal use of mobile phones.

Editing, also referred to as raw data verification, plays a vital role in the process of carrying out data processing. According to Kothari [Kothari, 2004], it involves careful scrutiny of completed questionnaires to assure that Data collected is accurate and consistent with the facts gathered and have been properly arranged to assure accurate coding and tabulation.

Central mode of editing was chosen over field editing, for the reason that the researcher could review the entire questionnaire at the end of the day with the aid of two assistants. Individual questionnaires were easily tracked to the particular interviewer since they had date, time, name and the location of the interview. This assisted the editors to refer easily in case of abbreviated inputs on the questionnaires. To make the analysis friendly, questionnaires were coded on the basis of every questions and numerals assigned. Statistical Package for the Social Sciences (SPSS)

software tool was used for carrying out analysis that was based on subject theme. Simple statistical correlation and cross tabulation analysis were used to do quantitative analysis.

4. RESULTS AND DISCUSSIONS

In this section, results, based on the seven guiding questions are presented. Discussions on our findings follow immediately after.

In the past, results of similar kind of studies have been presented in a quantitative manner, mostly in a form of complex statistical analysis. For easy dissemination to a wider population, a more descriptive method was adopted. We used frequencies, correlation analysis and cross tabulation to evaluate and analyze the findings.

Although we took all the necessary care, including cross checking randomly selected questionnaires against interview data, these results may depict the actual situation on the ground with some error margin. However, to the best of our knowledge, these findings are presented as information that can be used as a starting point for further investigations in this area.

4.1 Population

In this study we had a total of over 500 participants in the study, with 45.3% female and 54.7% male. The population that participated in this research was predominantly below fifty five years of age. 91.6% were the age of fifty six and below while those that were aged above fifty six years made just 8%. The ages 10 to 35 years accounted for 68% of the respondents which is well within the national population distribution, currently showing that the age below 40 years account for 60% [Kenya National Bureau of statistics economic survey, 2006;]

The distribution based on age was a critical factor in this research given that age is a factor in most technology models, particularly those that deal with technology adoption and use. This was also meant to check on the most productive age bracket as this is the age that most people earn a living by working as opposed to being dependent on others.

4.2 Literacy

We found that cumulatively more than 70% of the population has attained secondary school level education. 2.5 % of those interviewed had no formal schooling. These statistics have a relationship with those on employment and level of income as they are correlated. Those who have attained grade 8 (primary school) accounted for 34.6%. We found these numbers confusing as the estimates by CIA fact book [The world factbook, 2010;] indicates that 85% of all Kenyans are literate. Unless we say that some people who finish primary school cannot write and read, then it will be tempting for one to interpret our findings to mean that only about 2.5% of Kakamega east district are illiterate. This argument can however be admissible as the district is within the larger Kakamega Town, which is mainly an urban area.

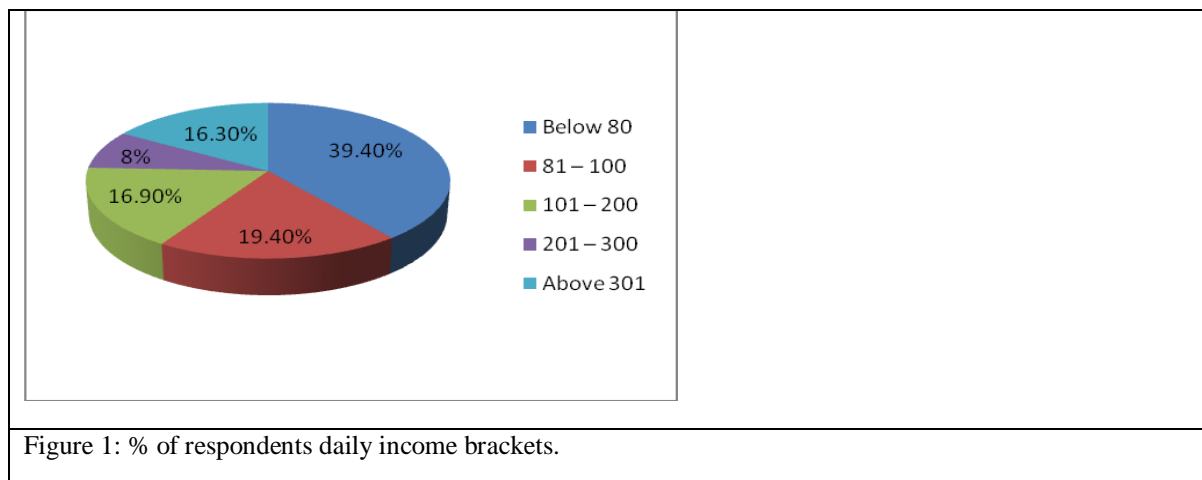
4.3 Earnings

Table 1: Respondents daily income

	Frequency	Percent	Valid percent	Cumulative Percent
Below 80	177	39.4	39.4	39.4
81 – 100	87	19.4	19.4	58.8
101 – 200	76	16.9	16.9	75.7
201 – 300	36	8.0	8.0	83.7
Above 301	73	16.3	16.3	100.0
Total	449	100.0	100.0	

Table 1 shows the distribution of income in Kenya Shillings per day. The question asked was: “What is your daily income in Kenya shillings”

Majority of our respondents, 58.8% (see figure 1) earn less than Kshs 100 (US dollars 1.25) per day. The daily income for this group is far below the national minimum wage by 50% (National minimum wage is about Kshs 200 - US dollar \$ 2.5 per day). This may be interpreted as that the mobile phone ownership and maintenance is more of a burden to this group of people.

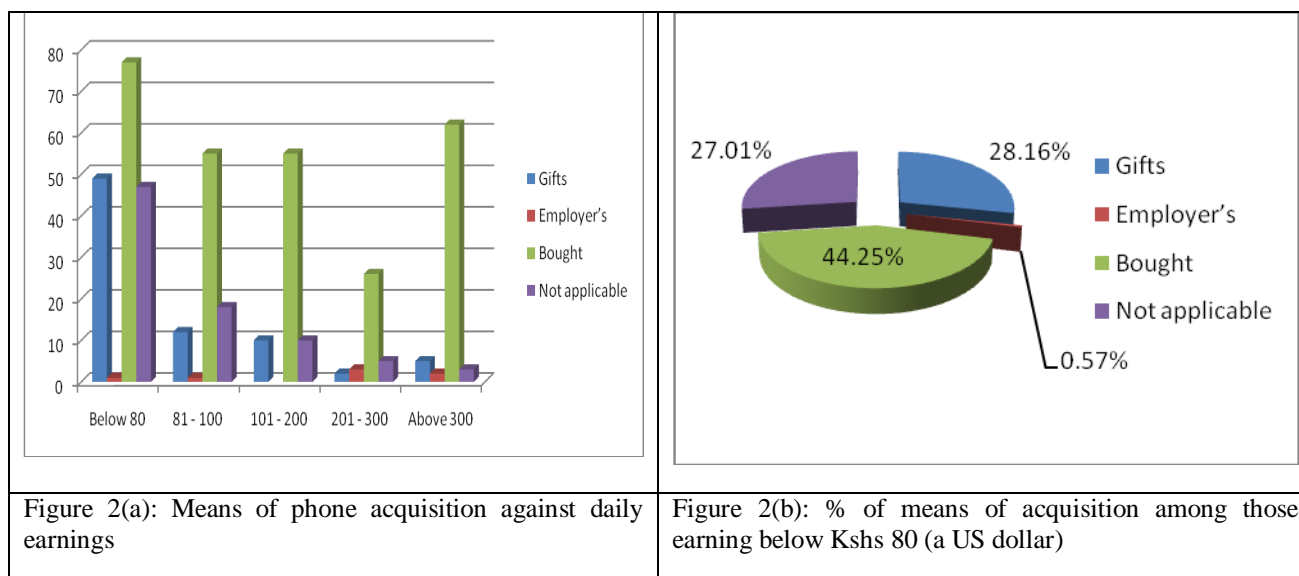


The earnings per day reflect the global statistics of people who are at the bottom of the economic pyramid (who earn less than 2 dollars a day) and who in practical terms, even if access to ICT service was available to them, it would still be difficult to close the gap unless their economic challenges are dealt with. To our surprise, these people still use and maintain mobile phones.

Table 2: Cross tabulation daily income vs. Phone Acquisition method

		What is your daily income in Kshs?					Total
		Below 80	81 - 100	101 - 200	201 - 300	Above 300	
<i>How did you obtain your mobile phone</i>	Gifts	49	12	10	2	5	78
	Employer's	1	1		3	2	7
	Bought	77	55	55	26	62	276
	Not applicable	47	18	10	5	3	83
		174	86	76	36	72	444

Table 2 shows different ways of phone acquisition tabulated against respondent's daily income. There were two dominant means of mobile phone acquisition, by buying and as a gift. Majority who acquired their mobile phones as gifts earn below Kshs 80 (US dollar 1) per day -the then exchange rate was about Kenya Shillings eighty to US dollar 1. The low income groups depend on buying low end phones and gifts in equal measure. About 31% of all the respondents who earn less than Kshs 150 (US dollars 1.5) a day acquired their phones as gifts from friends or relatives.



As shown in figure 2(a), income level plays a role in determining the means of phone acquisition. The number of those who bought their mobile phones increases proportionately with increase in income. The cost of acquiring a phone was very important to this study. We found out that most of the phones were acquired at prices well below five thousand Kenya shillings (US dollars 70). From our market review at that time, such phones did not have any internet capability or any other extra fancy features. It is however possible the situation may have changed hence eliminating the need for having it as an important point of discussion.

Majority of the people interviewed had a mobile phone and the networks were available. This represents 80% of the respondents. Only 9% of the respondents had no access to any means of communication save for the traditional methods.

4.4 Mobile phone maintenance and acquisition

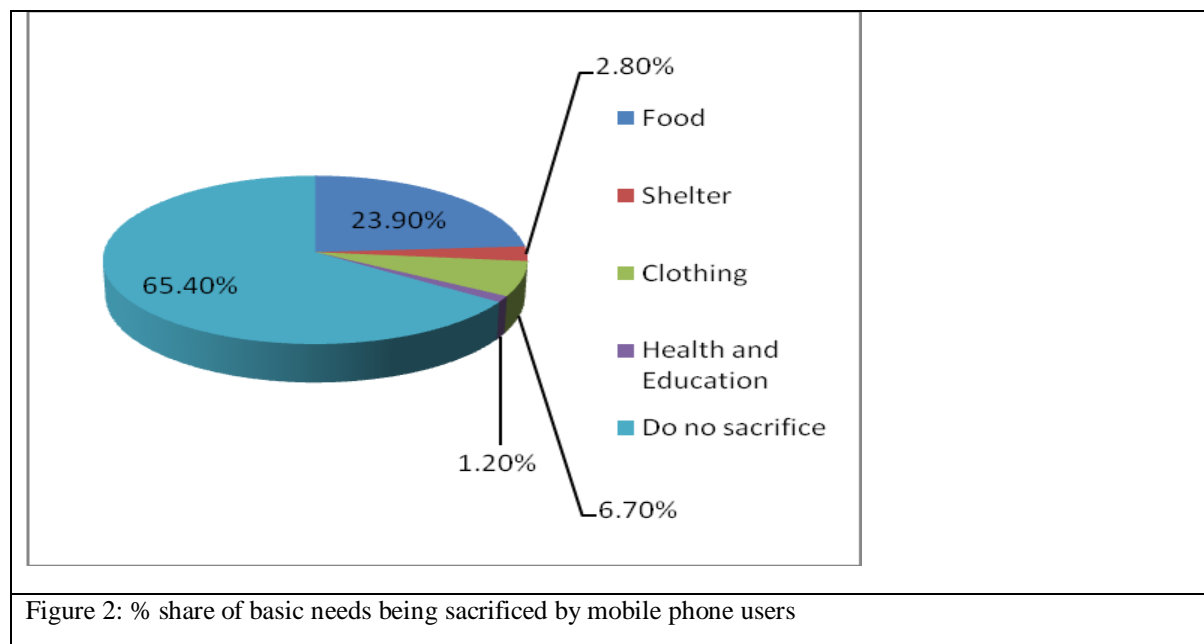
About 67.8% respondents maintained their mobile phones using salary/wages and/or business proceeds. On average this group spent between 12% and 25% of their income on mobile phone maintenance. Maintenance includes battery charging, airtime top up and repairing.

Table 3: Basic needs competing with mobile phone expenditure

	Frequency	Percent	Valid percent	Cumulative Percent
Food	103	22.9%	23.9%	23.9%
Shelter	12	2.7%	2.8%	26.7%
Clothing	29	6.5%	6.7%	33.4%
Health and Education	5	1.1%	1.2%	34.6%
Do no sacrifice	282	62.8%	65.4%	100%
Total	431	96.0%	100.0%	

Missing	18	4.0%		
Total	449	100		

One of the key objectives of the study was to find out whether there are people who acquire and maintain their mobile phones at the expense of basic needs. In table 3, some basic needs that mobile phone users in Kakamega east district tend to sacrifice at the expense of maintaining a mobile phone are shown. The valid percentage indicates the share of each basic need sacrificed (also see figure 2). Findings showed that 23% of our respondents sacrifice on food, 2.7% on shelter and 6.7% on clothing. For instance on food, some people reported that they would skip a meal, mostly lunch, to allow them buy airtime or pay for their phone recharging costs. It was not however clear how other needs such as shelter or clothing were sacrificed.



34.6% of all those interviewed reported a sacrifice on one thing or the other to allow them service/maintain their mobile phones costs. This in essence may mean that access and use of mobile phones may be more burdening to the population than can be imagined. Figure 2 is a graph showing a share of each item that gets sacrificed for mobile phone maintenance charges.

The findings further revealed that 61% of the respondents earned less than 1.25 dollars per day which translates to a monthly earnings of about Kshs 2400 (30 US dollars). This means that 61% of the rural population spent 20% of their income to carry out a one off payment on a mobile phone for every month that they buy a phone with a price tag of less than Kshs 5600 (US dollar 70). If unlucky to receive one as a gift from a friend or relative, this may be interpreted as that a mobile phone acquisition require the subscriber to use their savings, if any or forego other needs.

Amid all the reported low income earnings, spending and foregoing of basic needs, it was interesting to note that people were willing to spend on mobile phones at the expense of other basic needs. As a recommendation for further work, we believe there is a strong need to find out the forces that drive this behavior.

4.5 Airtime expenditure.

It was found that persons who earn below Kshs 120 (US dollars 1.5) a day preferred to buy air time of either Kshs 20 (US dollars 0.25) or Kshs 50 (US dollars 0.70) denominations on average. This group accounted for 67% of the total population. The main reason for this top up category was because it was perceived to be cheap and hence affordable. However, although on average this group topped up airtime three times a week, some could reload more than once in a day depending on the need to communicate. Overall this does not necessarily mean that the low denominations reload vouchers are good for the poor, but rather provides flexibility in topping up. On average, people earning under Kshs 120 (US dollar 1.5) per day would spend a minimum of Kshs 280 (US dollar 3.5) and a maximum of Kshs 672 (US dollar 8.4) per month on air time. This represents a minimum of 10% and a maximum of 20% of their monthly earnings.

On average the low income groups spent between 10% and 25% of their income on mobile phone communication. This expenditure is still much higher than the thresholds in the developed world where it needs to be below 5% of the disposal income.

5. CONCLUSION

In this paper, we have presented the results of a study done to find out how poor people in Kakamega east district from Kenya cope with high cost of maintaining their mobile phones. The results showed that although mobile phone uptake by the poor is higher than expected, their acquisition involve sacrifice, which sometimes requires foregoing the very basic needs.

Although still study does not provide the specific reasons that drive mobile phone related expenditure, it provides very interesting background or baseline study on how the poor in the developing use and spend on ICTs. Future work should look at the dynamics of mobile phone expenditure and aim to provide implementation models which are beneficial to the poor.

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Cellular Phone Usage and Productivity among Employees in A Ghanaian SME: An Assessment

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Abstract

The use of mobile phones in the manufacturing set up may be considered by some people as a distraction from work which may negatively affect productivity. Some also may be of the view that it will improve communication and as such impact productivity positively. A structured questionnaire with closed and opened ended question was used in collection of primary data. The questionnaire was validated by pre-testing it on a sample size of 10 staff. Sampling was aimed at 75 percent of the total workforce of 40 people. The questionnaire was administered to 30 employees of the company (both junior and senior ranks) that were available during the time of survey. The data collected was analyzed using SPSS version 12 software. Appropriate percentages and frequencies were computed to assist in analyzing the data. The survey results showed that the percentage of workers of Omega Beverages Ltd. who claimed their work output was not affected by making or receiving calls with their cell phones represented 86.7 percent and only 13.3 percent said cell phone usage during work impacted their output. The number of outgoing and incoming calls and the duration of calls made on mobile phones and the duration of calls translated into a considerable amount of time that was lost through cell phone conversations. This pointed to a negative impact of cell phone usage on productivity at Omega Beverages Ltd.

KEYWORDS: CELLULAR PHONE, PRODUCTIVITY, GHANA, SMALL AND MEDIUM-SCALE ENTERPRISES

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1. INTRODUCTION

The use of mobile telecommunication is growing so fast in a very distinctive way across the length and breadth of Africa and the demand for cell phones have exceeded the projections made by manufacturers particularly in Africa

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(Scott et al. 2004). The emergence of the use of mobile phones in the Africa was limited to the elite and wealthy upper class businessmen who could afford them. The high rate of diffusion of the mobile phone was attributed to the mass-market technology (Jagun et al. 2008). The price of cell phone was very high at the time of its introduction and only a few could afford it. The introduction of newer and more portable models of mobile phones and introduction of additional features like short text messaging, the radio, camera etc., caused the price drop of the older models which were generally bulky and could not be carried in the pocket. The fall in price and introduction of the cheap prepaid plans by mobile operators and improvement in service quality, have made the cell phone accessible and more affordable to a number of low income people. (Scott et al., 2004; Priege, 2004; Chan et al, 2006)

There have been some interesting sociological researches but few successful studies on the economic impacts of mobile telecommunication on the individual, businesses and overall economic activity.

Omega Beverages Ltd. is a newly established company which started commercial production in February 2008. The company was set up to produce world class premium fruit juices, fruit drinks and cocoa beverages in Ghana. The company which is a new entrant into an already vibrant market of fruit juices and beverage had to adopt a strategy of least cost of production through the use of advanced high speed and high volume technology and to attain the economics of scale a great deal of money was invested. The staff of Omega Beverages Ltd. is made up of both high skilled professionals and unskilled workers. The professionals are made up of engineers trained on Tetra Pak machines, food scientists, Technicians, machine operators, microbiologist, accountants and administrators. The unskilled workforce who form the majority of workers in Omega Beverages Ltd., are made up of loaders, line packers, cleaners and laborers. The use of cell phones in Omega beverages is not regulated by any company policy and the workers make and receive calls irrespective of position or rank in the organization. The rampant and uncontrolled use of cell phones by everybody has raised some concerns among the managers and hence the study.

2. RESEARCH OBJECTIVES

The research objectives include assessing the impact of mobile phone usage on productivity by the workforce of the company, investigating the extent of mobile phone usage in Omega, establishing the factors contributing to using mobile phones at the work place and suggesting measures to control the unproductive use of mobile phones at work places.

3. MOTIVATION FOR THE RESEARCH

Research in this area is necessary because a number of enterprises in Ghana are trying to derive down their cost of production in order to beat the competition they face with cheap imported goods. For a manufacturing company such as Omega, whose products face a lot of competition from these imported products, eliminating waste in all forms, including time wasted in making unproductive cell phone calls will help in the company's drive to become the least cost producer. It is important for management to find out if the use of the mobile phones was having any positive or negative impact on the business process, hence this research.

4. CELL PHONE USAGE IN AFRICA

Even though the use of cell phones in Africa has not been as widespread as in other areas of the world, as at 2007, analysts had put the number of mobile phone users in Africa at 250 million with 65million additional subscribers added in year 2007. Africa now has the fastest growth rate of mobile subscribers. (Nnamdi, 2008)

A study by Vodafone (2005) makes the assertions that "The first cellular call in Africa was made in Zaire in 1987 and by the year 2005 there were over 52 million mobile users on the continent and in 19 African countries mobile phones accounted for at least three quarters of all telephones. The rapid spread of mobile in so many of its countries is a remarkable phenomenon especially in the context of their huge economic and social challenges".

The history of mobile telecommunications in Africa and the developing world has been a successful one in the sense that it is one area of investments that continues to be profitable to investors. Investments in large infrastructure have provided mobile communication service to the poor, a tool that has enabled millions of people to communicate better. The innovative and entrepreneurial use to which cell phone have been put in Africa has reached unimaginable height since the time of introduction of the gadget. It now extends beyond individual ownership to

revenue generation, (Vodafone, 2005). A typical example is 'mobile to mobile' business in Ghana where individual allow the use of their cell phones for a fee. It may seem that extent which the poor in Africa access telecommunication services may be low because of low Tele-density figures in Africa. However, the sharing of phones and access to public facilities makes the extent e access of telecom services high.

Research shows that as at 2003, up to 80% of households made regular use of phones in some remote areas of Africa. (McKemey et. al. 2003). In other parts of the world such as Bangladesh cell phones have been put to economic use, whereby farmers use the cell phones to get the best price for their crops and live stock thus improving their income and wellbeing. Similarly, in Africa cell phones are put to economic use in Cote d'Ivoire, where farmers are able to monitor the price changes for coffee with the use of mobile phones and se their produce when the coffee price was best for them. (Ahmed F, 2000; Lopez, 2000)

Scott et al., (2004) provide the following statistics on the growing market for cellular phones i Africa, they claim that in 200 I access to telephone by Africans was less than 3 percent of the population and by 2004 the percentage had increased to 7percent. They put the growth rate of the cell phone subscribers at 35 percent per annum. The liberal regulatory environments, where operator have been given the freedom to respond to customer requirements is one of the reasons given for the fast growing usage of mobile phones in Africa. The need to be constantly accessible and connected to friends and colleagues is one of the main reasons for mobile phone addiction in the youth in a study conducted in India (Chakraborty, 2006), even though there are no such studies in Africa the same assertion can be said of the youth in Africa. The youth in Africa are notable for "flashing/beeping", text messaging and multimedia such as playing music, and listening to radio.

5. USE OF CELL PHONES AND PRODUCTIVITY

It is recognized that the use of cell phones can be very useful for small businesses. The phones help the business owner to be in contact with clients and suppliers without always having to be on the job physically. However, most employers also tend to believe that constant use of the cell phones by their employees especially on the job tends to distract them and lower productivity (Thompson, 2006). Thompson in his research paper the effect of cellular phone use in the modern workplace contends that most of the calls received by employees while on the job have nothing to do with business. According to him, the mere receipt of a call, irrespective of whether the receiver picks it up or not may negatively impact productivity. This he says is because, deciding whether or not to pick up a call in itself can make an employee lose concentration (Thompson, 2006). This lose of concentration has more serious consequences if the employee is engaged in some production line activity. Thompson goes on to quote a research by Basex (2005) which found that American companies lost \$ 588 billion that year due to interruptions from cell phones and other electronic technological gadgets. The interruptions amongst other things caused workers to lose focus which consequently could lead them into not meeting deadlines. In his research, using different categories of workers, Thompson found that approximately 47 percent of his respondents found mobile phone calls disruptive. Majority of those who said they did not find it disruptive however admitted that they had put measures, such as putting their cell phones off in place. This confirmed that unconsciously, they did know that mobile phone calls could be disruptive (Thompson, 2006). Thompson does concede however that some available research suggests that not all phone interruptions are detrimental to productivity. He states that in cases where there is the need for immediate information to address a pressing issue, mobile phone calls may actually enhance productivity.

Youngbin et al (1991), identified productivity as a major reason for using cell phones by commuters who spend more than two hour on the road while convenience was given as reason for people who travelled less than two hours in their cars. They also gave the following statistics for the usage of cellular phones. Heavy use of cell phone for business was 71.8 percent among respondents and for personal activities 28.2 percent. Their survey also indicated the primary reason for getting a cellular phone associated with productivity was 36.7 percent and with convenience was 34.0 percent.

Research has shown a positive impact of cell phone communication on economic growth (Baliamoune, 2002). Reduction in transaction cost, widening of markets and becoming substitutes for expensive travels and better information flow are some of the economic benefits associated with cell phone. However, the face-to-face societal interaction has rather been on the decline thereby reshaping the culture. Diego (2007) The other areas of increasing

importance of mobile phones in Africa were identified as, improving efficiency of markets, promoting investment, improving government revenue through payment of taxes by mobile operator (Nigel et al., 2004).

A survey by Frempong et al. (2007), found that micro entrepreneurs in Ghana used the phones for checking of prices, ordering materials, contacting their clients and suppliers and checking customer orders. The frequency of use of the cell phones for business purposes though was low among the micro entrepreneurs, using the cell phones for the above business activities contribute to increased marginal profits, by cutting down on transportation cost, having easy access to their suppliers and clients.

6. RESEARCH METHODOLOGY

The staff strength of the company stands at 40 employees and attempt was made to administer the questionnaire to at least 30 employees, which makes the sample size about 75 percent of the population. A structured questionnaire with closed and open ended questions was used in the collection of primary data. Questionnaire was designed to gather demographic data of the employees of Omega Beverages Ltd, to sample workers views on effect of mobile phone usage on their output and performance.

Demographic data collected was on gender and age. In an attempt to get data on the usage of cell phones by the staff of Omega Beverages Ltd., respondents were asked questions on the whether they owned mobile phone, the frequency at which the workers receive and make calls during their work hours, the average time that they spend making or receiving calls, how much time they spend on the average making call. What other uses they put their phones to.

The category of people they call to distinguish the work related calls from social calls. They were also asked questions on whether mobile phone calls disrupt their work. What do they do when their work is disrupted by receiving mobile phone call? The questionnaire was validated by pre-testing it on a sample of the 10 staff. Sampling was aimed at 75 percent of the total workforce of 40 people. The structured questionnaires were administered to the 30 employees of the company (both junior and senior ranks) that were available during the time of survey. Statistical Package for Social Sciences version 12 was used to analyze the data.

7.0 DATA ANALYSIS AND DISCUSSION

7.1 DEMOGRAPHY

Demographic data collected from respondents for the survey shows that there were more males (63.3%) than females (36.7%) working at Omega beverages ltd. This is attributable to the nature of work that is available at time of the survey. The operations at Omega Beverages Ltd. can be classified into beverage production process, which involve mixing machine operation, processing machine operation, filling machine operation, packaging machine operation and palletizing of finished product. The computerization and automation of these equipments require people with electrical and mechanical background, who must have good trouble shooting skills in programmable logic controllers (PLC). Warehousing, Sales, Administration and Accounting constitute the other sectors of Omega Beverages Operations. Some of the female employees work in the Quality Assurance department as analyst and a majority of them on the packaging lines, where finished products are packed into cartons and arranged on pallets. Females are also engaged in cleaning and sanitation within the factory and outside the factory premise. The male employees in Omega Beverages Ltd. are mostly managers, machine operators, drivers and casual workers. The casual workers do manual works like palletizing, loading and offloading of trucks and drivers for some of the company's vehicles.

The ages of the respondents range from 19 to 45 years with the modal age group being 19 25years. Over 53.57 percent of the respondents fall within the age bracket 19 - 25 years and 25 percent are within the 26-30 years age group. Over 75 percent of the workforce are below 30 years of age and can therefore be described as young and dynamic work force

7.2 JOB CLASSIFICATION AND CONDITIONS OF WORK

The majority of respondents were casual workers and they form 66.7 percent of the work force and they clearly outnumber the rest of the employees put together. They are followed by the 'others' which include drivers, machine operators and administrative staff, whose responsibilities were not defined and they form 20 percent of the respondents may represent a group made up of the administrative and support staff.

Whereas managers form just 6.7 percent, supervisors constitute 6.7 percent. It is obvious from these that the organizational structure is broad based and pyramidal with majority of worker at the bottom of the pyramid. The organizational structure is closer to a flat type of organization than a lean structure. The Flat organizational structure has its advantage over the other organizational structures and the choice of organizational structure also depend the size and age of the organization. As the organization grows, a flat organization may tend to become hierarchical in nature, resulting in bureaucratic and complex systems. With a wrong organizational setup, jobs may not get completed on time within the limited budgetary resources of the company and it also affects the company's response time to changing conditions and customers reactions. An effective organizational structure will facilitate good working relationship between the various departments thus avoiding the bureaucracies associated with large institutions and hence enhances efficiency in the organization (Wikipedia.org).

7.3 DURATION OF WORK (WORK HOURS)

The respondents were asked to state the number of hours they worked in a day and this was to determine if work extended beyond the normal eight hours which could be due to delays caused by stoppages of machine as a result of breakdown, interruption due to call made or received etc.

Forty percent (40 %) of respondents answering the question claim they work more than eight hours per day and this can increase the companies overhead cost in running equipments on electricity, water and other amenities as well as increasing its wage bill by way of overtime payments. However, 60% claimed they worked 8 hours or less.

7.4 CELL PHONE OWNERSHIP AND USAGE

The answers to the question, whether the workers owned cell phones has shown that 96.7 percent of the sampled workers owned cell phones. This means that there was a high teledensity among the workers. The workers were not limited in assessing telecommunication. The workers were accessible to each other even when they were not at their desk or workstation and this will ensure the smooth flow of information and directives at the right time.

In response to the question whether those who own cell phone switched off their phones during work hours, it was revealed that the majority of the respondents representing 80 percent kept their phones on while at work and 20 percent of the workers claimed they switched off their phones while at work. This indicates that 80 percent of the workers were likely to be making or receiving calls at the expense of company time or will be engaged in productive communication to enhance efficiency and productivity.

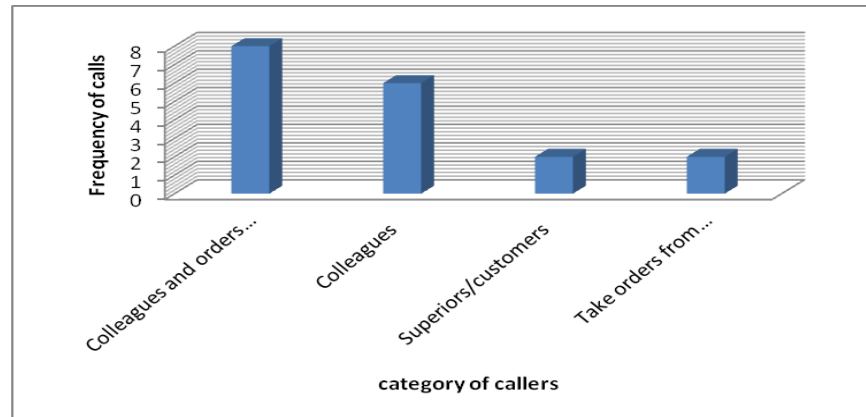
When asked further if the use of cell phone was necessary for the performance of their work, about forty-seven percent of the respondents indicated that the cell phone was necessary for the performance of their work. This means that this group of workers may be relying on information from other people to get their job done. The other fifty-three percent of respondents claimed the use of cell phones was not necessary for their work, which implies that their phone was for purposes other than communicating on work related issues.

About forty-seven percent of the respondents did not think the cell phone was necessary for the performance of their work. This group of people depends on their cell phones to perform their job. It may be inferred that they use their cell phones to engage in productive communication like taking orders from customers, giving and receiving feedback from colleagues and superiors and issuing out of directives.

44.5 percent of the respondents who claim their mobile phone help them with their work use their phones to

communicate with their colleagues on the job and also make calls to their customers to take orders. 33.3 percent of the respondents communicate with their colleagues on the job, an indication that there is some level of coordination and team work at play for quick and easy resolution of issues that may come up during the course of their work (see Figure 1).

Figure 1: Frequency of calls per call category that help with work performance



Source: Field Data

Of those respondents that said the use of the cell phone enhanced their work, 27.8 percent use their phones to communicate with their colleagues and give feedback to their superiors implying that the communication channel is both lateral and vertical which is essential for easy flow of information, clarity of instruction and for fast execution of job. Reaching out to their clients was very important for the sales team in the execution of their job. The number of respondents who made calls solely for the purpose of taking orders from customers represented 11.1 percent of respondents. The productivity of respondents who use their phones purposely to take orders from customers depended on the number of orders taken and successfully executed.

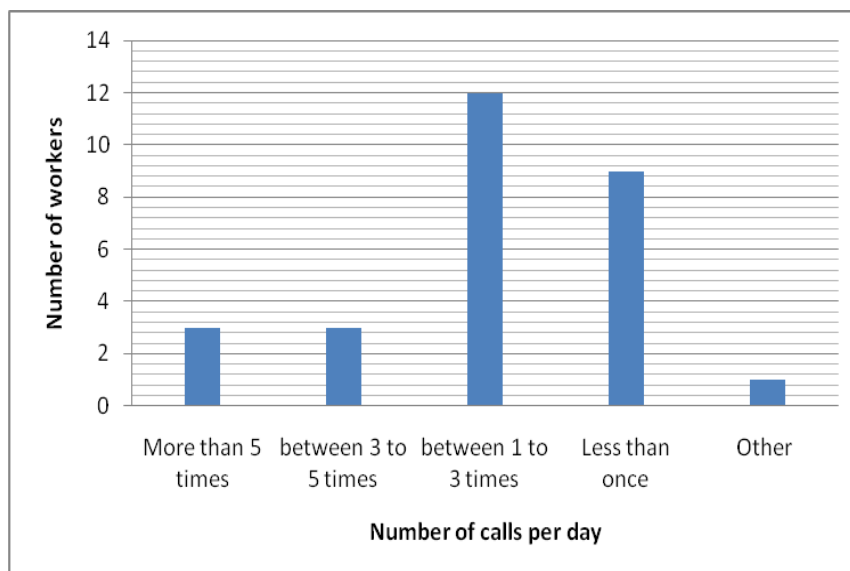
7.5 AVERAGE NUMBER OF OUTGOING CALLS PER DAY

Figure 2 shows that the percentage of respondents who made between 1 to 3 calls in a day, was 42 percent of the workers with cell phones. Respondents who claimed they make only one call or none at all were 32.1 percent. 10.7 percent of the respondents make more than five calls in a day. The percentage of respondents who made between three and five calls was 10.7 percent.

The rest of the respondents who could not estimate the frequency and amount of time they spend on the cell phone form only 3.57 percent.

It can be deduced from Figure 2 that the frequency of mobile phone usage was moderately high among the workers of Omega beverages Ltd, and if these calls are not work related or calls that will improve the productivity of the workers involved, then the allocated time for effective job performance for these individuals will be adversely affected and daily targets may not be met.

Figure 2: Number of outgoing calls per day



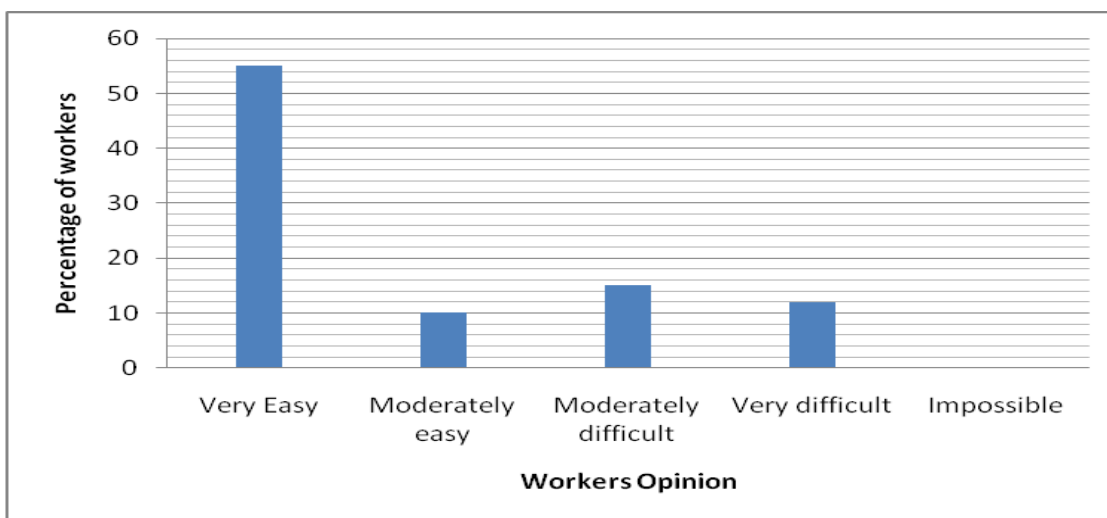
Source: Field data

7.6 MEASURE OF DIFFICULTY OF JOB PERFORMANCE WITHOUT CELL PHONE

The question of how difficult it was to perform ones duties without a cell phone was asked to identify cell phone users whose use of their phones aid their effectiveness and efficiency thereby contributing to higher productivity. Majority of respondents, Figure 3 representing 56.6 percent were capable of working without their cell phone. The remaining respondents depended on their cell phone to perform their work. 16.6 percent would find it moderately difficult to perform their duties and 13.3 percent will find it very difficult to perform their work and 10 percent of the respondents said it was moderately easy to work without their cell phone.

3.3 percent of the respondents would find it impossible to work at all without their cell phones. It was obvious that cell phones were not necessary for those who did not have any difficulty in working without their cell phones in the performance of their work. Likewise those who found it moderately easy could do without the cell phones in their job performance. These categories of people i.e. those who found it moderately easy and very easy to work without their cell phone constitute over 60 percent of respondents that took part in the survey. However, this did not mean that those who said they used their cell phone to work were entirely telling the truth.

Figure 3: Workers opinion on difficulty of working without the cell phone



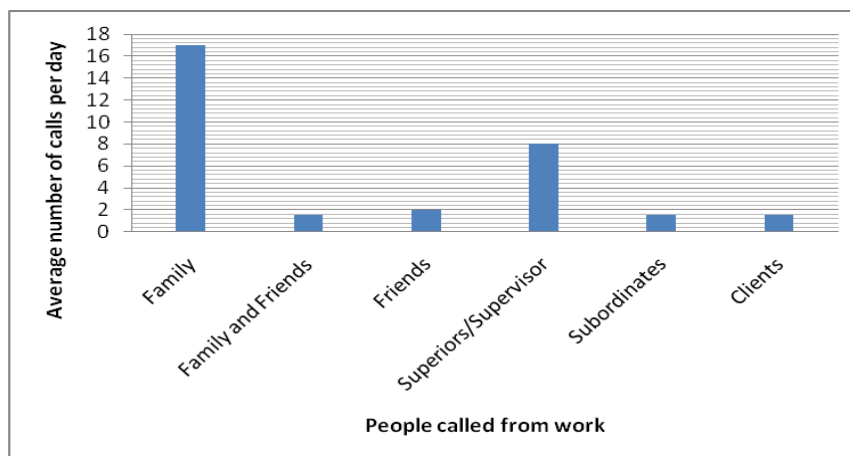
Source: Field Data

Those who found it moderately difficult, very difficult and impossible to work without their cell phones put together represent about 33 percent of respondents and this implies that cell phone usage could positively impact productivity in the job performance of only these respondents. The answers to this question were to confirm the responses to the earlier question of whether cell phones were necessary for the performance of job. The 46.7 percent of respondents who said the mobile phones were necessary for the performance of their job was in agreement with the 43.4 percent of respondents who found it moderately easy to impossible to work without their cell phones.

7.7 CATEGORIZATION OF PEOPLE CALLED AT WORK

Grouping the responses to the question “which category of people do you call from work with your cell phone?” into social and job related calls, the data gathered indicate that calls made to only families accounted for 58.6 percent, family and friends accounted for 3.4 percent. Respondents who called their friends only constitute 6.9 percent and the job related calls make up to 30.9% of the total calls made (see Figure 4).

Figure 4: Number of Calls per category of people called from work



Source: Field Data

Making a call is most of the time at a person’s convenience. Unlike the process of making calls, receiving calls can be disruptive to a person’s chain of thought and concentration on a job. Unwanted disruptions can cause interruptions in work flow if not managed properly. Some interruptions are believed to provide timely information for job execution and real-time data for timely decision making (Thompson, 2006). Thompson suggests that it can take the knowledge worker up to 15 minute to return to the same level of productivity and in some cases of interruption, the work never gets completed. Most of the calls received were social call i.e. calls to family and friends put together constitute 68.96% and these calls can cause a great deal of distraction or disturb the chain of thought and thereby affect efficiencies that may lead to shortfall in productivity.

7.8 NUMBER OF CALLS RECEIVED IN A DAY PER CALL DURATION

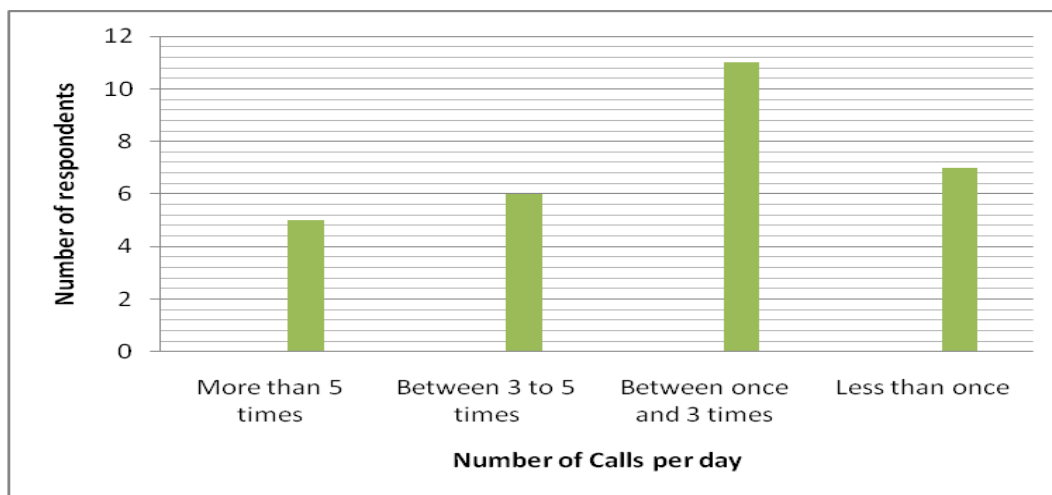
Analysis of the data shows that 37.9 percent of respondents receive between 1 and 3 calls in a day, 24 percent receive less than one call in a day, 20.7 percent receive between 3 to 5 calls in a day and 17.2 percent of respondents receive more than 5 calls in a day as shown in the data Figure 5 below

The number of calls received can be directly linked to work interruptions caused by receiving cell phone calls. Some of the calls received may be useful for job performance but some may not be useful and may negatively impact productivity. Over 50 percent of calls were coming from family and friends which means that these calls may not be contributing to efficiency improvement. Tying the responses of this question to the difficulty of working without cell phones and bearing in mind that most of the calls were social calls with modal call rate of 1 to 3 times of calls per day, a lot of time may be wasted in receiving calls. Time is a valuable resource that

cannot be regained. Drucker (2007) said “One cannot buy, rent or hire more time. The supply of time is totally inelastic. No matter how high the demand, the supply will not go up.

There is no price for it. Time is totally perishable and cannot be stored. Yesterday’s time is gone forever, and will never come back. Time is always in short supply. There is no substitute for time. Everything requires time. All work takes place in, and uses up time. Yet most people take for granted this unique, irreplaceable and necessary resource.”

Figure 5: Number of Calls received in a day per call duration



Source: Field data

7.9 ACTIONS TAKEN TO AVOID INTERRUPTIONS

The question „what do you do when you receive a call“ was asked in order to ascertain how the workers handle their calls to avoid interruptions and to know if making or receiving calls can cause a stop in the work flow. Figure 6 shows that 13.7 percent or 4 of the respondents stop work in order to receive or make calls especially with the casual workers who are engaged in manual work on the packing lines. Thompson (2006) indicated that an intrusion is an interruption which temporarily stops the work flow and this has a bearing on productivity since it has some great deal of impact on how a worker will manage his time. Sixty-six percent (65.5%) or 19 of the respondents claim they continue to work whenever they make or receive calls. These respondents fall into the class of workers who handle automated equipments or may be using earpieces to receive or make calls. About 20.7 percent or 6 of the respondents do not stop work but ask their colleagues to cover up for them whenever they have to receive or make calls whilst at work. This means that the work does not suffer any hold ups with the making and receiving of calls. The rest of the respondents actually have to stop their work to make or receive calls and they constitute

13.7 percent of the respondents. The time spent on making cellular phone calls can be translated into loss of profit. (Thompson 2006). Most of the workers spend between one to three minutes making calls in a day.

The percentage of respondents spending between 1 to 3 minutes on their cell phones making calls in a day was as high as 60 percent or 18 respondents. 23 percent or seven of the staff who took the survey spend less than 1 minute on the phone in a day. Two of the respondents representing 6.7 percent spend more than 5 minute in

making calls. Relating the amount of time with the frequency of making and receiving calls it became apparent that a considerable amount of time is spent on making and receiving cell phone calls which most of the time are call made to family and friends.

7.10 STAFF OPINION ON WHETHER CELL PHONES CALLS DISTURB THEIR EFFICIENCY

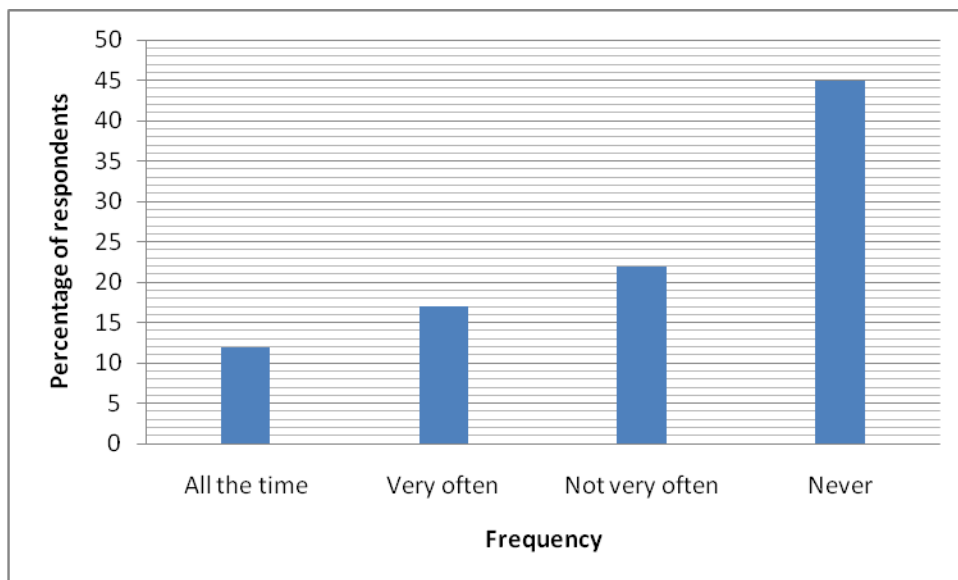
In the opinion of 40 percent of respondents, cellular phone calls did not disturb their efficiency that often which means that there are times their efficiency was affected. 10 percent of the respondents said receiving call on their cell phone disturbs their efficiency or output all the time.

3.3 percent of the respondents said the use of cellular phone very often disturbs their efficiency and or their output. An example could be when worker is called to his or her bosses" office irrespective of what the subordinate was doing. A good number of the respondents said that receiving cell phone calls did not affect their efficiency at all. The respondents making this claim represent 46.7 percent of the work force that took part in the survey.

7.11 STAFF OPINION ON WHETHER CELL PHONE CALLS IMPROVES THEIR EFFICIENCY OR OUTPUT

In the opinion of 10 percent of the respondents, making or receiving call improves their efficiency. This was comparable to the 10 percent of respondents who said cell phone calls disturb their efficiency or output.

Figure 6: Workers opinion on whether cell phone improved their efficiency



Source: Field data

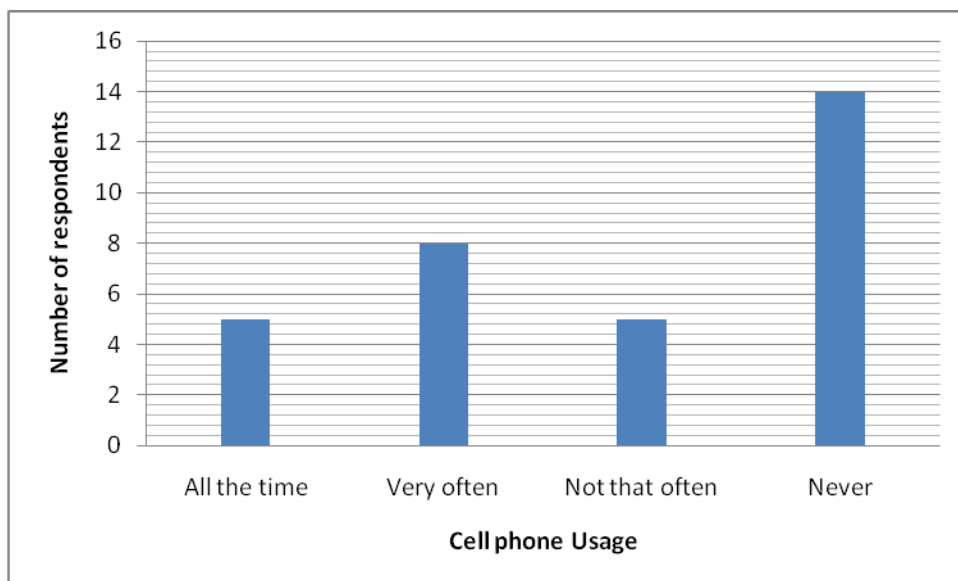
43.3 percent claim the usage of the cell phone never improved their output or efficiency. This is comparable to 46.7 percent of respondents who said cell phone calls did not disturb their work output (see figure 6). 23.3 percent of respondents said the phone calls did not very often improve their output or efficiency and 20 percent said their efficiency was improved very often by the use of the cell phone compared to the 3.3 percent who said

cell phone calls often disturb their efficiency. 10 percent of the respondents were of the view that it improves their efficiency all the time.

7.12 DISSEMINATION OF JOB RELATED INFORMATION BY CELL PHONE

26.7 percent of the respondents very often use their phone for disseminating job information and 16.7 percent of the respondents do not do this very often. 10 percent of the survey respondents use cell phones to disseminate or receive information pertaining to work during working hours all the time. Less than half of the respondents (46.7%) do not in any way use their cell phone to send or receive job related information. This category of workers who form the majority may not be taking part in any decision making process. They represent the casual or temporal workers who are given verbal directives and are not communicated to by their superiors by cell phones. In addition, the respondents who use their cell phones to disseminate or receive information pertaining to their job all the time (10%) and very often (26.7%) are the ones that use their phones productively (see Figure 7).

Figure 7: Number of respondents who use cell phones to disseminate job related information



Source: Field data

7.13 OTHER USES OF CELL PHONES AMONG OMEGA BEVERAGE WORKERS

Cell phones are constantly evolving with the latest gadgets having added and improved functions with more and attractive and sleek designs (Thompson 2006). The earlier designs were meant for cars and did not have text messaging functions, radios, calculators, calendars, music and video players. Some of these new features on cell phones if not used in a controlled manner can lead to serious neglect of assigned duties. Using cell phones to do calculations was very common among the respondents with 34.5 percent of them using the cell phones for this other purpose apart from making calls. Using the cell phone as radio ranked second with 17.2 percent of respondents using the phones for that other purpose only. 10.3 percent of respondents were using the cell phones for text message only apart from making calls. 6.9 percent of respondents use their cell phones to listen to the radio and text messaging. Text messaging is an immediate and yet non intrusive form of communication

where the recipients of the text message will respond at their own convenience. However, 10.3 percent of them also use it for text messages and calculations.

7.14 MODE OF MEASUREMENT OF WORK OUTPUT

The question as to how work output was measured was asked to ascertain whether figures were put on work output or performance and to find out if the worker were conscious of what was expected of them by the close of work. 25 of the respondents representing 83.3 percent were able to indicate how their output was measured. The significance is that the workers were aware of their employer's expectation of them at the end of the day and were not likely to hide and indulge in lengthy phone calls that will affect their performance at the end of the day. Most of the respondents' performance was assessed by number of cartons packed in a day and they represent 48 percent of respondents. Delivery time as a performance indicator was used by 20 percent of the respondents as a mode of measuring their work performance. 20 percent of respondents were also assessed using number of dispatches as the mode of measurement.

"Can your work output be affected by receiving or making phone calls?" was a question asked differently to confirm their first response to the question whether cell phone in their opinion affected their efficiency and the majority of the respondents representing 86.7 percent said making or receiving calls did not affect their work output. Only 13.3 percent of the respondents said their work output was affected by making or receiving call with their cell phones. These responses confirm the earlier responses given to the question whether cell phone in their opinion affected their efficiency.

8. CONCLUSION AND RECOMMENDATIONS

The results of the survey conducted at Omega Beverages Ltd. have shown that a considerable amount of time is spent in making cell phone calls. The number of cell phones calls and the time spent on calls that are not work related outnumber the calls that are work related. The cell phones were used for other activities like listening to music and the radio on their phones, doing calculations, sending text messages etc. The number of respondents who claim their work output is not affected by making or receiving cell phone calls represented 86.7% of respondents and only 13.3% said their work output was affected by cell phone calls. However, a high percentage of respondents representing 42.85 percent made calls at a rate of 1 to 3 times in a day and most of the calls made last between 1 to 3 minutes per call. Likewise, the number of respondents receiving calls at a rate of 1 to 3 calls per day represents 37.9 percent. The number of call outgoing and incoming and the duration of the calls translate into a considerable amount of time that is lost through cell phone conversations. The findings from the study point to the fact that over 60 percent of these calls were social calls that are made to friends and family and these calls do not help in improving business communication and the sharing of job related information to improve efficiency. It became obvious that the cell phones in the hands of a greater number of workers, the majority of whom were casuals were not being put to any beneficial use to the company. The percentage of respondents who found it very difficult to work without their cell phones was 13.3 percent. Those who found it impossible to work without the cell phone were 3.3 percent. These two categories of workers depended on their cell phones to work and their productivity is positively influenced by the use of cell phones but they rather fall in the minority of respondents.

It is obvious from the study conducted on the workers of Omega Beverages Ltd., that the extent of use of mobile phones at the work place was wide spread. The usage of the mobile phone ran through the whole organization. The majority of calls made or received with cell phones were social calls that were made to family and friends and only 30.9 percent of calls were job related. A few respondents representing 3.3 percent found it impossible to work without their cell phones which implied that only this group of workers actually used their phones productively. It can therefore be concluded that since the unproductive use of cell phones outweigh productive

use, the use of mobile phones at Omega Beverages Ltd. may not contribute positively to productivity gains.

The policy suggestions made by the workers if implemented will go a long way to curb the abuse of cell phones in the company. A total ban of the use of cell phones when driving will be highly recommended since other studies cited suggest that the use of mobile phones while driving have resulted in a number of fatal accidents. Some suggestions made by respondents on cell phone policy for the company include:

1. Key personnel like operators of vital equipments, supervisors, managers, sales and marketing personnel should be the only persons allowed to use cell phones while at work.
2. The other workers were to switch off their phones and only switch them on during their break periods and emergencies.
3. Company drivers were to make use of earpieces while driving and they should park off the road when they have to receive and make calls.
4. Putting off all cell phones or putting them on vibration mode during meetings

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A Reference Model for Biomedical Ontology Evaluation: The Perspective of Granularity

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Abstract

There have been many attempts using ontologies to develop systems that integrate data from the domains of medicine and biology, across levels of granularity. Such integration systems have not gained wide adoption and reuse. This is largely due to a lack of an approach with metrics as frame of reference to enable users evaluate these systems for their representation of biomedical structure, across levels of granularity. In this paper a reference ontology against which such evaluation of biomedical ontologies may be conducted is presented. Requirements for the reference ontology were validated in a descriptive study. Basic formal ontology with its support for representing biomedical structure across levels of granularity is adopted as the underlying theory for deriving the reference ontology. Metrics for determining the suitability of an ontology to integrate biomedical data across levels of granularity are derived using the reference ontology. The utility of the reference ontology was tested by a prototype tool that was used to evaluate the infectious disease ontology. The results were validated in a questionnaire based study with users.

Categories and Subject descriptors: H.1.1 [**Models and Principles**]: Systems and Information theory – General Systems Theory; J.3 [**Life and Medical Sciences**]: Medical Information Systems, Biology and Genetics

General terms: Reference Ontology; Biomedical Ontology; Ontology Evaluation; Biomedical Data Integration; Granularity; Additional key words and phrases: Levels of Granularity; Biological data; Clinical data.

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1. INTRODUCTION

Biomedical Ontologies [BOs] are used to integrate data from disparate biological and clinical databases [Kumar et al. 2006; 2006; Rey-Perez et al. 2006; Sioutos et al. 2006]. However, their reuse and wide adoption in distributed computing environments remains constrained by the lack frameworks with metrics for users to assess their suitability in specific applications [EON 2006]. To integrate data from the domains of clinical medicine and biology BOs have to address the problematic issue of treatment of granularity across biomedical

structures [Yu 2006]. This problem continues to undermine efforts to develop frameworks for their evaluation and underlies the difficulty of selecting an ontology for use during data integration [Alani and Brewster 2006].

The challenge of evaluating and selecting ontologies to be used in biomedical applications therefore remains an important research and development endeavor, especially for distributed computing environments [Kalfoglou and Schorlmer 2006]. Existing approaches largely assess an ontology based on its taxonomy, and not the ability to integrate across levels of granularity commonly found in biomedical structure. This makes them unsuitable for assessing the suitability of an ontology for use in a biomedical data integration task. The result has been the proliferation of ontologies whose reuse and wide adoption in ontology-based biomedical data integration systems by industry has, like with other domains not yet been realized [Gangemi et al. 2005; EON 2006].

In this paper the results of a study to develop a reference ontology for biological and clinical data integration, as a frame of reference for assessing biomedical ontologies are presented. The reference ontology represents the essence of a biological and clinical data integration system. The properties of the reference ontology as identified from the literature were validated in a descriptive questionnaire based field study.

The rest of this paper is organized as follows. Section 2 discusses the role of biomedical ontologies for data integration. Section 3 explores current approaches to ontology evaluation, while section 4 explains how a reference ontology and metrics for biomedical ontology evaluation are derived. Section 5 presents the validation of the reference ontology. Conclusions are made in section 6.

2.0 BIOMEDICAL ONTOLOGY

Integrating data from the domains of biology and clinical medicine using ontologies is important for biomedical knowledge representation [Hongzhan et al. 2004]. Existing bio-ontologies are challenged when it comes to representing biomedical data due to its complexity, differences between and within disciplines and research groups [Keet 2003]. The vast amounts of data generated from biology and clinical medicine require integration systems to represent semantically heterogeneous data sources across levels of granularity and biomedical processes. There is therefore continuing development of new ontologies for biomedical data integration systems, and rapid evolution of existing ones involving many researchers [Perez-Rey et al. 2006; 2006; Kumar et al. 2006]. Despite these models, the lack of a unifying ontology based approach for integrating biomedical data persists [Grenon et al. 2004; Yu 2006].

Attempts to standardize data integration on a large scale have used upper level ontology theories [SUMO 2008; Gangemi et al. 2005; Grenon et al. 2004]. These ontologies have an unbounded universe of discourse, are built using different tools and theories and differ in their theoretical representation of processes, temporality, granularity, spatiality and structure [Grenon et al. 2004]. These differences become important for selecting an ontology based theory for to support data integration and knowledge representation in all fields including biomedicine [Alani and Brewster 2006].

Whatever the data integration approach used, for ontology based systems to gain wide acceptance and reuse, they need to be evaluated. Integrating biomedical data structures, function, processes across levels of granularity using ontologies therefore remains challenging, with no unifying approach against which the integrated systems can be assessed by users. This lack of a standard integration model presents a challenge for biomedical ontology evaluation. Comparing the performance of different ontology based integration systems in use thus remains problematic due to the lack of standard approaches and metrics [Kalfoglou and Schorlmer 2003].

2.1 Importance of Granularity for Biomedical Data Integration

Granularity, the ability to represent and operate at different levels of detail in data, is indispensable for managing and analyzing huge amounts of data found in biological databases and ontologies [Keet 2008]. Granularity articulates something hierarchically according to some criteria - the granular perspective [ibid]. There is no single unifying perspective for articulating granularity. Thus Keet [2008] identify perspectives of granularity as: i) arbitrary scale versus non scale dependent; ii) how levels, and its contents, in a perspective relate to each other; iii) difference in emphasis, i.e. being entity, relation, or criterion-focused; and iv) representation based on set theory or mereology.

Other granular perspectives consider range size and collectivity dealing with aggregations of individuals into collections have also been proposed [Kumar et al. 2005; Rector et al. 2006]. There is a distinction between the notions of collectivity and size range as the two dimensions of granularity [Rector et al. 2006]. The notion of collectivity is pervasive across size ranges, and is key to providing an account of whether the *part-whole* relation is, or is not transitive in biomedicine [ibid].

Health care workers require data on structures, processes and functions of organisms at the coarser levels of granularity, while for molecular biologists it is at the finer levels. This underlies the need for biomedical ontology models that integrate data across levels of granularity [Kumar et al. 2005; Rector *et al.*, 2006]. For instance, the Gene Ontology with the cell as its highest level of granularity does not offer a good framework for representation of biological processes that occur at coarser levels [Kumar et al. 2005]. Good representation of granularity in a model enables tracking of entities and attributes across levels, leading to building of better data integration systems [Kumar et al. 2006].

2.2 Issues for Ontology-based Biomedical Data Integration

Integrating biomedical data using ontologies is challenging for several reasons. There is need to overcome problems of semantic heterogeneity and bridge across levels of granularity between data sources. Biological and clinical data is to be found at different levels of detail [Smith et al. 2006; Rector et al. 2006]. Biomedical data is diverse, rapidly changing, and stored in autonomous sources that can freely modify their design, change or block access to data without notice [EMBL, 2005]. Ontologies for biomedical data integration also have to address issues of changing structure, function and processes presented by the different data sources [Kumar et al. 2005; Rector et al. 2006].

Biomedical data integration ontologies also vary in scope (purpose and users). They range from single domain (domain dependent) to generic (domain independent) models. The latter are used to integrate data across domains in the life sciences. Many approaches to ontology based integration of biomedical data have been attempted [Perez-Rey et al. 2006; 2006; Kumar et al. 2006]. However, the lack of a single unifying strategy to the problem of biomedical data integration across scope, granularity and heterogeneous data sources persists [Davidson et al. 1995; Ding and Foo, 2002].

3.0 APPROACHES TO ONTOLOGY EVALUATION

There is no unifying definition of ontology evaluation. It is a technical judgment of the contents of an ontology with respect to requirements specifications, competency questions, or a reference ontology as frame of reference [Gangemi et al. 2005; Gomez-Perez 2004]. Evaluation determines the quality and adequacy of an ontology for use in a specific context and goal [Fernández et al. 2006]. There is no unifying approach with metrics for evaluating an ontology across contexts. This remains an obstacle for their reuse and wide adoption by industry and the wider web community [Alani and Brewster 2006; Kalfoglou and Schorlmer 2006]. The result has been a multiplicity of proposed approaches for ontology evaluation based on either: i) the level of complexity of an

ontology; ii) the use of multiple criteria, and iii) the use of approaches based on semiotic theory to evaluate an ontology.

3.1 Level Based Approaches to Ontology Evaluation

Various contexts are used to conduct ontology evaluation at different levels of complexity. A taxonomy of evaluation approaches based on type and purpose and adopting levels of vocabulary, taxonomy, semantic relations, application, syntax, structure and design is provided by Brank et al. [2005], as shown in table 1.

Table 1: A level based Taxonomy of Ontology Evaluation approaches [Brank et al. 2005]

Evaluation level	Evaluation approach			
	Golden standard	Application based	Data or corpus driven	Human assessment
Lexical, vocabulary	X = applied	X	X	X
Hierarchy	X	X	X	X
Semantic relations	X	X	X	X
Content application	X	X	Not applied	X
Syntactic relations	X	Not applied	X	X
Structure, architecture, design	Not applied	Not applied	Not applied	X
Process, function, granularity	Not applied	Not applied	Not applied	Not applied

This level based taxonomy categorizes existing ontology evaluation approaches into: i) golden standard approaches that compare an ontology to a gold standard [Gomez-Perez 1994; Hovy 2001]; ii) task based approaches that assess results after using the ontology in an application [Porzel and Malaka 2004]; iii) data or corpus driven approaches that compare the fit of an ontology to domain texts [Brewster et al. 2004]; iv) human assessment against some predefined criteria [Lozano-Tello and Gomez-Perez 2004; Supekar 2005]. Table 1 illustrates the lack of a unifying approach for conducting ontology evaluation across all levels of complexity.

3.2 Ontology Evaluations Based on Semiotic Theory

Based on Semiotic theory, an ontology is a semiotic object with three evaluation levels of structure, function and usability. The structural level assesses the ontology syntax and formal semantics; the functional level assesses the ontology's cognitive semantics while the usability-related level for assesses its pragmatics [Dividino and Sonntag 2008]. Based on semiotic theory, metrics for ontology evaluation therefore consider its syntactic, semantic, and pragmatic aspects. As an application of this theory, the Semiotic-based tool [S-OntoEval] has been proposed and used to evaluate the Ontology of the Smart Web project – SWIntO, using metrics for each semiotic ontology level [ibid]. At the structural level it checks the logical consistency of an ontology model and graph theory measures e.g. depth. The functional level is a task-based evaluation approach

measuring the quality of the ontology, and [iii] on the usability-profiling level a quantitative analysis of the amount of annotation is applied [Dividino and Sonntag 2008].

Similar to the semiotic based ontology evaluation, a framework with metrics to evaluate the structure, usability and function of an ontology is described by Gangemi et al. [2005]. Functional measures assess the intended use of an ontology. Usability-profiling measures use its level of annotation to assess user-satisfaction, completeness and reliability [ibid].

3.3 Multi-Criteria Based Approaches to Ontology Evaluation

Multiple criteria approaches deal with the problem of selecting a good ontology from a given set based on defining several decision criteria or attributes. For each criterion, the ontology is evaluated and given a numerical score and an overall score computed as a weighted sum of its per-criterion scores [Lozano-Tello and Gomez-Perez 2004]. While this approach requires a lot of manual involvement by human experts, it allows a combination of criteria at many levels [ibid].

3.4. The Role of Classes and Relations for Ontology Evaluation Metrics

Classes and properties are used to describe the structure, function, knowledge representation and level of integration of an ontology and so play an important role in deriving metrics for their evaluation. Metrics provide a way to assess an ontology during its engineering and application and have been classified according to what they measure i.e. structure, function, use and semantics. The structural topology [depth and breadth] or inheritance richness, which determines the distribution of information in an ontology has been used to derive ontology evaluation metrics [Dasgupta et al 2007]. Structure and coverage metrics rank ontologies using both the ratio of class to property definitions, and the level of integration [connectedness] between ontologies [Buitelaar et al 2007].

Based on structure, Alani and Brewster [2006] describe the Class Match Measure [CMM], the Density measure [DM], Semantic similarity [SS] and Betweenness [BM] measures for ranking ontologies. The CMM assesses the coverage of an ontology for a given search term. The Density Measure estimates information-content and level of knowledge detail of classes. Structural similarity determines how close the classes that match search terms are in an ontology. Betweenness determines classes that are central to an ontology. The ratio of non *is_a* relations to the total number of relations [relational richness] is another structure based metric for comparing ontologies [Tatir et al 2005].

3.5 The Challenge for Biomedical Ontology Evaluation

Current approaches largely evaluate an ontology based on the technical aspects of design, taxonomy, content and knowledge representation and so are useful for ontology evaluation from the designer's viewpoint. The need therefore remains for studies to determine; i) the properties users require when judging the suitability of an ontology [Alani and Brewster 2006]; and ii) a holistic evaluation strategy with a greater role and participation of user communities in the evaluation process [Kalfoglou and Hu 2006].

The literature shows that for ontology evaluation metrics, emphasis has been placed on defining structural metrics on the basis of concepts while ignoring relations between concepts and their semantics [Buitelaar et al. 2007; Dasgupta et al. 2007; Tatir et al. 2005; Vrandecic and Sure 2007]. This is a major limitation since relations provide valuable information in the search for the right ontologies, at the correct level of granularity [Sabou et al 2006].

For comparing and evaluating biomedical ontology [BO] integration systems from the user's perspective, the existing approaches remain unsuitable. BOs also need to be assessed for their suitability to represent structure at differing levels of granularity. Their evaluation is related to, but can therefore not entirely be conducted solely using existing approaches. The lack of a unifying framework for evaluating biomedical ontologies therefore remains an obstacle for their reuse and adoption by industry [Alani and Brewster 2006; Fernandez et al. 2006].

The approaches and metrics presented in this paper have found use in evaluating the structure of an ontology as represented by its taxonomy. They however remain inadequate for evaluating biomedical ontologies. This is attributed to the need to conduct evaluations on both: 1] the quality and adequacy of the structure and knowledge representation in an ontology; 2] the need to model [represent] dynamic processes, function and granularity presented by biomedical ontology, in the absence of a unifying frame of reference against which such evaluation can be conducted.

4. DERIVING A REFERENCE MODEL FOR BIOMEDICAL ONTOLOGY EVALUATION

Reference or Top domain ontologies have general core classes of a given domain. These core classes interface with both top and domain ontologies. They are general purpose resources designed to generalize to other domains and offer support to a range of different types of research and clinical applications [Stenzhorn et al. 2008]. The reference model presented here is the result of a study to develop a target model as frame of reference for evaluating and selecting an ontology for use to integrate biomedical data, from among alternatives. The model presents core classes and relations that are instantiated with biomedicine as the universe of discourse. It captures and represents the essence of a biomedical ontology and together with its derived metrics are part of a framework against which other ontologies for use in integrating biomedical data may be assessed.

The reference ontology was derived using the following major steps were followed: i] description of requirements from the literature sources and their validation using a descriptive survey; ii] informal specification of the model using the requirements; iii] examining theories to fit and explain these requirements; iv] using requirements and the informal specifications to extend an existing ontology theory.

4.1 Determining Requirements for the Reference Ontology

The literature review guided the description of the scope, structure and properties of a theoretical model for biomedical data integration. A questionnaire based descriptive survey was used to validate the theoretical reference ontology with users (biologists & medical doctors) of the model. The descriptions of the theoretical model guided framing of the data collection questions on evaluating a biomedical data integration model along the themes of scope (users and use cases) and properties of a biomedical data integration model, and its representation of granularity. The descriptive survey tested the level of agreement by respondents to proposed characteristics of the reference model. The questionnaire, pretested on twenty (20) medical doctors and five (5) biologists was used to collect data and clarify requirements for the model. The study population had six hundred thirty (630) randomly selected biomedical workers (580 medical doctors and 50 biologists). Completed questionnaires were returned by four hundred four (404) medical doctors and forty six (46) biologists. The statistical package for social sciences (SPSS) was used to analyze the data and determine the level of respondent's agreement with the theoretical integration model. The resulting requirements for the integration model and its informal specification are presented in Tables 2, 3 and 4.

Table 2: Requirements for a Biomedical Data Integration Model

User category	Biologists		Medical Doctors	
	No. of responses	Agreement Level [%]	No. of responses	Agreement Level [%]
Model Genericity	46	94	404	77
Model Flexibility	46	94	404	78
Adequacy of Detail	46	87	404	75
Represent Aggregation	46	88	404	68
Supporting Meta Meta Language (theory)	46	72	404	53

The results in Table 2 confirm that a biomedical data integration model should be: i) generic in scope to cater for different biomedical data sources; ii) flexible to accept input of new biological and clinical models and formats from different sources; iii) detailed enough for users to easily recognize the important properties that make it suitable for their task; iv) represent biomedical data from sources across levels of aggregation (granularity); v) supported by a theory or language for good knowledge representation for clinical and biological concepts.

4.2. Informal specification of the Reference Ontology from Use Cases

The results in Table 3 provide respondents perspectives on the use cases for a biomedical data integration system from the descriptive survey. A use case corresponds to a requirements model and summarizes the scenarios for a single biomedical integration task or goal. Table 3 presents use cases as functional requirements a biomedical data integration model. These use cases are adopted and used to further scope the model by revealing classes and relations to be represented in the informal specification of the reference ontology structure as presented in Table 4. The requirements specifications and general properties of the reference model were derived from analyzed data from the survey. In the absence of a single unifying methodology for building ontologies, the method outlined combines aspects of several existing methodologies [Fernández López 1999; Gruninger and Fox 1995; Uschold and Gruninger 1996].

Table 3: Use cases [Competence areas] for a Biomedical Integration System

	MOLECULAR BIOLOGIST	MEDICAL DOCTORS

USE CASES [COMPETENCE AREA]	Number of respondents	Agreement Level[%]	Number of respondents	Agreement Level[%]
Relate a genetic profile to a patient	46	90	404	91
Relate clinical history to a patient	46	97	404	97
Relate patient gene profile to a disorder	46	92	404	94
Relate a person's trait to a genetic profile	46	95	404	91
Relate genetic profile to characteristics	46	92	404	93
Relate role of genes in develop. of proteins tissues and organs	46	96	404	91
Relate tissues to a genetic disorder	46	85	404	85
Relate gene prevalence to population	46	87	404	88
Determine disorder prevalence in population	46	90	404	90

Use cases in table 3 were used to informally specify requirements for the reference ontology presented in Table 4. Deriving the informal specification of the reference ontology was guided by methodologies for ontology construction that emphasize flexibility in formalizing knowledge and use of competency areas [Ushold and Gruninger 1996]. Competence areas [in Table 3] were used to re-scope the reference-ontology by identifying its main motivating scenarios and applications. Motivating scenarios are used to extract the main concepts and relations of the reference-ontology, and the resulting description taken as requirements specification against which an ontology can be assessed [Gomez-Perez 2004].

Analysis of the statements presented by these scenarios enabled biological and clinical concepts, and their corresponding relationships for the reference-ontology to be derived. These concepts and relationships between biological and clinical types derived from use case statements are given as informal specification in table 4. These concepts [objects] and relations are the basis for the derived informal specification of the reference-ontology for biomedical data integration.

Table 4: Informal specification of the Reference-ontology

COMPETENCE SCENARIO	BIOLOGICAL OBJECTS	CLINICAL OBJECTS	OBJECT RELATIONS
Genetic profile of a patient	Genetic profile	Patient	Patient <i>has</i> genetic profile
Clinical history of a patient		Clinical-history, Patient	Clinical history <i>has_participant</i> Patient

Patient gene profile to disorder or disease	Genetic profile	Patient, Disease, Disorder	Patient <i>has</i> gene profile; Gene <i>participate_in</i> disorder
Persons genetic trait to a genetic profile	Gene trait, Genetic profile	Person	Person <i>may have</i> trait Genetic profile <i>cause of</i> trait
Role of genes in develop. of proteins tissues and organs	Gene, Protein dev, Protein, Tissue, Organ		Gene <i>participates_in</i> Protein-dev. ; Protein <i>part of</i> tissue Tissue <i>par_of</i> organ
Tissues or organs affected by a genetic disorder	Tissues, Organs	Disorder, Disease	Organ <i>participates_in</i> disorder.
Prevalence of genetic disorder in population	Gene	Population, disorderPrevalence	Population <i>may have</i> disorder prevalence

Table 4 reveals classes and relations in the informal specification that are used to derive the biomedical reference ontology. Classes like disease and disorder are revealed as processes, while others [e.g. organ] are shown as non process distinct types for structuring knowledge during biomedical data integration.

Intra and *trans_domain* relationships within and between biological and clinical classes are also revealed. Intra domain relationships are identified between biological objects [e.g. Gene *participates_in* Protein development], or clinical objects [e.g. Clinical history *has_participant* Patient] of the same hierarchy. Trans domain relations between different hierarchies are also revealed between clinical and biological objects. Trans domain relations are also seen to model biomedical objects at different levels of aggregation [e.g. Patient *has* gene]. Relations between processes and non-processual types are also revealed [e.g. Organ *may_have* Disorder].

The informal specification in table 6 provides concepts and relations to be represented in the structure of the biomedical Reference ontology. Examining table 6 also revealed that the proposed biomedical reference-ontology represented in the specification models via its relations: 1] structure and processes for clinical and biological data integration; 2] biological and clinical data types across levels of granularity. Biomedical structure [objects and relations], processes and representation of granularity are therefore properties that need to be captured in the design of a biomedical integration reference-ontology. The choice of an ontology theory to reuse and extend is therefore informed by its fit to these requirements. The informal specification [Table 6] is therefore considered in the selection of the ontology theory to reuse and in the design of the reference or target biomedical reference-ontology [TaMO].

4.3. The Role of Basic Formal Ontology in Deriving Model

Basic formal ontology [BFO] with its modular framework has been used to model biomedical reality. It is a bi-ontological theory having the Snap [continuant] and Span [occurrent] sub ontologies. The snap sub ontology

models independent entities and function, while the span sub ontology models processual entities [BFO, 2008; Grenon et al. 2004]. The two complementary sub ontologies provide a framework for modeling biomedical structure, function and processes. BFO's structure supports both *intra* ontological relations [e.g. *is_a*, *has_part*, *contained_in*] between classes in the same ontology and *trans* ontological relations [e.g. *participates_in*] between classes of different ontologies [Grenon et al. 2004]. These relations provide the basis to model BFO's universal classes as the mereological sum of its objects [e.g. *ObjectAggregate*] or processes [e.g. *ProcessAggregate*]. These mereologically defined universal classes together with the *intra* and *trans* ontological relations offer a suitable framework for multiple representation of granularity by BFO. The ability to represent structure, function, processes and granularity justify the adoption of BFO as a suitable upper level ontology theory for modeling biomedical reality. It provides a suitable framework for representing the requirements of the biomedical reference-ontology. It was thus adopted in this study as the underlying baseline theory for developing a reference ontology for biomedical data integration. The informal specification (Table 4) with its newly defined biological and clinical classes was therefore used to extend selected universal classes of BFO in order to derive the reference ontology model.

4.4 The Reference Ontology

From the informal specification descriptions, the reference-ontology was implemented using the Web Ontology Language [OWL DL] in protégé. OWL DL is supported by description logics that offer a good formal foundation plus automated reasoning to check the classification hierarchy of the taxonomy and its consistency. Protégé, is a First Order Logic based, OWL compatible stand alone ontology development and editing tool. It supports ontology browsing, documentation, import and export to and from different formats. BFO OWL files were imported into Protégé and extended to generate the biomedical reference-model. The resulting reference-model extends BFO via *its object*, *objectAggregate*, *quality*, *role* and *process* universals. Selection of the appropriate universal to extend was based on their theoretical definitions as provided by BFO [Grenon et al. 2004]. The resulting reference-model is illustrated in figure 1 as an OWL file of Protege' using the OWL Viz plug in tool.

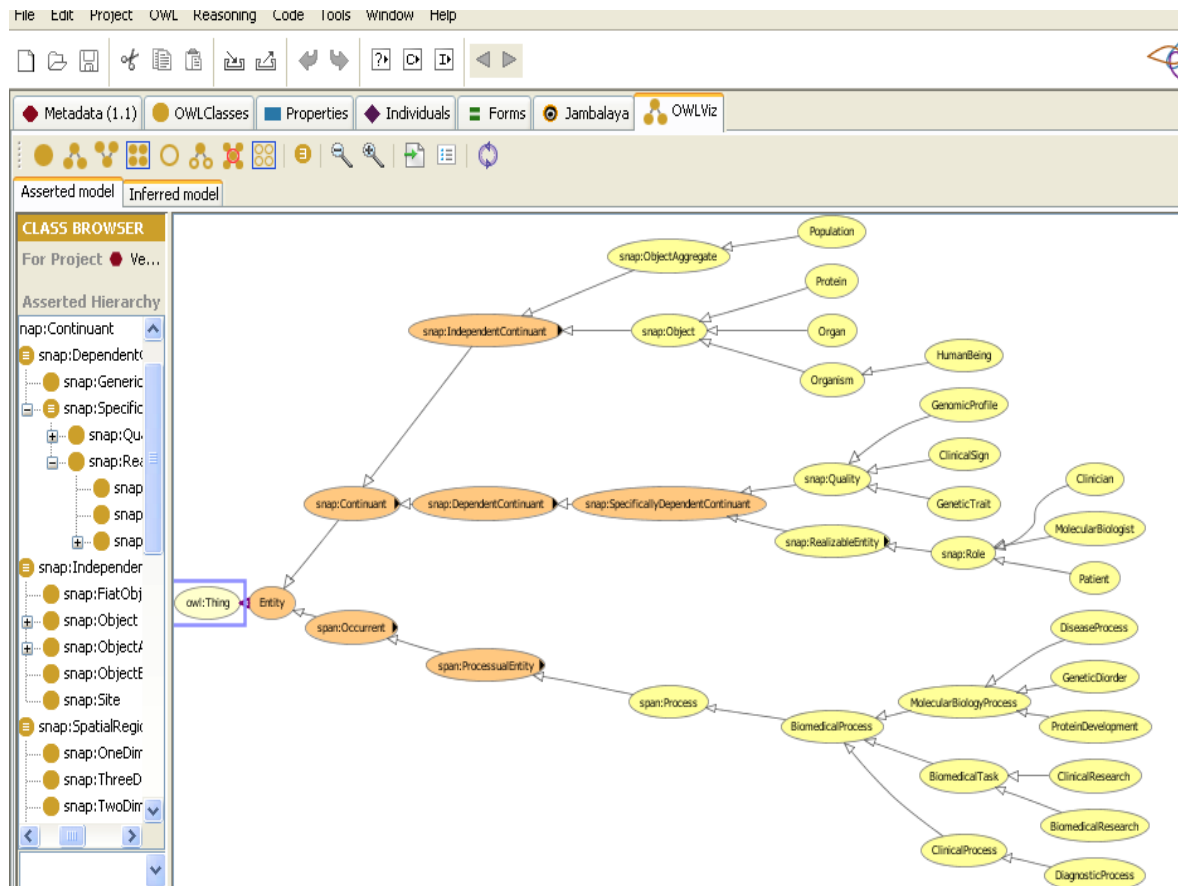


Fig. 1. The Reference Ontology extending a BFO file in Protégé, shown using OWL Viz.

The reference ontology [Figure.1] models biomedical structure across levels of granularity; important properties required for selection of a biomedical data integration model. By modeling biomedical structure and granularity, the reference ontology provides the basis for their use to define metrics useful in evaluating these properties.

4.5. A Metric for Measuring Representation of Granularity [Granular Density]

The metric defined for representation of granularity using the model provides an evaluation measure from properties agreed on by users. The metric is derived from biomedical relations by adopting the principles of mereology. To define metrics for use in selecting a suitable ontology for representing biomedical structure across levels of granularity, relations as defined in BFO and the relational ontology are used [Smith *et al.*, 2005]. The OBO relational ontology [RO] provides consistent and unambiguous formal definitions of the relational expressions used in OBO library ontologies, [ibid].

In the reference ontology [Figure 1], granularity is articulated using descriptions of relations of class aggregations e.g. *part_of* and *contained_in*. The *part_of* relation is both *intra* and *trans* ontological as it can be

used to model relationships between biological and clinical classes e.g. the relation *human being part_of population*. This is an aggregation relationship in which population is a collection of human beings. Another example is *object contained_in objectAggregate* that articulates granularity based on size. By describing different relationships between objects and packages, the reference ontology supports multiple perspectives of granularity according to size and collectives.

This perspective of granularity as collectives linked by relations is used to derive a metric that assesses the representation of biomedical data across levels of granularity in an ontology. *Intra* and *trans* ontological relations in the reference ontology are used to define the metric. Trans ontological relations like *part_of*, *has_part* and *contained_in* model collectives. Their density in an ontology is therefore an indicator of its ability to model collectives. A metric for measuring the level to which an ontology models granularity in the ontology is therefore expressed as, the ratio of trans ontological relations that model collectives to all trans ontological relations present in the ontology. This ratio or the granular density is derived as follows.

Deriving Granular Density [G_d].

Let R_{co} represent a trans ontological relation modeling collectives per node in an ontology. Suppose the number of nodes which have the R_{co} is K ,

All R_{co} will be given by $\sum_{i=1}^k R_{co}$

Let R_{to} represent a trans ontological relations per node in an ontology, and let the nodes in an entire ontology be n .

All R_{to} will be given by $\sum_{i=1}^n R_{to}$;

where $k \leq n$; and k is a subset of n .

Then the Granular density G_d is given by:
$$\frac{\sum_{i=1}^k R_{co}}{\sum_{i=1}^n R_{to}} \quad \text{[Equation 4.7]}$$

An ideal ontology should have a G_d ratio of 1.0 for a given integration task. A G_d ratio of 0 [zero] denotes a lack of relations to represent granularity. The higher the G_d ratio, the better an ontology is for modeling granularity. This metric provides a basis for selecting the most suitable ontology for integrating biomedical data across levels of granularity that are common in biomedicine.

5. VALIDATION OF THE REFERENCE MODEL APPROACH

The utility of the Reference-model approach was demonstrated by a tool developed as part of a flexible user centered framework for evaluating biomedical ontologies [Maiga and Williams 2008]. The tool was implemented in the visual studio 2005 integrated development environment, in C# and SqlExpress2005 database management system. The tools database consisted of summaries of the human phenotypic ontology [HPO] and the infectious disease ontology [IDO], selected from the open biomedical ontologies [OBO] library [Smith et al 2007].

The tool based on the algorithm in figure 2 allows different users the flexibility to iteratively search through an ontology library using multiple criteria. This is more likely to result into the selection of a suitable ontology for a given task, or re-specification of new requirements for an ontology to fit the task. The prototype tool

developed using this algorithm enables a user to select a biomedical ontology that supports development of a suitable application for their integration using Granular density as one of the metrics applied.

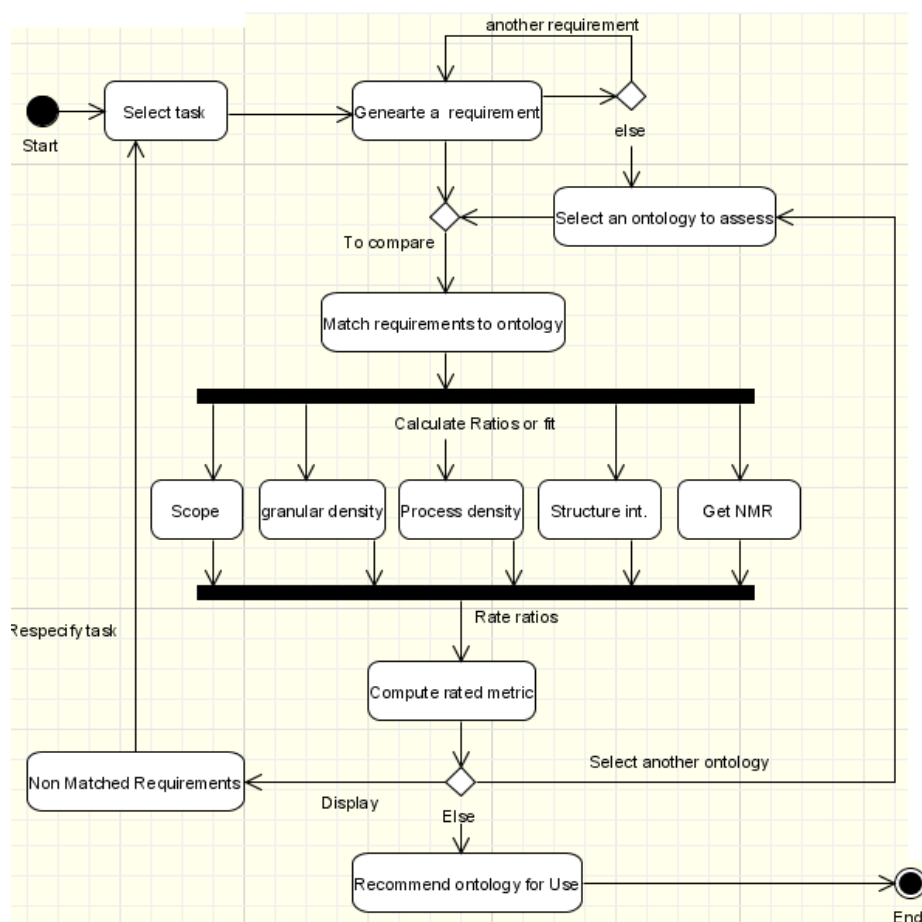


Figure 2: The Assessment Tools Algorithm as a UML Activity Diagram

5.2 Evaluating the infectious disease Ontology [IDO]

Previous attempts to validate ontology evaluations have used tools that either: i) compared the results of assessing an ontology in experiments using the tool to those by other approaches as controls or ii) compared the results of assessing an ontology using the tool to human assessment by expert users, ontology consumers and domain experts [Tartir et al. 2005; Alani and Brewster 2006; Cross and Pal 2006]. The first approach is ideal for mature ontologies that have previously been evaluated by other tools using similar or related metrics, with data available for comparison. For IDO, no such data was available. The tool was used to assess the ability of IDO to match requirements for a selected biomedical data integration task. IDO is a set of interoperable ontologies that provide coverage of the infectious disease domain. They define general entities relevant to biomedical and clinical aspects of infectious diseases. Experiments using the tool compared the ontology for their ability support different use case scenarios of biomedical data integration applications. Use case scenarios differed by the integration task selected, the requirements generated as a set of search terms and by the relative importance

of these requirements or search terms for the users task. The output of using the tool to assess the IDO ontology for the different use case scenarios as illustrated in Figure. 3

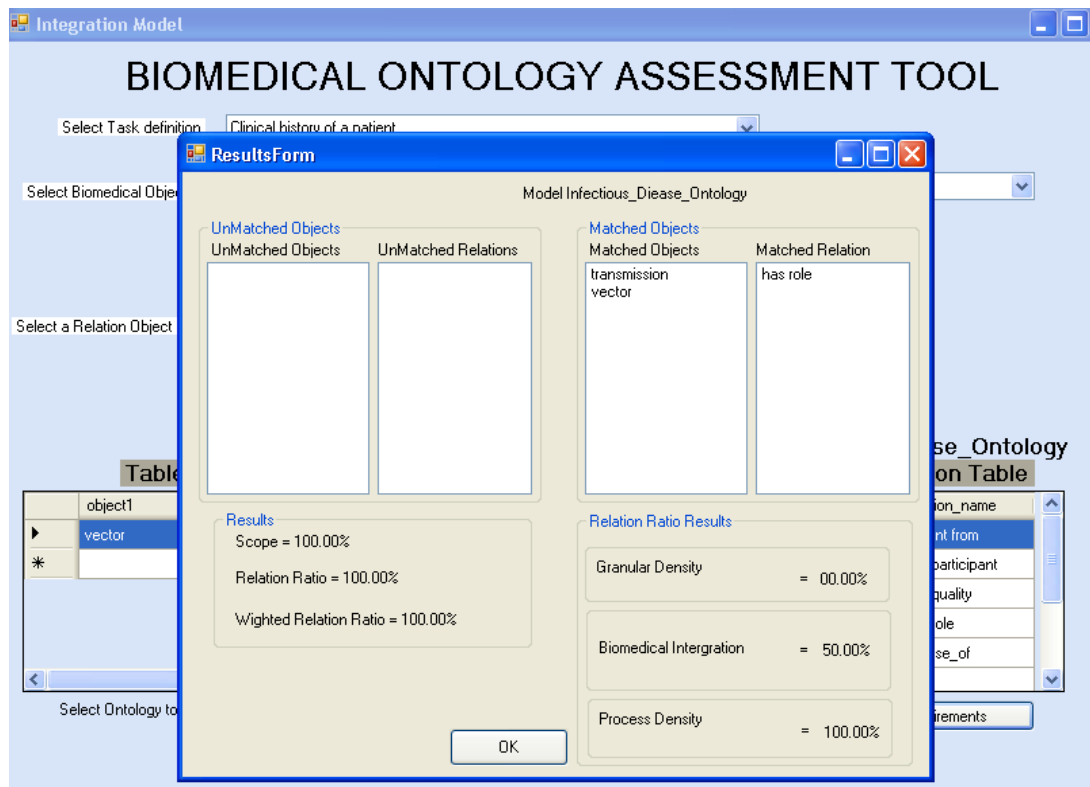


Figure.3. The Tool's Results Interface

The results displayed as scores of scope, process density, granular density and biomedical integration. Scope indicates of how well an ontology's classes represent requirements for an integration task. For the tool, it is expressed as the number of objects [% search terms] in the requirements that are present or found in the ontology model. These scores are basis for a user to select the ontology, re-specify requirements or select another ontology to rate. The result also displays any unmatched requirements [search terms].

5.8. The Pearson Correlation

The results of assessing IDO with the tool [TA] were compared to those by a questionnaire based human assessment [HA] study using a Pearson correlation [r] for significance. A random selection of 32 biomedical workers [18 medical doctors and 14 biologists] was used for this test. The questionnaire had a screen shot of the IDO model, two tables with six use case scenarios for applying the model and instructions on how to fill in the tables. For each scenario, a question was asked about the models [IDO] ability to represent biomedical processes and representation of levels of granularity. Answers to these questions were used to calculate the

granular and process density ratios. The tool results [TA] of assessing IDO and corresponding ones from a questionnaire based human assessment [HA] for the different use case scenarios were compared and the corresponding Pearson correlation coefficients are given in table 6.

Metric scored	The Pearson correlation [r]	Valid metric?
Granular density	0.968	Yes
Process density	0.657	Yes

Table 6: Pearson Correlation [r] of Tool Scores against Human Assessments for IDO

The r values from the tool and corresponding ones from the questionnaire based human assessment show a moderate to strong positive correlation between the two sets [r = 0 means zero correlation; r = 1 means strong positive correlation; r = -1 means strong negative correlation].

The strong positive correlation between TA and HA is an indication of the success of the tool used, and the validity of our approach.

6. CONCLUSIONS

This paper presents a reference ontology as frame of reference for user evaluations of ontologies for biomedical data integration. The reference ontology is neither a top level nor a domain [or application] ontology. It is an interface between the two, making it a top domain ontology. Requirements for the model from a field study were used to derive the core classes of the reference ontology that are used to extend Basic formal ontology [BFO] as a meta theory to support the model. Core classes of the reference ontology extend five BFO classes of Object, Quality, ObjectAggregate, Role and Process. Relations between these core classes are used to derive metrics for assessing structure, process and granularity as dimensions against which biomedical ontology evaluations may be performed. The metrics provide a theoretical basis for evaluating biomedical ontologies.

The strength of this model is underlined by: [i] the theoretical support offered by the basic formal ontology in representing biomedical structure, processes and multiple aspects of granularity; [ii] the flexible and extensible nature of the model since new objects, processes and relations can be added to it, [iii] providing theoretical metrics to be used for biomedical ontology evaluation based on the principles of mereology; [iv] providing the design of an easy to use evaluation tool.

The reference ontology is both flexible and extensible. New objects can be added to the model. New relations can also be described to support emergent classes a definite advantage as it allows for description of objects, new processes and definition of multiple perspectives of granularity within the same model. The reference model is therefore adaptable to other domains that integrate data across levels of granularity and processes.

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Reduction of Poverty Using ICT in SADC Region: A case Study

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Abstract

Poverty reduction is a prominent issue for both governments and international organisations. It is one of the millennium development goals of the UN. Developing countries have high poverty levels than developed ones. However the diffusion of basic information and communications technologies (ICTs) services have penetrated majority of developing countries. Using SADC (South African Development Community) region as a case study, this paper explores ways through which ICTs can help in poverty reduction. Data from Botswana is used to investigate how ICTs can be used in poverty reduction. Some Asian countries, India in particular have shown that it is possible for developing countries to position themselves and improve their economies using ICTs. Previous research on impact of ICTs concentrated more on issues of education, national economic development, social and cultural aspects and less on ICTs as a means to achieve poverty reduction in developing countries. ICT landscape within some SADC countries shows the realisation that ICT can leverage economic development. However, there is lack of concrete practical steps on making the necessary social and administrative adjustment to promote ICT use. Administrative operations in majority of these countries are still paper based. Commercial banks are far ahead of government institutions in innovative use of ICT for example major banks have embraced internet, telephone and mobile banking. Lack of cyber law in SADC is the major limiting factor for expanded application of ICT. The ability ICTs to allow working from “anywhere anytime” means that if well implemented ICTs can distribute employment opportunities within a country as well as reduce rural to urban migration which is the major cause of poverty in urban areas of developing countries.

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1. INTRODUCTION

1.1 Definition of Information and Communication Technologies and Poverty

Information and Communication Technologies (ICTs)

Information and communication have been advancing very fast. Today ICTs are generally regarded as the driving force behind the economy in every country. ICTs include all communication devices or applications, electronic networks services including hardware applied through networks services [1], [24]. These include mobile phone, internet, software systems, hardwares, computing information services, multimedia, telephone, fax, and electronic news. Businesses, organisations and the commercial sectors depend heavily on this technology [15].

Some of the benefits of using technology in communications may include faster and enhanced communication, and provision of services efficiently. In many cities, ICTs are a source of employment for citizens (ICT professionals), providing faster and easier working patterns, helping to define the role of organisations and simplifying the nature of work and also helping in growing the country's economy through its adoption by SMEs [8],[34]. Public service, commercial and industrial organisations are using ICTs to do purchasing, marketing, operations, customer profiles, suppliers profile, information exchanges, clients contact, suppliers contact and customers contact [11]. Today, many company directors and managers have taken advantage of e-commerce and e-business as new concepts in their day-to-day service delivery, to ensure that their services and business decisions are promoted to attract many customers efficiently [38].

Governments have also resorted to e-Governance, to better offer their services to clients. Others have also adopted e-Democracy especially in democratic states where governments would want to allow participatory majority through dialogues and chats as a means of communication at government and public forums [22]. At schools ICTs are fused into education to enhance research and expand the quality of learning [40]. One of the major concerns has been the importance of ICT as a means to reduce poverty. As Duuff has put it, "History shows how ICTs have developed over years: from the agricultural society, through the industrialised society and now to the information society" [12 p.354]. Many places now use ICTs. Today, more benefits of ICTs are even extended to the economical status of each country which is made up of a wider society. According to Duff, it is important to look at such areas where ICT has been developing, to find out whether society has been informed and whether they have benefited from it as a result of new technological developments [12].

Botswana like many other countries worldwide is not left behind in ICTs. In local cities, towns, villages and settlements there are some form of ICTs that are being utilised. The country has also introduced policies for expanding and enhancing ICT use. These policies are part of the liberalization of the national telecommunication plans to bring the government and the whole country into the global information age [30]. One significant effect of the policies is that usability of ICT in the country is growing faster due to level of access rollout across the country.

Poverty

The debate on the definition of poverty and its measures has been on-going since the first half of the 20th century. Poverty has no generally accepted definition. For many people poverty is state of vulnerability which makes the people susceptible to abuse and exploitation by those who have a better life. The old school definition of poverty was premised upon Charles Booth's (cited in Davies 1978) invention of "poverty line" [10]. According to this definition, a person whose incomes fall below poverty datum line was regarded poor. Booth's original work also showed that poverty is a social condition. By contrast, recent studies argue that poverty cannot be understood based on figures only. In other words, poverty is regarded as a multifaceted issue, which cuts across all sectors of the economy. It has a social, economic, political and cultural dimension which makes it a priority to policy makers worldwide [16]. According to World Bank, poverty is defined as "the inability to attain a minimal standard of living" [48]. This definition was adopted by many countries over the years. An overview of the economy with regard to poverty shows that there are some disparities between urban and rural centres across the world. Rural areas are hard hit by inequalities and high poverty levels. Most studies perceived a "poor" person to be somebody who is unskilled, unqualified and have little power to make demands [27], [16]. However, Vandenberg view is that, although some of the perceived causes of poverty can be related to intelligence, it is erroneous to equate poverty with low ability and character defects [44]. Vandenberg is of the view that people under economically poor category would not fit in such description.

Due to levels of poverty in Botswana, the country is classified among the third world and developing nations. Many of these countries worldwide have since looked for means to fight poverty [7]. Some developmental goals have been set to push the standard of living for citizens. This include millennium development goals especially the provision of a good life to citizens. National leaders seem convinced that ICTs can be used in this area to counter crises of poverty, especially through complex situations which are economic, educational, political, and even the other challenges facing the poor [24].

1.2 Scope of the paper

Based on the introductory notes, one on ICTs use as an economical player, and the other on the definition of poverty, this paper provides links between the two, giving glimpses of a wide variety of research and action regarding ICTs and its uses in the society. Such links include human development as part of provisions by the government of Botswana to improve the lives of citizens, universal access based on pricing of the information communications technologies and services offered and ICT innovation for faster service delivery, all of which have the potential to lead to poverty reduction. The paper seeks to look into data from literature and other sources especially reports on the impact of ICTs and poverty reduction. Literature is then reviewed to find out the impact of ICTs as a means to reduce poverty. Recommendations are proposed at the end to foster extra supplementary improvements for the rollout of ICTs, issues around ICTs adoption and use by members of the society in an attempt to reduce poverty. While the paper seeks to inform on the relationship between ICTs and poverty reduction in Botswana, its other objective is to help address the paucity of the literature of ICT in Botswana.

1.3 Research Questions

In order to investigate the role of ICT in reducing poverty, the following research questions were formulated to guide the study. The escalation and use of ICT worldwide has been emerging faster, what has been the case in regard to its readiness and use in Botswana? What about the relevance of ICTs to the society, and its impact to Botswana in the indices of poverty reduction? Does ICT reduce socio-economic divisions between the rich and the poor?

2. METHODOLOGY

The study used case study approach involving the use of multiple sources of evidence to understand a phenomenon [47]. Document and textual analysis involving the use of data from reading and analysing reports, news and information were sourced from the Ministry of Communications Science and Technology of Botswana government, Botswana Telecommunications Authority and local ICT service providers. News on the efforts by the state government and other local ICT service providers to enrich the citizenry regarding ICT access and policies were studied from online newspapers and other internet sources for evidence. Telephone interviews were conducted with senior personnel at Mascom Wireless and Orange Botswana (mobile phone and internet providers), Botsnet (Internet service providers) were asked to define their roles in rolling out ICTs in Botswana to help reduce poverty from affected members of the society. The study was undertaken in March 2010.

3. LITERATURE REVIEW

There is limited research on the role of ICTs in the reduction of poverty and promoting socio-economic development in developing nations [21], [33], [8]. Clarke and Englebright have attempted to define ICT as a basic skill, which includes computing technologies, domestic and commercial systems and equipment [8]. This paper supports literature that ICT covers the use of technology to handle information and aid communications, and that its main characteristic is that it keeps changing and improving for the better, with newer versions released from time to time.

Kelles-Viitanen concurs with the UNDP report that “using ICT in pursuit of developmental goals allows countries to achieve a wide diffusion of benefits from ICT, which, in the end will benefit broad-based economic growth, too” [23 p.85], [43], [29]. In her report, Kelles-Viitanen mentions that ICTs can create some employment opportunities for the poor, citing examples such as Grameen Bank in Bangladesh, and other countries such as Malaysia and Taipei. In a report by the World Bank, Information communication technologies are reported to have played an important role in the growth of the economy across many countries [17]. In their study, the researchers considered ‘Trade and the reduced transactions costs of business,’ and ‘capital accumulation,’ as significant factors around ICTs and economic theory. Trade and the reduced transactions costs of business as a result of ICTs refer to the level of business increase, increase in variety of service related activities, efficient supply chain across borders. These factors according to Grace et al., “have created new opportunities for large and small firms from developing countries to increase their sales range and tap into the global market for goods and services” [17 p.7]. Capital accumulation through the use of ICTs refers to the situation when finance networks become digital, and get expanded. An example cited here is ‘AutoBank E,’ a fully automated savings system which minimizes paperwork and transactions costs. This system has been developed and intended for use by the poorest depositors in South Africa [28]. This simply increases the ability of the poor to access financial services.

A study by Spence & Smith has also revealed that indeed there has been some booming of ICTs in many countries irrespective of their economic status, and its use is known to facilitate the expansion of markets, social businesses and public services [42]. A couple of examples cited by Spence and Smith include the explosion of

mobile phone use, internet communication and networking services, which enable banking systems and financial transactions, marketing and distributions, employment creation, personal and public services [42]. While some of these can be equated to major economical impacts, expectations are that they improve the personal well being of an individual, thereby reducing and preventing poverty. Mobile phone service providers employ many people to serve as ICT shop managers, back office staff, networking specialists, cashiers, marketing and advertising agents thereby adding to their wealth and improving their well being. Mobile phone users are able to save money by utilising their cell phones instead of going to the banks for financial transactions, and their personal securities are improved [4]. Another benefit cited by Spence & Smith is communication and networking enabled by ICTs as these have the potential to transform the economics of a country even the poorer ones [42]. When connectivity is expanded to the poor, through ICT services, they would get employment, be served better, faster and efficiently through these networked services.

It has become a surety in many countries that information communication technologies are being utilised to become instruments of government policies. ICTs have been used to create information intensive activities to serve national goals and also serve as the developmental opportunities of information for intensive industries [3]. Examples cited here include the impressive economic success of Singapore, Korea, Hong-Kong and Taiwan. Many countries like India and Indonesia have used mass media technologies for national building purposes. In India, SITE (Satellite Instructional Television Experiment) project – a satellite – was used to reach and educate remote communities, while in Indonesia the satellite communications were used to reach many people in the country's many islands (Morison cited in [42]). Other countries like Mauritius have developed several cycles of e-strategies as part of their broader national development programs, and others are already looking into the potential role of ICTs in the developmental efforts to help reduce poverty among citizens [39].

Many developing countries have faced challenges to fight health related issues including the HIV/AIDS scourge. In India for example, the development of Health-care databases, telemedicine, web-based initiatives, and health information systems are some ICT initiatives that have been adopted by the health system [37], [5]. Examples elaborated in this research include “the management of HIV programmes which requires data from various sources such as the mother, child and HIV- specific programmes” [37 p. 268] While the Indian health sector has gone through challenges at its initial stages, the results also proved that as ICT in India developed during those years, signs of serious rewards were also emerging. One other example of ICT use is ICT as an enabler for education for Africa. With the call for education for all, governments have since been committed to meeting the growing demand for the delivery of education services to its populations. ICTs have been placed at the centre of educational developments especially in Africa [20].

4. PRESENTATION OF SECONDARY DATA

4.1 ICT infrastructure and access in Botswana

Many of the Sub-Saharan countries fall in the low-income category. Botswana is counted among the countries regarded as middle-income due to the higher levels of per-capita telecommunications infrastructure, personal computers, internet hosts, telephone main lines, and mobile phones [39]. Compared to other countries in this spectrum, the economical performance of Botswana has a direct bearing on the state of education, infrastructure, health and services through the availability and affordability of ICTs for public, business and private use.

The government of Botswana through the Ministry of Communications Science and Technology has established ICTs tele-centres nationally equipped with necessary infrastructure for ICT related businesses. At these centres, citizens, especially the youth are provided with internet facilities, telephone, fax and other secretarial services on daily basis. These tele-centres are under the care of district youth officers. As confirmed by Saboo in email, at these centres the government wants to develop human resources - especially among the youth - that support

the deployment and rehabilitation of modern ICT infrastructure [41]. Commercial developments especially at the rural areas are also supported through tele-centres, and there are computer training, thereby giving desktop skills to the unemployed youth who could later get employment elsewhere. Also at these centres, there are job advertisements, application forms for national identity (Oman) and passport, one can obtain funding and school registration, etc.

One area which has not been effectively impacted by ICT in Botswana is health services. Recently, there have been reports of introducing ICTs at health centres of hospitals and clinics to provide fast and modernised health services to citizens. The Internet nowadays is loaded with most popular sites offering health services to online audience members. Specific health agencies like NACA (National AIDS Coordinating Agency), BOTUSA (BOTswana-USA), BOCAIP (BOTswana Christian AIDS Intervention Programme), BOFWA (BOTswana Family Welfare Association) and even the Ministry of Health, provide all members of the public with information and advice on health issues through their websites. Other ICT services found in Botswana's health sector include free direct telephone services, and new hospitals like Bokamoso (<http://www.bokamosohospital.com>) have websites where patients from all walks of life can contact their medical doctors from time to time. At some local private clinics, medical records are kept in databases and this is beneficial to all people since doctors can easily deal with patients understanding their medical histories. Recently, in a survey report by BOPA (BOTswana Press Agency) in the *Daily News* Mr Nick Ndaba (columnist) indicated that the newly introduced telemedicine in Botswana would help reduce the shortage of health professionals and extend health care resources in Botswana [6]. Mr Ndaba also mentioned that Botswana intends to implement national telemedicine centre, and this will be carried out in stages.

Local post offices are equipped with relevant ICT infrastructure to ease service delivery. There is electronic mail service, fax, electronic money transfer, emailing and internet services provided. Significant efforts are being made by the government to make sure that citizens at rural areas utilise ICT through these post offices. Vehicle registration and licence fees can be paid at most of the post offices in the country.

The government of Botswana has recently launched e-governance service, to ensure that its citizens are provided with information which calls for public participation in national developments. Through e-governance, there is a government portal – a web portal- where citizens are provided with information as to how the government can serve them better. Information on the portal is linked with websites of all the ministries to also extend the information to citizens about how such ministries can serve them better. Other ministries have gone an extra mile to reach their potential customers through ICTs. At the Ministry of Agriculture, video films are provided through television broadcasts (BTV-BOTswana TeleVision) and DVDs to reach to potential farmers, training them on farming and arable agriculture skills so that they can improve yields out of their farming businesses. Using ICTs, the ministry of Defence and Security through Botswana police has also produced videos on Botswana television to alert citizens on issues of crime. Through telephoning 999, which is an ICTs service, customers with telephone lines can call for help in cases of danger and when in need of emergency. The police, the ambulance and the fire department can send help and appropriate action will be taken.

The government of Botswana through the Ministry of Education intends to build an educated and informed nation and ICTs are critical in making this possible. Many ICTs are utilised to expand knowledge sharing through educational centres, television, radio, newspapers, electronic billboards and many other mediums. The Botswana Examination Council has also provided e-service through the internet, where graduating students from primary, junior secondary and senior secondary schools can access their examination grades online. At the local schools, the University of Botswana for example, part of the teaching and learning is done through e-learning. Other services provided in the education sector include advertising schools through ICTs, via the Internet, offering services like online registration through ITS systems, etc. Libraries of data are also available

through the internet; therefore working from home in your own natural environment instead of commuting to school library is possible.

Financial institutions in Botswana have introduced e-banking and through use of debits cards customers do not have to carry money around when shopping. At some banks including FNB and Barclays, telephone banking has been introduced. Through the service, customers are able to communicate with bank representatives who will assist them anywhere they are at any time. In addition, automatic teller machines (ATMs) are availed to many towns and large villages in Botswana. These technologies allow customers to transfer money and provide them with extra facilities, such as mini statements. Commercial banks in Botswana are exploiting existing ICT infrastructure to meet their business needs. They have enabled online banking, mobile banking as well as online bill payments. Commercial banks in Botswana are in the forefront of application of ICT than even central government.

Internet shopping, which is a new development in Botswana, is likely to widen choice for goods, lower costs and better selection especially those coming from physical shopping, and increase convenience as it expands [32]. With ICTs, a lack of transport can at least be partially removed. Although not all shoppers have access to online shopping especially the poor, it is still a welcome development and hopes are that this will soon be possible for all shoppers in the near future, when everyone will have access to the internet.

An area where ICT use has the potential to have significant impact in Botswana's environment is in e-commuting. This is because urban areas are facing acute shortage of accommodation forcing property prices to be beyond reach of many. A significant number of employees in Botswana commute long distances and yet the transport sector is well behind in application of ICT to improve e-commuting as practiced in developed countries where a single ticket can be used in buses, trains and airplanes, a feature that serves the tourism sector well.

4.2 Level of ICT use in Botswana

While ICT infrastructure in Botswana is among the best in Africa, not many Botswana (Botswana nationals) especially in rural areas benefit directly from it. Several factors including lack of skill to utilise ICT equipment, lack of skill to utilise ICT service and levels of acquisition in relevance to the economical stand of each household are a hindrance to the use of ICTs in Botswana. Research has been made easy through the internet, and new teaching and learning methods' including the use of WebCT at the University of Botswana has been a welcome development. In an interview with Mr Grant Son, General Manager of Botsnet, his organisation has realised that not many Botswana have access to ICTs services of internet; therefore they have decided to reduce the pricing for internet service provision. They have embarked on a wide marketing campaign for this service, and other additional benefits to make sure it is accessible to customers including laptop vouchers as part of the package. Other mobile phone company managers interviewed (Orange and Mascom Botswana), mentioned that reducing prices for the internet service at Botsnet has made it affordable to many Botswana and other internet service providers are compelled by these low market prices to also reduce theirs.

As researchers have put it, information communication technology provides the necessary to pay for services, and through this, new job opportunities are created and labour intense duties become easier [46]. Civil servants and officers at private institutions and other organisations are utilising the computer, phone and fax machines provided in their office to their benefit and to the benefit of the society. With the use of the internet, through online and virtual communications, the poor communities are assisted easily and quickly. Even during national disasters, citizens are given information faster through televisions, radio and telephones, and this makes them understand national issues.

The advent of mobile telephony has transformed the communication landscape and added value to personal communication. This new form of communication has a number of advantages over fixed lines. Many cell phone models now have digital video and still cameras, radio, and internet capabilities thus making the device a digital media hub. Users are not limited to any location as long as network coverage is available by their service providers. As a consequence, users can make calls, send text and multimedia messages, chat, send email and voice mail, play games, music and videos. The cell phone has rapidly transformed the lives of many individuals [19]. The device provides some nearness in relevance to communication, and through its use it has positively impacted the social bonds between families and friends [25]. Mobile phone service providers support local artists by signing contracts to provide ringtones, caller tunes etc [13]. Through these services, even the less popular artists benefit through advertising since they are able to reach over 1 million Mascom subscribers and sell their music to them through this platform.

Through online and telephone banking services provided by some of the local banks, they can now sell their products to customers easily. Studies have shown that many bank customers have resorted to the services, citing that it saves both time and costs [31]. Although this sector may pose threats due to challenges of security and full access; such developments have been welcome by many who now see it as an important way to cut costs. There is no need to pay transportation fees to travel to banks, and the prices of using ICTs provided by the banks from anywhere is less compared to those of getting the service straight at the banks. Also at the banks, “computers and communication systems provide instant information on the state of accounts and provide fast transfer of transactions between branches of the same bank and between different banks” [35 p.120]. In a survey sponsored by two of the commercial banks in Botswana (Barclays and Standard Chartered Bank), it has been noted that cell phone-based remittance and banking services may be one way to extend the reach of financial services to the poor [45]. Online services requiring e-commerce are found in almost every commercial webpage. As the number of products sold on the web keeps increasing, the web becomes populated and internet commerce will rise [18]. The incentive for both users and host is that the services are catering for everyone and provided at cheaper prices.

Through e-governance, the government of Botswana managed to push service delivery for the betterment of its citizens. The idea by many countries to do this is to make sure that all government services are available electronically [26]. Most ministries and departments in Botswana now provide services through ICT infrastructure. E-passports are now provided at the ministry of Home Affairs, with the idea to catch up with the developed world standards and also to check frauds. Such services are also extended to short message services where clients to the ministry are sent messages to alert them that their passports are ready. The service is good for all, ensuring that customers do not have to keep coming to the ministry (losing a lot of money through transportation) to check if their passports are ready.

ICTs are also available in Botswana for recreational purposes. This includes radio broadcast online, computer games, webcasts, DVDs, and social networking through sites like <http://www.facebook.com>, <http://www.twitter.com> and <http://www.myspace.com> etc, which are essential for the youths and academics as well in Botswana. In fact, ICT based entertainment is expanding. While studies have shown that youth from poor communities are vulnerable to criminal acts, recreational activities through ICTs will engage them and keep them away from illegal acts.

Although low bandwidth is currently limiting advance application of internet ICT based application, this will soon not be the case as connection to the East Africa Submarine System (Eassy) begins to yield results [2]. This will be improved further once Botswana has connected to the West Africa Cable System (WACS) which will further increase internet speed in Botswana [2].

4.3 Level of Readiness

A level of readiness refers to the degree to which the user is prepared and willing to make use of ICT. As Gasco-Hernandez, Equiza-Lopez, & Acevedo-Ruz, have put it, “Often the true value of ICT for poor people will reside in how their intermediaries – local government, public-service institutions like schools or clinics, non-governmental organisations, community radio stations, and so forth – can use ICT to better address their individual needs” [14 p.xi]. One of the reasons why the poor cannot access ICTs fully is their limited access to technologies [24]. Internet use in Botswana is estimated to be about 6%, a very low figure in comparison with European countries; however this is a gradual increase from figures of previous years [49]. The level of readiness is gradually increasing, since many young people are showing interest and the Ministry of Communications Science and Technology is busy making sure that citizens are given access through rollout to post offices, youth centres and tele-centres. In many countries especially in Europe, these tele-centres have been developed in rural areas to assist local groups to collect, manage, and disseminate information that other citizens needed to live independently [36]. As part of Botswana government’s service to its people, incorporating ICTs must come secondary to broader reform agenda considered on its own merits. In the process of introducing and implementing ICTs, acceptance by all key stakeholders is necessary, there should be identification for reform, identification of system requirements, and identification of the need for ICTs. While such efforts by the government of Botswana to rollout ICT services through tele-centres, post offices, there is need to monitor these projects and ensure that every member of the society is guaranteed access. With these efforts in place to push for access for all, maximum impact is guaranteed especially through service delivery [9]. Access should precede service rollout and prioritization should be given to the members of the rural community, marginalised groups and the poor.

5. CONCLUSIONS

Current status of ICT in Botswana shows a political will to develop and expand ICT infrastructure within the country. However, in terms of poverty reduction, the impact of infrastructure and connectivity is limited because ICT is used as a commodity. There is a need for Botswana in particular and the SADC region in general to undertake paradigm shift from paper based data/information exchange and develop models for the future that will enable competitive differentiation using ICT. For instance, India has shown exemplary achievements by focusing on high quality tertiary education in ICT domain as a country and it has become a net exporter of ICT graduates who are highly in demand globally.

The potential for ICT role in reduction of poverty in developing countries is enabling access to global markets, expansion of markets of goods, minimizing rural urban migration etc. ICTs generate economic value when they are used to support innovation. The banking industry in Botswana is a motivating factor in the area of ICT and has continuously been growing. At the moment there is a need for Botswana to develop security, stability, integration of information systems to facilitate secure digital data and information exchange to meet global business needs. This will open up market opportunities in Botswana as soon as bandwidth and internet speed problems are solved through Eassy/WACS and indirectly reduce poverty levels in the country through ICT based business operations. There is also an urgent need to develop cyber law in Botswana which the country has been striving of with an output soon.

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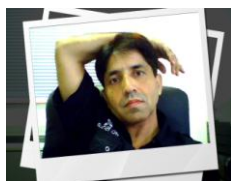
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A Formal Approach to Modelling Delegation Policy Based On Subject Attributes And Role Hierarchy

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Abstract

There are considerable number of approaches to policy specification both for security and policy driven network management. This specification sort security policies into two basic types: authorization and obligation policies. Most of the researches in security policies specification over the years focus on authorization policy modelling. In this paper, we report our approach in developing an information security policy model with specific emphasis on delegation of roles as a form of obligation policy. Whilst noting the previous research works on delegation modelling, we considered subjects and roles attributes in refining and formulating delegation relation attributes rules using concept of set theory. The work was further extended by developing a formal model for role hierarchy based on permissions and integrating it into the delegation model developed to eliminate flatness of subject roles. Future works proposed include the development of a formal model for revocation after delegation and extension of the model with the principle of separation of duties.

Categories and Subject Descriptors: F.4 [Mathematical Logic and Formal Languages] - F.4.1 Mathematical Logic – Model Theory.

D.4 [Operating System] – D.4.6 Security and Protection – Access Control.

General Terms: Information Security, Delegation Policy, Modelling, Role Hierarchy

Additional keywords and Phrases: Subjects, Objects, Roles, Attributes

1. INTRODUCTION TO SECURITY POLICIES

According to Slomam and Lupu (2002), security policies can be sorted into two basic types: authorization and obligation policies. Authorization policies specify what an action a given subject (agent, roles, user or process) is permitted or forbidden to perform on a set of target objects. The concept is similar to the role – based access control (RBAC). Authorization policy can either be positive (defining the actions subjects are permitted to perform on the target objects) or negative (specifying the actions subjects are forbidden to perform on target object). Therefore, authorization policies are used to define access control rules implemented by several types of mechanisms in a network security system such as packet filters, Kerberos and Virtual Private Networks (VPNs).

Authorization policies are of the form:

```
auth [+/-] <subject>      ───────────▶ if <condition> then
                               <target> <action>;
```

1.1

Obligation policies are rules that specify what activities a subject must or must not perform on a set of target object under an optionally specified condition or system event. In other words, obligation policies are used to specify job functions related to security management. Obligation policies are event triggered condition – action rules that can be used to define the activities subjects must perform on objects in the target domain i.e. the duties of these subjects. In network security context, obligation policies can be used to specify the behaviour of mechanisms such as logging agents, intrusion detection systems and watchdogs.

Obligation policies are of form:

```
on <event> do
    if <conditions> then
        <target> <action>;
```

1.2

2. SECURITY POLICY REPRESENTATION

There are considerable number of approaches to policy specification both for security management and policy driven network management purposes as reported by Sloman and Lupu (2002). However, Model Based Management (MBM) proposed in (Luck et al, 2001 and Luck et al, 2002) will be adopted as the basis of the research policy modelling. The MBM approach supports the building of policy hierarchies by means of an interactive graphical design. It adopts concept of object oriented design and employs a model of the system that is vertically structured into three sets of layers. Three abstraction levels are recognised: Roles and Objects (RO), subjects and Resources (SR) and Processes and Hosts (PH). Each level is a refinement of the superior level in the sense of policy hierarchy (Moffet and Sloman, 1993). The uppermost level (RO) is based on the concept of Role-Based Access Control (RBAC) (Sandhu et al, 1996 and Ferraiolo et al, 1999). The Roles which are the acts of the people working in the modelled environment, and Objects of the modelled environment which should be subjected to Access Control and AccessModes form the main classes at the first level.

The Second level (SR) offers a system view of the model defined from the standpoint of the services that the system will provide. Objects of these classes represent (a) the people working in the modelled environment (Users); (b) Subjects acting on the user's behalf (SubjectTypes), (c) Services in the modelled environment that are used to access Resources (Services); (d) dependency of service(s) on another service(s) (ServiceDependency), and (e) Resources in the modelled environment (Resources).

The lowest level (PH) is responsible for modelling the mechanisms that will be used to implement the security services defined in SR

AccessPermission can be further sub divided into one or more ServicePermissions which expresses an authorization for SubjectType (on behalf of user) to use a Service to access Resource. Further to this, a class ProtocolPermission is now defined in the lowest level PH as the rules that either validate or invalidate the ServicePermission.

Policies development, formalization and validation must start at the Subject Resources level where the following entities have been earlier identified at this level, the User Objects (U_{sr}) of the system, the SubjectType (SubTy), the Services (Srv) and the Resources (Rsc).

A problem of MBM occurs when dealing with large system since the representation of the policies and objects tends to lose much of its understand ability and getting obscure due to the great number of elements (Albuquerque et al, 2005). Another issue is that it does not model obligation policy since it is built on RBAC strictly.

Albuquerque et al, 2005 designed the Diagram of Abstract (DAS). It was introduced as a layer immediately above the PH level as an extension of the MBM. Its main objective was to describe the overall structure of the system in a modular fashion. i.e. to cast the system into its building blocks (Abstract Subsystem) and to indicate the connection between them. Therefore DAS is a graph comprises as Abstract Subsystems as nodes with edges that represent the possibility of bidirectional communication between ASs. An AS, in turn, is an abstract view of a system segment; i.e. a simplified representation of a given group of system components. As such, an AS is itself a subgraph of a DAS.

This model represents a typical network environment, for which three *AccessPermissions* are defined at the uppermost level (RO), in order to regulate the access rights of the users in the internal network with respect to service request. To complete the modelling, each AS in a DAS is expanded into a detailed view of the actual mechanisms of the system; i.e. the PH level. it can be observed that modeling through abstract subsystems offers concrete advantages in the conciseness and understandability of the model, as well as providing an intelligible view of the system architecture.

Aside from the aforementioned modeling improvements, the DAS is also advantageous to policy support and model validation.

DAS also has a problem dealing with large system since the representation of the policies and objects tends to lose much of its understand ability and getting obscure due to the great number of elements (Albuquerque et al, 2005). Another issue is that it does not model obligation policy.

3. INFORMATION SECURITY POLICY MODELING

The information security policy model (PolM) proposed is a 5 – tuples represented as follows:

$$PolM = \{RolObj, SeClr, SBjRsv, PerM, Dlg\} \quad 3.1$$

Where

- (i) $RolObj$ is a set containing the different roles (Rol_n) and objects (Obj_n) belonging to the various ROLES and OBJECTS within the modelled environment.

Therefore,

$$RolObj = \{Rol_n \in Rol \wedge Obj_n \in Obj\} \quad 3.2$$

- (ii) $SeClr$ denotes a set of SECURITY CLEARANCE which corresponds to a set of disjoint classes of sensitivity level and category sets. Instead of being restrictive in using the terms employed in the military system such as “TOP SECRET”, “SECRET”, “CONFIDENTIAL”, “UNCLASSIFIED”, e.t.c; $SeClr$ shall be defined as follows

$$SeClr = \{seclr_1, seclr_2 \dots \dots \dots seclr_n\} \quad 3.3$$

Where n is a finite integer and the relationship between two security clearance within this set is denoted by \leq where \leq is a partial order on $seclr_i$ for $1 \leq i \leq n$ such that $(SeClr, \leq)$ is a partial ordered set.

- (iii) $SBJRsv$ denotes the set of subjects (Sbj_n), Subject dependency ($SbjDep_n$) and Resources (Rsv_n) and Resources dependency ($RsvDep_n$) within the modelled environment.

Thus,

$$SBJRsv = \{sbj_n, SbjDep_n \in SBJ \wedge Rsv_n, RsvDep_n \in RSV\} \quad 3.4$$

- (iv) $PerM$ is defined as the permission which shall be referred to as the authorization constraint. It modelled the authorization policy aspect of the modelled environment and is a set containing Service Permission ($SrvPm$) and Access Permission ($AccPm$) which is a function of Access mode ($AccM$) as granted by the Security Clearance ($SeClr$).

Therefore,

Access Permission is a function $AccPm$ which allows explicit permission for Subject (Sbj) to access Objects (Obj) in a way defined by an AccessMode ($AccM$) as granted by the Security Clearance ($SeClr$).

$$AccPm = f\{Sbj \Leftrightarrow Obj \text{ as defined by } AccM\} \quad 3.5$$

For all $Sbj_n \in Sbj$, $Obj_n \in Obj$ and $AccM_n \in AccM$

Subject to;

$$SeClr = \begin{cases} Authorized, & 1 \leq i < n \\ Not Authorized, & otherwise \end{cases}$$

On the other hand,

the triples of Subject, Object and Access Mode not supported by the function Access Permission denotes negative authorizations and are completely forbidden but must be enforce by the security mechanisms.

From the above, authorization policy is define in RoObj as a class Access Permission which allow a subject through the define Role to access a particular Object in a way approved by the Access Mode subject to Security Clearance.

Service Permission is a function SrvPm which allows explicit permission of Subject (Sbj) to access Resources (Obj) depending on the availability of the Resources and Security Clearance (SeClr). Service Permission (SrvPm) can therefore be viewed as the relations between UserObjects, SubjectType, the Services and Resources according to the object security clearance and is depicted as

$$SrvPm = f(Sbj_n \Leftrightarrow Obj_n \text{ subject to Seclr}) \quad 3.6$$

In developing the policy model, the following assumptions will be made:

- i) The classification of an object is always at least as high as the maximum classification of the objects it contains.
- ii) All Access permission requests must have a classification label achieve by security clearance.
- iii) A request on an object or resources by a subject or services can only be granted if the clearance level of the subject or services is equal or greater than the classification label of the object or resources.
- (v) Dlg is defined as the delegation (Dlg), which is the mechanism that enables active entity(ies) in a system to transfer authority to another active entity(ies) in order to carry out some functions on its behalf based on trust (Trt) (Barka and Sandhu, 2000). This model the Obligation policy aspect of the modelled environment. Abdallah and Takabi (2010) developed a formal representation for delegation and integrate it into RBAC models; Chunxiao et al, (2006), Barka and Sandhu (2000), and Barka and Sandhu (2000) developed an attribute based delegation model and its extensions, a role based delegation model and some extensions and role based delegation model/Hierachical roles respectively. Hence, the delegation model proposed extract the best features of their works, refine it and introduce subject attributes as an extension of delegation in order to satisfy the condition for obligation policy.

Hence, when Subjects (Sbj) are assigned Roles (Rol) and are authorised through Permission (PerM) to perform tasks on Object (Obj) and or Resources (Rsv). Thus, we define

$$Role_Permission : \{Sbj \leftrightarrow Rol\} \text{ are authorised by } PerM \exists AccPm \vee SrvPm$$

3.7

While

$$Task_Permission : \{Sbj \leftrightarrow ((Obj) \vee (Rsv)) \text{ as defined by Role_Permission}\}$$

3.8

Therefore, the Relations: Role_Permission that assigns roles to each subjects; and Task_Permission that allowed subjects performed tasks on each objects or resources form the main classes and serve as the basis of the delegation modelling.

Information Security Policy Delegation (PoDl_g) is the ability of delegator (Subjects) to assigned roles to a delegatee (another subject or group of subjects). Policy Delegation can only be said to be successful if the delegator has the capability to allocate roles and the delegatee should be capable of being assigned the roles. For the purpose of the modelling, the following assumptions will be made:

- (i) Each Subject is assigned at least one Role.
- (ii) All Roles assigned to known Subject are recognized roles (Subset of Roles).
- (iii) Each recognised role is associated with a non – empty set of tasks permitted to perform. i.e. the task permitted by each roles are valid (subset of Tasks.)
- (iv) Roles are defined in hierarchical manner as stated in (Barka and Sandhu, 2000) but which may be subjective.
- (v) All Subjects within the modelled environment have a well defined attributes.
- (vi) Subjects may have one or more attributes but that are related.
- (vii) Objects and Resources within the modelled environment all have defined attributes.
- (viii) Roles are defined within the context of separation of duties (SoD) of subjects.

Delegation can be sorted into two by refining the Subjects, Roles and Role_Permissions into two differentiable units; Original (Subjects, Roles and Role_Permissions) and Delegated (Subjects, Roles and Role_Permissions).

From this we represent Core_Role_Permission and Core_Task_Permission as follows:

$$\begin{aligned} \text{Cor_Role_Permission} = \\ SBj_o((Rol_o)) \text{ authorised by } PerM_o[Role_Permisision_o] \Rightarrow \\ SBj_d((Rol_d)) \text{ authorised by } PerM_d[Role_Permisision_d] \end{aligned}$$

3.9

Where Role_Permission is as defined in equation 3.7 and the subscript o and d denote original and delegated respectively.

Equation 3.9 can further be simplify as follows by factorisation

$$\text{Cor_Role_Permission} = \\ SBj_{o\wedge d}((Rol_{o\wedge d})) \text{ authorised by } PerM_{o\wedge d}[Role_Permisision_{o\wedge d}]$$

3.10

While

$$\begin{aligned} \text{Core_Task_Permission} &= \text{Sbj}_o \leftrightarrow \\ &((\text{Obj}_o) \vee (\text{Rsv}_o)) \text{ authorised by } [\text{Role_Permission}_o] \end{aligned} \quad 3.11$$

Therefore, Core Delegation is defined as a relation as follows:

$$\text{Core_Dlg} : \{ \text{Core_Role_Permission} \leftrightarrow \text{Core_Task_Permission} \} \quad 3.12$$

Hence, the relation Core_Delegation relates Subjects to the Roles which originally have been assigned to them as well as to the Roles which have been delegated to them. Thus, a Subject is permitted to assume Role to carry out Task originally assigned to it in addition to those Role(s) and Task(s) delegated to it.

Core_Delegation can be sorted into Independent_Core_Delegation and Dependent_Core_Delegation.

Independent_Core_Delegation identify the Subject Original Roles and the Subject inherited Role (Subject Delegated Roles).

$$\text{Ind_Cor_Dlg} \cup \text{Dep_Cor_Dlg} = \text{Core_Dlg} \quad 3.13$$

while

$$\text{Ind_Cor_Dlg} \cap \text{Dep_Cor_Dlg} = \emptyset \quad 3.14$$

Core_Delegation can also be Permanent or Temporary.

Permanent Core delegation can be formalized as follows:

$$\begin{aligned} \text{Pr_Core_Dlg} &= \\ f \left\{ \begin{array}{l} \text{Core_Dlg} | \exists (\text{Rol}_o, \text{Rol}_d \in \text{Rol}_{Pr}) \text{ and } (\text{Sbj}_o^i, \text{Sbj}_d^k \in \text{Sbj}_{Pr}^n) \\ \text{where} \\ (\text{Sbj}_o^i(\text{Rol}_{o(Pr)})) \rightarrow (\text{Sbj}_d^k(\text{Rol}_{d(Pr)})) \text{ authorised by Role_Permission}_o \end{array} \right\} \end{aligned} \quad 3.15$$

This can be further simplify as

$$\text{Pr_Core_Dlg} = f \left\{ \begin{array}{l} \text{Core_Dlg} | \exists (\text{Rol}_o, \text{Rol}_d \in \text{Rol}_{Pr}) \text{ and } (\text{Sbj}_o^i, \text{Sbj}_d^k \in \text{Sbj}_{Pr}^n) \\ \text{where} \\ (\text{Sbj}_{o=d(Pr)}^{i=k}(\text{Rol}_{o=d(Pr)})) \text{ authorised by Role_Permission}_o \end{array} \right\} \quad 3.16$$

While Temporary Core Delegation can formalized as follows:

$$\text{Tr_Core_Dlg} = f \left\{ \begin{array}{l} \text{Core_Dlg} | \exists (Rol_o, Rol_d, Rol_{Tr} \in Rol_{Pr}) \text{ and } (Sbj_o^i, Sbj_d^k \in SBj_{Pr}^n) \\ \text{where} \\ (Sbj_o^i(Pr)(Rol_o(Pr))) \rightarrow (Sbj_d^k(Tr)(Rol_d(Tr))) \text{ authorised by Role_Permission}_o \end{array} \right\}$$

3.17

This can further be simplify as

$$\text{Tr_Core_Dlg} = f \left\{ \begin{array}{l} \text{Core_Dlg} | \exists (Rol_o, Rol_d, Rol_{Tr} \in Rol_{Pr}) \text{ and } (Sbj_o^i, Sbj_d^k \in SBj_{Pr}^n) \\ \text{where} \\ (Sbj_o^i \geq_d^k(Pr \geq Tr)(Rol_o(Tr))) \text{ authorised by Role_Permission}_o \end{array} \right\}$$

3.18

4. MODELING DELEGATION POLICY WITH ATTRIBUTE OF SUBJECTS, ROLES AND OBJECTS

Zhang et al, 2003; identify three types of situations in which delegation takes place: backup of roles, decentralization of authority and collaboration of work. Many studies have been done in delegation (Stein, 1987; Moffett, 1990; Gasser and McDermott, 1990), and considerable attention is paid to human to-human delegation (Zhang *et al*, 2001, Zhang *et al*, 2003; Barka and Sandhu, 2000a; Barka and Sandhu 2000b; Barka , 2002; Barka and Sandhu 2004). But there are still some problems in delegation needing to be solved (Chunxiao et al, 2006):

1. Because delegation is controlled by the delegator itself, a malicious user can delegate some important permission to low level delegates.
2. The delegation security relies heavily on the security administrator.
3. Delegation prerequisite condition cannot restrict the scope of delegates more strictly.
4. It may be difficult for a delegator to select qualified delegates.

Chunxiao et al, 2006 designed an attribute based model and its extension (ABDM_X). They proposed a novel delegation model ABDM and its extension ABDM_X. As a delegation model based on permission and user's attributes, the main feature of it is that it uses user and permission attributes expression as a part of delegation constraint. ABDM is a securer delegation model for it can restrict delegatee candidates more strictly. ABDM_X is more flexible than ABDM in delegation. In ABDM_X, a delegator can temporarily delegate *Non Monotonic Permission* to low level users without causing any security problems. Both ABDM and ABDM_X can be used in temporary and permanent delegation and make delegation securer and more flexible.

The Delegation Model designed and described above is extended by refining ABDM_X and extending it into our model with the formalization of Subjects' attributes, and extension with Role hierarchy Model.

The concept of attribute – based delegation identify that all Objects, Subjects and Roles within the modelled environment must have unique attributes and access control are enforced based on computation of attributes

expression relations. In some of the existing models (Al-Kahtani and Sandhu, 2002; Al-Kahtani, 2003), only users can have attributes and attributes expression. Chunxiao et al, (2006), made an improvement over this by extending attributes and attributes expression to permissions. They identify user's Delegation Attributes Expressions (DAEs) to include user's qualifications and abilities, while permission's DAE indicate a Delegation's qualifications and abilities required by the permission in delegation. We extend the works with the introduction of Roles and Objects attributes; attributes expression and the formulation of Delegation Relation and Delegation Relation Attributes Rules. Thus, we define the following notations:

- Sbj_Atr , Rol_Atr , Obj/Rsv_Atr , Rol_Hry , Sbj_Atr_Exp , Rol_Atr_Exp , are Subject attributes, Role attributes, Object/Resources attributes, Role Hierarchy, Subject attributes expression and Role attributes Expression respectively.
- Delegation Attribute is a relation of Sbj_Atr , Rol_Atr and Obj/Rsv_Atr given as

$$Dlg_Atr = \{Dlg_Atr | where \exists (Sbj_Atr_i \in Sbj_Atr) \times (Rol_Atr_i \in Rol_Atr) \times (Obj/Rsv_Atr_i \in Obj/Rsv_Atr) \forall Sbj_Atr, Rol_Atr, Obj/Rsv_Atr \in Atr\}$$

4.1

- Delegation attribute expression is formulated as follows based on the validity of the rules given below:

Table 1: Delegation Attribute Relation Expression

RULES	ATTRIBUTES RELATION EXPRESSION	DESCRIPTION
Rule 1	<p>if $\exists (Sbj_Atr_Exp_i \cup Sbj_Atr_Exp_k)$ and $(Rol_Atr_Exp_i \cup Rol_Atr_Exp_k) \forall Sbj_i, Sbj_k \in Sbj$ and $Rol_i, Rol_k \in Rol$</p> <p>Then</p> $Dlg_Atr_Exp = \{Dlg_Atr Rol_i: Rol_i(Sbj_i) \rightarrow Sbj_k\}$ $\therefore Sbj_k \rightarrow Obj/Rsv_i$ <p>where $i = k$</p> <p style="text-align: right;">4.2</p>	A situation where Sbj_i of Rol_i and Sbj_k of Rol_k share the same or similar attributes and attributes expression.
Rule 2	<p>if $\exists (Sbj_Atr_Exp_i \cap Sbj_Atr_Exp_k)$ and $(Rol_Atr_Exp_i \cap Rol_Atr_Exp_k) \forall Sbj_i, Sbj_k \in Sbj$ and $Rol_i, Rol_k \in Rol$</p> <p>Then</p> $Dlg_Atr_Exp = \{Dlg_Atr Rol_i: Rol_i(Sbj_i) \rightleftharpoons Sbj_k\}$ $\therefore Sbj_k \rightleftharpoons Obj/Rsv_i$ <p>Where $i \geq k$</p> <p style="text-align: right;">4.3</p>	A situation where Sbj_i of Rol_i and Sbj_k of Rol_k share some similar attributes and attributes expression but not all.
Rule 3	<p>if $\exists (Sbj_Atr_Exp_i \cap Sbj_Atr_Exp_k) = \emptyset$ and $(Rol_Atr_Exp_i \cap Rol_Atr_Exp_k) = \emptyset, \forall Sbj_i, Sbj_k \in Sbj$ and $Rol_i, Rol_k \in Rol$</p> <p>Then</p> $Dlg_Atr_Exp = \{Dlg_Atr Rol_i: Rol_i(Sbj_i) \nrightarrow Sbj_k\}$	A situation where Sbj_i of Rol_i and Sbj_k of Rol_k did not share nor

	$\therefore Sbj_k \nrightarrow Obj/Rsv_i$ Where $i \neq k$	4.4	have any attributes and attributes expression at all.
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5. MODELING DELEGATION POLICY WITH ROLE HIERARCHY

It is pertinent to state that all the roles that we have been in consideration for delegation model above are flat roles and inheritance between roles are not absolutely considered. However, role hierarchy is to be considered with inheritance between roles to extend delegation and delegation attributes rules that we have modelled above. Abdallah and Takabi (2010) captured the concept of role hierarchy as a partial ordering relation denoted by “SENIOR”, on a set ROLE such that $r1 \text{ SENIOR } r2$ indicates that role $r1$ is higher in the role hierarchy than role $r2$. Being a partial order means that the relation is transitive, reflexive and anti – symmetric. A schematic diagram depicting role hierarchy is shown below

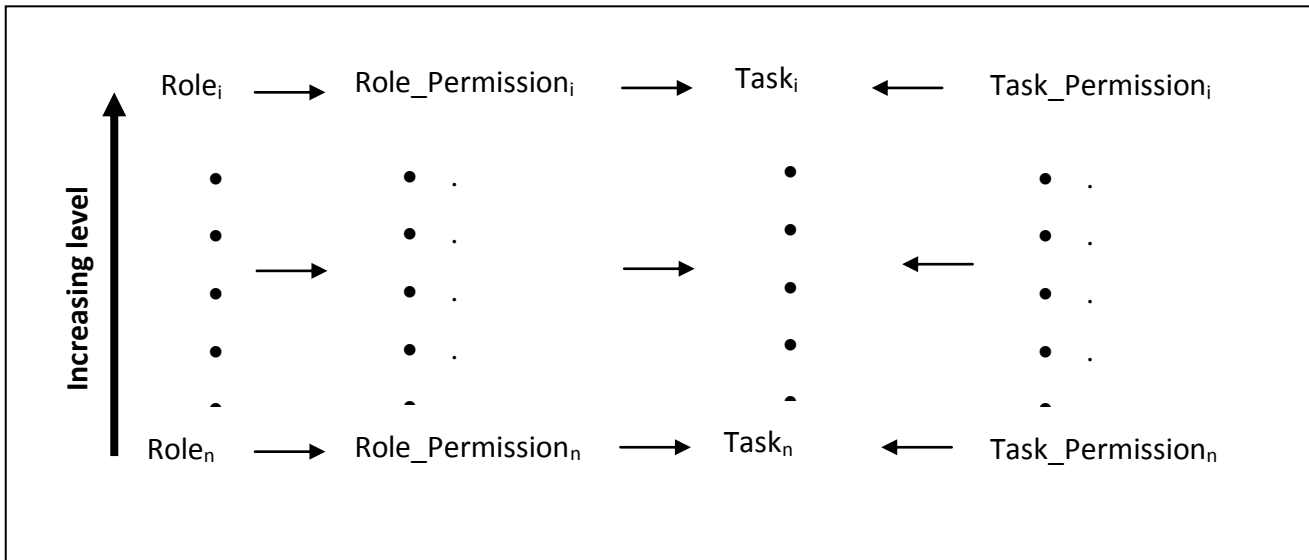


Fig 1: Regular Role Hierarchy

Therefore, we formalized Regular Role hierarchy Rol_Hry as follows:

$$\forall Rol_i \dots \dots \dots Rol_n \in Rol \quad \text{where } Rol_i \dots \dots \dots Rol_n \text{ are sets of Roles}$$

and

$$Role_Permission_i \dots \dots \dots Role_Permission_n \in Role_Permission \quad 5.1$$

$$if \exists Rol_i > Rol_{i-1} > \dots \dots \dots > Rol_n$$

and

$$Role_Permission_i > Role_Permission_{i-1} > \dots \dots \dots > Rol_n \quad 5.2$$

such that

$$Rol_i \neq Rol_{i-1} \neq \dots \dots \dots \neq Rol_n \quad 5.3$$

and

$$Role_Permission_i(Task_i) \cap Role_Permission_{i-1}(Task_{i-1}) \cap \dots \dots \dots \cap \\ Role_Permission_n(Task_n) = \emptyset$$

5.4

where

$$n \leq level \leq i$$

Then, we have a valid Regular Role Hierarchy

From the above, we extend our delegation model above by formalizing and integrating it with regular role hierarchy

Therefore, Delegation Model based on Regular Role Hierarchy defined as *Dlg_Rol_Hry* can be formalized as follows:

$$(if \exists (Sbj_i, Sbj_n \in Sbj) \text{ and } (Obj_i, Obj_n \in Obj)) \text{ belonging to } (Rol_i, Rol_n \in Rol)$$

$$\forall Role_Permission_i, Role_Permission_n \in Role_Permission \quad 5.5$$

where

$$Rol_Hry : \{Rol, Role_Permission\} \text{ satisfied } Rol_Hry \text{ as defined in (5.1 to 5.4)} \quad 5.6$$

then

$$Dlg_Rol_Hry : Rol_i(Sbj_i) \rightarrow Sbj_n \quad 5.7$$

and

$$Sbj_n \leftarrow Sbj_Atr_Exp_i(Sbj_i) \quad 5.8$$

such that

$$Role_Permission_n(Rol_n) \subseteq Role_Permission_i(Rol_i) \quad 5.9$$

$$\text{Then } Sbj_n \rightarrow Obj_i \quad 5.10$$

This mean that based on valid computation of the above, we can have a delegation model based on attributes and Role Hierarchy.

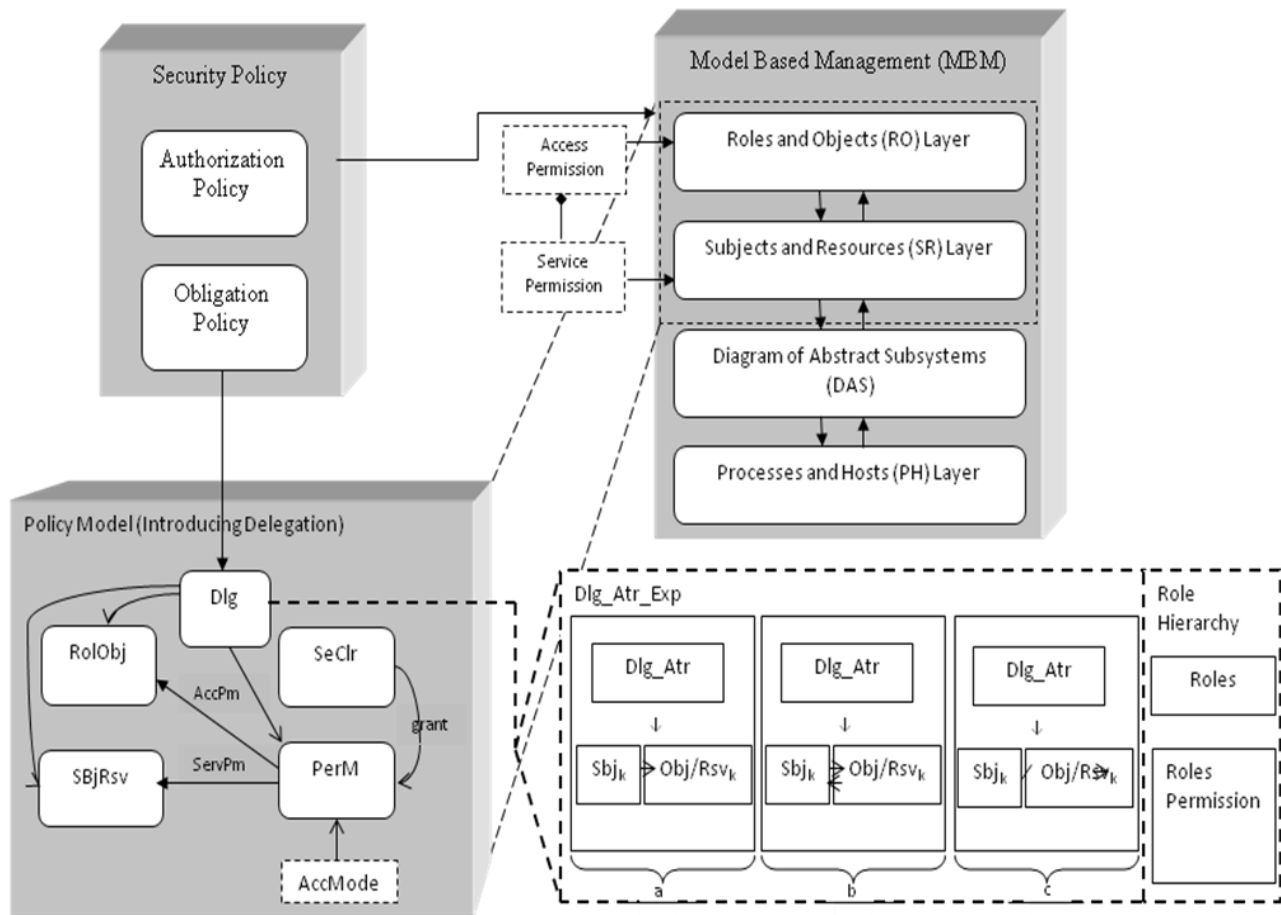


Fig 2: Schematic Architecture of the Information Security Model Designed.

6. CONCLUSION

In this paper, we have described the development of a formal model for information security design with particular emphasis on delegation. The delegation model developed outline new simple rules for a delegator to assign roles to a delegatee based on subjects and roles attributes. The work considered subjects and roles attributes in refining and formulating delegation relation attributes rules using concept of set theory. The work was further extended by developing a formal model for role hierarchy based on permissions and integrating it into the delegation model developed to eliminate flatness of subject roles. The model considered the hierarchy in subject roles as an extension to the formalization, and a pre – requisite condition for successful delegation to ensure secure access control.

Future works proposed include an analytical computation of the model, the development of a formal model for revocation after delegation, extension of the model with the principle of separation of duties and adaptability of the model to real world environment to validate and further refine the model.

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