Policies for Green Computing and E-Waste in Nigeria

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Abstract: Computers today are an integral part of individuals' lives all around the world, but unfortunately these devices are toxic to the environment given the materials used, their limited battery life and technological obsolescence. Individuals are concerned about the hazardous materials ever present in computers, even if the importance of various attributes differs, and that a more environment - friendly attitude can be obtained through exposure to educational materials. In this paper, we aim to delineate the problem of e-waste in Nigeria and highlight a series of measures and the advantage they herald for our country and propose a series of action steps to develop in these areas further. It is possible for Nigeria to have an immediate economic stimulus and job creation while moving quickly to abide by the requirements of climate change legislation and energy efficiency directives. The costs of implementing energy efficiency and renewable energy measures are minimal as they are not cash expenditures but rather investments paid back by future, continuous energy savings.

Keywords: Green Computing, eco trends, climate change, e-waste and eco-friendly

1. INTRODUCTION

Green computing is the environmentally responsible and eco-friendly use of computers and their resources. In broader terms, it is also defined as the study of designing, manufacturing/engineering, using and disposing of computing devices in a way that reduces their environmental impact. Green computing aims to attain economic viability and improve the way computing devices are used. Green IT practices include the development of environmentally sustainable production practices, energy efficient computers and improved disposal and recycling procedures.

To promote green computing concepts at all possible levels, the following four complementary approaches are employed:

- **Green use:** Minimizing the electricity consumption of computers and their peripheral devices and using them in an eco-friendly manner
- **Green disposal:** Re-purposing an existing computer or appropriately disposing of, or recycling, unwanted electronic equipment
- **Green design:** Designing energy-efficient computers, servers, printers, projectors and other digital devices
- **Green manufacturing:** Minimizing waste during the manufacturing of computers and other subsystems to reduce the environmental impact of these activities

Government regulatory authorities also actively work to promote green computing concepts by introducing several voluntary programs and regulations for their enforcement.[l]

At a macro level, as the ecotrends are sweeping across the globe, the European Union, for example, has established guidelines for a computers' end of life (EOL) making manufacturers responsible for the implementation of measures during and after the sale to ensure that their products are sold and then collected, deposited or recycled so as to reduce their impact on the environment.

Europe's strong stance on the environment has strong support from it newest member states in Eastern and Central Europe. These transitioning economies are in the process of transferring legislation and incorporating EU policies. Nigeria has developed a National Strategy for Sustainable Development for 20 13—2020—2030 which set out the following priorities: climate change and clean energy, sustainable consumption and waste management, conservation and management of natural resources. However, there is still a gap between legislation and practice [2]. Particularly, in the reduction of e - waste, Nigeria is working to set up the infrastructure to facilitate these directives that closely mirror those established by the EU. However, as public awareness of environmental standards has increased, companies have grown more compliant with environmental standards and regulations. Currently, Nigeria is situated at the bottom of the list according to its Environmental Performance Index, having less scores for health impacts and forests and needing to improve its management of fisheries and water resources.

In this paper, we aim to delineate the problem of e-waste in Nigeria and highlight a series of measures and the advantage they herald for our country.

2.0 E-WASTE

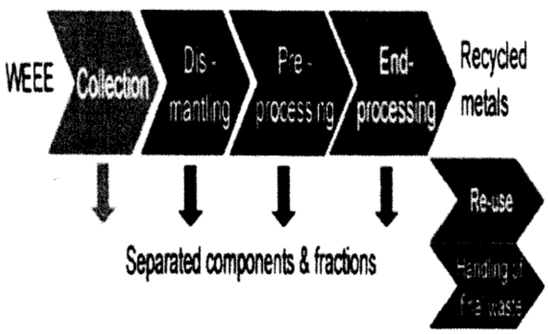
"Electronic waste" may be defined as discarded computers, office electronic equipment, entertainment device electronics, mobile phones, television sets, and refrigerators. This includes used electronics which are destined for reuse, resale, salvage, recycling, or disposal. Others are re-usable (working and repairable electronics) and secondary scrap (copper, steel, plastic, etc.) to be 'commodities", and reserve the term "waste" for residue or material which is dumped by the buyer rather than recycled, including residue from reuse and recycling operations. Because loads of surplus electronics are frequently commingled (good, recyclable, and non-recyclable), several public policy advocates apply the term "e-waste" broadly to all surplus electronics. [3]

Today the electronic waste recycling business is in all areas of the developed world a large and rapidly consolidating business. People tend to forget that properly disposing or reusing electronics can help prevent health problems, create jobs, and reduce greenhouse-gas emissions. Part of this evolution has involved greater diversion of electronic waste from energy-intensive down cycling processes (e.g., conventional recycling), where equipment is reverted to a raw material form. This recycling is done by sorting, dismantling, and recovery of valuable materials. This diversion is achieved through reuse and refurbishing. The environmental and social benefits of reuse include diminished demand for new products and virgin raw materials (with their own environmental issues); larger quantities of pure water and electricity for associated manufacturing; less packaging per unit; availability of technology to wider swaths of society due to greater affordability of products; and diminished use of landfills.

If one attempted to break the e-waste recycling process into several connected steps, the following cycle would be of use:

1) Collection
2) Sorting/dismantling and pre-processing (i.e. sorting, dismantling, mechanical treatment)
3) End-processing (i.e. refining and disposal) — see Table 1

Table 1: Recycling chain for e-waste



Taken from UNEP 2009, Recycling —from E-waste to resources

On the whole, the efficiency of the entire recycling chain is inextricably linked to the efficiency of each step and to how well the interfaces between these interdependent steps are managed.

Therefore, in a context characterized by fundamental changes in demographic and pronounced regional disparities, sharp dynamics of technical progress combined with a relative increase in living standards significantly contribute to increased sales of electronic products and consumer goods which translate, at the end their lifetime, in an increase in the amount of e-waste generated in Nigeria. Of course, a potential e-waste management system must be carefully tailored and well organized, so it would be able to collect, recycle and dispose of electronic used equipment. E-waste collection from households in Nigeria is organized through three collection channels: by organizing a collection day at fixed dates from the population, by giving back to the store the old equipment when purchasing a new one (free take- back system) or by giving it directly to the municipal collection centers. [4]

Regarding the acquisition trends of c-waste collection, national studies conducted in 2008 and 2009 on the electronic market revealed the following:

- penetration of small appliances increased;
- there is a tendency to abandon the use of old equipment which are more than five years;
- although the percentage of people who keep in their household non-operational equipment decreased, many of them still keep it because they don't know very well the alternatives. They should be attracted by offering discounts on the purchase of new equipment, or by collecting the old ones from their home.

Consequently, one can say that in Nigeria, the difference between the amount of equipment placed on the market and the amount of equipment collected from consumers is the quite high compared with other countries in the AU.

There are special legal provisions for c-waste and used batteries, but their implementation and enforcement have a long way to go. Good practices are visible though there is a monthly national campaign for collecting e-waste, encouraging people to put old fridges, TV sets, washing machines and computers outside their houses, which the local waste management company then collects. Due to this campaign, the average amount collected in 2009 was almost 2% of the national target, experts estimated. E-waste associations had an online media campaign in 2009 to advertise their services. In May-June 2010 a public awareness campaign, funded by e-waste management companies, called for photos and videos of e-waste, which it called "the monsters of your community".[3]

The media campaign is backed by the Ministry of Environment — a good example of cooperation between civil society, business organisations and the government. Perhaps as a result, research on e-waste-related attitudes and behaviours, conducted in Nigeria urban areas, has shown positive trends in terms of a willingness to recycle dysfunctional appliances. At the same time, however, 70% of the Nigeria urban population surveyed is not aware of the laws and regulations related to c-waste.

The attitudes and habits concerning electrical and electronic waste can be discerned from the following data, issued by a recent survey done by ECOTIC (data for the survey was collected between August 10 and August 31 2014, on a sample of 1,000 people from the urban area, aged between 15 and 65):

- some 60% of Nigerians who live in urban areas say they separate waste for recycling, mainly plastic, paper, glass and metallic products;

- Only 4% separately collect electrical and electronic waste;
- 87.5% of respondents know that they can recycle this kind of waste; -.
- when asked “Why do you think electrical waste should be recycled?”, most of Nigerians relate to the re-use of materials — 38%, environmental reasons — 36% and to repairing and putting back into use— 15%.
- only 36% of respondents have actually turned in electrical waste to licensed entities, such as specially arranged centres in different areas of the city (over 30% took the electrical waste in such places), in stores when buying a new product (26%), and specialized firms (13%).
- 6% gave such waste to people who periodically pass through residential areas to collect scrap iron.
- the most common waste equipment Romanians recycle are TV sets— 49%- refrigerators — 33% and washing machines — 28%.
- of the 64% of respondents who don’t give electrical waste to licensed operators, 27% say they give it to people who collect scrap iron waste on the streets, 26% keep them in their homes and 34% give them to friends or relatives.
- most respondents say they keep electrical waste for parts or because they intend to repair them, that they don’t know about any disposal facilities nearby, they don’t know what to do with them or that they can be recycled; others say they just lack the time.
- Nigerians should collect 4 kg of electrical waste per year per person for recycling, according to EU quotas, but the recorded results don’t exceed 1.5 kg per capita.

The factor that would most motivate the Romanians to give-up non-functional home electronics and appliances are buy-back campaigns, where consumers receive a discount on the purchase of new equipment when they give in return the old ones. Furthermore, surveys indicate that over 90% of respondents admit that selective waste collection activity is important, but still they do not operate in this direction. They are willing to adopt an ecological environmental behaviour regarding electronic equipment only to the extent that this does not require great efforts on their part.

There are several implications for these findings. If these implications should be translated into steps of an e-waste programme, they should focus on the following aspects:

- First and foremost, consumers need to be educated regarding the toxicity of computers and the problems of e - waste. The results of the survey suggest that when presented with information the consumers positive attitudes toward green computing and e-waste collection increase significantly in. This education would best be carried out by public policy holders, educational institutions and various non - profit agencies such as the Green Electronics Council on a prolonged basis to initiate attitude change.
- In 2001, the Western Electronic Product Stewardship Initiative (WEPSI) proposed developing environmental assessment criteria of electronics as a means to direct governments and other entities into environmentally better purchasing decisions. The EPEAT system is used in at least eight nations including the US and Canada and is used to identify environmentally friendly electronics; however, expansion of this system is needed in more countries as the proliferation of e - waste continues. In this system electronics are evaluated based such criteria as reduction of harmful materials, recyclability, energy conservation, corporate performance, end - of life(EOL) management, and product longevity. EPEAT registered computers have reduced levels of toxic metals, are energy efficient and are easy to upgrade and recycle. Although many manufacturers subscribe to the EPEAT system, getting the message to consumers is not without difficulties. Findings show that consumers are proactive regarding energy savings; however, regarding other components of computers, such as batteries and materials, they lack the knowledge necessary to make informed choices.
- Marketing can play a vital role in increasing favorable attitudes towards green computing and prompting sustainable development of computers and other similar devices minimizing their impact on the environment while satisfying consumers’ needs and wants. Depending on the country the role of government in moderating consumer purchasing behavior of green computers and other electronics through educational materials could be perceived both positively and negatively.

Electronics manufacturers must realize that consumers in developing nations are environmentally conscious and desire access to eco - friendly computer products and accessories. Hence, manufacturers that subscribe to EPEAT should develop labeling and symbols that are incorporated into packaging and product design to further communicate their support of green computing initiatives such as EOL. Further, these manufacturers should communicate this distinction as a point of brand differentiation when developing advertising messages. Until now, differentiation among computer manufacturers has been based on after - sale service, brand reputation, speed, and technological capabilities. Additionally, product strategies should include educational seminars provided to resellers in the form of employee trainings so that they are better able to communicate the features and benefits of “green” computer brands and models to consumers in developed, transitioning and LDC countries.

As an overall recommendation, the development of collaboration between institutions with responsibilities in waste management should be enhanced and more support rendered by competent state bodies to private sector is required. There are insufficient actions of ecological parties and nongovernmental organisations to promote solutions and measures for waste management. Environmental awareness of citizens should be continued and intensified and the national awareness campaign on the importance of selective collection is still needed to be implemented. [5]

Keeping a close interest in e-waste recycling is important considering the hazardous substances contained in many of the products in this waste stream. One key issue is the multi-criteria nature of the challenge: it is desirable to maximize reuse of equipment and economic development while minimizing environmental burdens and economic costs.

3. CONCLUSIONS

Currently, c-waste receives more and more public attention as it is considered to be one of the fastest-growing waste streams. This sector operates within a long-established legislative framework that covers issues such as product safety, energy labeling, minimum efficiency requirements, ecodesign and waste. Two Directives (2008/34 and 2008/3 5) on waste electrical and electronic equipment and the restriction of the use of certain hazardous substances in electrical and electronic 'equipment were introduced in 2008 in order to amend the Directive 2002/96/EC and Directive 2002/95/EC. The EU aims to take measures to prevent the generation of electrical and electronic waste and to promote reuse, recycling and other forms of recovery in order to reduce the quantity of such waste by encouraging manufacturers to design products with the environmental impacts in mind throughout their entire life cycle.

In Nigeria, it can be said that environmental issues still evolve on a rocky path, though with visible signs of improvement. In order to develop a green agenda in the country, several steps have been looked at:

- Key stakeholders should be educated in order to promote a green approach to c-waste and a clean-tech approach to the environment.
- A set of economic indicators should be publicly available in order to assess the environmental impact of e-waste use, e.g. monitoring the availability of environmental content on the internet as a measure of the success of awareness-raising efforts.
- A set of environmental indicators should be developed in order to assess the impact of c-waste on the environment, and made publicly available.
- Primary research on c-waste collection and the environment should be encouraged through funding.
- Romanian environmental protection officials should be more actively involved in international discussions taking place at green computing events.
- Civil society organisations should have a more active role in promoting the green computing agenda, along with businesses and governmental agencies.

In conclusion, computers today are an integral part of individuals' lives all around the world; but unfortunately these devices are toxic to the environment given the materials used, their limited battery life and technological obsolescence. Individuals are concerned about the hazardous materials ever present in computers, even if the importance of various attributes differs, and that a more environment - friendly attitude can be obtained through exposure to educational materials. The costs of implementing energy efficiency and renewable energy measures are minimal as they are not cash expenditures but rather investments paid back by future, continuous energy savings. Sustainable innovation, understood as the shift of sustainable technologies, products and services to the market, requires a market creation concept and one common global agenda. The challenge is to raise awareness among all actors of the different sectors in order to realize the innovation potential and to shift to eco-innovations that lead to sustainable consumption and production patterns.

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Assessing the Influence of Green Computing Practices on Sustainable IT Services

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Abstract: This study focused on the practice of using computing resources more efficiently while maintaining or increasing overall performance. Sustainable IT services require the integration of green computing practices such as power management, virtualization, improving cooling technology, recycling, electronic waste disposal, and optimization of the IT infrastructure to meet sustainability requirements. Studies have shown that costs of power utilized by IT departments can approach 50% of the overall energy costs for an organization. While there is an expectation that green IT should lower costs and the firm's impact on the environment, there has been far less attention directed at understanding the strategic benefits of sustainable IT services in terms of the creation of customer value, business value and societal value. This paper provides a review of the literature on sustainable IT, key areas of focus, and identifies a core set of principles to guide sustainable IT service design.

Keywords: Green Computing, Sustainable IT Services, Optimization, Virtualization, Workload Managements

1. INTRODUCTION

Green computing or its alternative "Green IT" have recently become widely trendy and taken on increased; their conceptual origin is almost two decades old. In 1991 the Environmental Protection Agency (EPA) introduced the Green Lights program to promote energy-efficient lighting. This was followed by the ENERGY STAR program in 1992, which established energy- efficiency specifications for computers and monitors [13, 50]. The swift growth of Internet-based business computing, often allegorically referred to as "cloud" computing, and the costs of energy to run the IT infrastructure are the key drivers of green computing. Over the last several years the link between energy use and carbon generation and the desire to lessen both has given rise to the green computing tag.

Drastically, increased energy use driven by the rapid expansion of data centres has increased IT costs, and the resulting environmental influence of IT, to new levels. Enterprise data centers can easily account for than 50 percent of a company's energy bill and approximately half of the corporate carbon footprint [15, 25].

Although energy use and its associated cost have been the key driver for green computing, a growing appreciation of the risks of climate change and increasing concerns about energy security have elevated green computing to a global issue. The new administration in the United States has stated intentions to endorse a "green energy economy" which will likely cap carbon emissions; increase energy costs, and holds companies more accountable for their impact on the environment [9].

Due to the immediate influence on business value, it is likely that green computing will remain focused on reducing costs while improving the performance of energy- hungry data centres and desktop computers. However, it is not likely that this first wave of activity will fully extend to the general minimization of the ecological footprint of IT products and services for companies and their customers. Ecological issues involving IT product and service design, supply chain optimization, and changes in processes to deal with e-waste, pollution, usage of critical resources such as water, toxic materials, and the air shed will need to be more fully addressed. Although these first-signal activities are driven more by cost-reduction-based business value there is growing potential for green IT products and services being the deciding factor in terms of the intangible benefits of "greenness" to the customer. Vendors are now able to position products and services in terms of energy consumption and lower costs, but the real benefit over time may be in positioning on environmental and social responsibility of the company itself [27, 32, 40].

"Sustainable IT" and especially "sustainable IT services" are terms that are becoming synonymous with an emergent second signal of green computing innovation. Sustainable IT strategies are driving sustainability beyond just energy use and product considerations. This broader approach to corporate sustainability will necessitate the redesign of the IT organization and indeed the company itself if the strategic benefits of green computing are to be realized. This second signal will include the adoption of ecological strategies that will redefine markets, spur technological innovation, and lead to shifts in process, behavior and organizational culture that will integrate business models with environmental and social responsibility [9, 32]. These changes are being driven by the evolving changes in customer requirements from a sole emphasis on the tangible cost-benefit of reduced energy usage to increasingly intangible green benefits and cultural issues motivated by concerns for global warming and climate change [40].

For this paper, we define green computing as the practice of maximizing the efficient use of computing resources to minimize environmental impact. This includes the goals of controlling and reducing a product's environmental footprint by minimizing the use of hazardous materials, energy, water, and other scarce resources, as well as minimizing waste from manufacturing and throughout the supply chain [1]. Green computing goals extend to the product's use over its lifecycle, and the recycling, reuse, and biodegradability of obsolete products. We define sustainable IT services1 in broader terms to include the impact of IT service strategies on the firm's and customers' societal bottom line to include economic, environmental, and social responsibility criteria for defining organizational success. Therefore, as defined, green computing practices inform a company's sustainable IT service strategies and process decisions.

The purpose of this paper is to review the current literature on green computing and its influences on sustainable IT services with the idea of identifying critical issues and leverage points to improve customer value, business value, and societal value.

1.2 GREEN COMPUTING: THE FIRST SIGNAL

Since its inception, the IT industry has focused on the development and deployment of IT equipment and services that was capable of meeting the ever-growing demands of business customers. Hence, the emphasis has been on processing power and systems spending. Less attention was afforded to infrastructure issues which include energy consumption, cooling, and space for data centres, since they were assumed to be always available and affordable. Over the last decade these issues have become limiting factors in determining the feasibility of deploying new IT systems, while processing power is widely available and affordable [47].

Data centres typically account for 25% of total corporate IT budgets and their costs are expected to continue to increase as the number of servers rise and the cost of electricity increases faster than revenues. One study indicated that the cost of running data centres is increasing 20% per year on average [15]. With annual energy costs for computing and cooling nearly matching the costs for new equipment, data center expenses can squeeze out investment in new products, make data intensive products uneconomic, and squeeze overall margins. The quest for data centre efficiency has become a strategic issue [15].

The high and increasing use of electricity makes data centres an important source of greenhouse gases. For information-intensive organizations, data centres can account for over 50% of the total corporate carbon footprint. For service firms, data centers are the primary source of green house emissions. Data centres, with their high energy costs and increasingly negative impact on the environment, are the driving force behind the green computing movement.

1.3 Factors Driving the Adoption of Green Computing

The following trends are impacting data centers, and to a lesser degree, desktop computers, and driving the adoption of green-computing practices:

- **The rapid growth of the Internet**

The increasing reliance on electronic data is driving the rapid growth in the size and number of data centers. This growth results from the rapid adoption of Internet communications and media, the computerization of business processes and applications, legal requirements for retention of records, and disaster recovery. Internet usage is growing at more than 10 percent annually leading to an estimated 20% CAGR in data center demand [51]. Video and music downloads, on-line gaming, social networks, c-commerce, and VoIP are key drivers. In addition, business use of the Internet has ramped up. Industries such as financial services (investment, banking, and insurance), real estate, healthcare, retailing, manufacturing, and transportation are using information technology for key business functions [2]. The advent of the Sarbanes-Oxley Act with its requirement to retain electronic records has increased storage demand in some industries at 50 percent CAGR [48]. Disaster recovery strategies that mandate duplicate records increases demand further. Finally, many federal, state, and local government agencies have adopted c-government strategies that utilize the Web for public information, reporting, transactions, homeland security, and scientific computing [131.

- **Increasing equipment power density**

Although advances in server CPUs have in some cases enabled higher performance with less power consumption per CPU, overall server power consumption has continued to increase as more servers are installed with higher performance power-hungry processors with more memory capacity [42, 47]. As more servers are installed they require more floor space. To pack more servers in the same footprint the form factor of servers has become much smaller, in some cases shrinking by more than 70% through the use of blade servers. This increase in packaging density has been matched by a major increase in the power density of data centers. Density has increased more than ten times from 300 watts per square foot in 1996 to over 4,000 watts per square foot in 2007, a trend that is expected to continue its upward spiral [13, 42, 45, 47].

3. Increasing cooling requirements

The increase in server power density has led to a concomitant increase in data center heat density. Servers require approximately 1 to 1.5 watts of cooling for each watt of power used [16, 24, 39]. The ratio of cooling power to server power requirements will continue to increase as data center server densities increase.

- **Increasing energy costs**

Data centre expenditures for power and cooling can exceed that for equipment over the useful life of a server. For a typical $4,000 server rated at 500 watts, one study estimated it would consume approximately $4,000 of electricity for power and cooling over three years, at $0.08 per kilowatt-hour, and double that in Japan [2]. The ratio of power and cooling expense to equipment expenses has increased from approximately 0.1 to 1 in 2000 to I to 1 in 2007 [47]. With the likely increase in the number of data centers and servers and the advent of a carbon cap-and-trade scheme, the cost of energy for data center power and cooling will continue to increase [26].

- **Restrictions on energy supply and access**

Companies such as Google, Microsoft, and Yahoo with the need for large data centers may not be able to find power at any price in major American cities [14]. Therefore, they have built new data centers in the Pacific Northwest near the Columbia River where they have direct access to low-cost hydroelectric power and do not need to depend on the overtaxed electrical grid. In states such as, California, Illinois, and New York, the aging electrical infrastructure and high costs of power can stall or stop the construction of new data centers and limit the operations of existing centers [24]. In some crowded urban areas utility power feeds are at capacity and electricity is not available for new data centers at any price [10].

- **Low server utilization rates**

Data center efficiency is a major problem in terms of energy use. The server utilization rates average 5-10 per cent for large data centers [15]. Low server utilization means that companies are overpaying for energy, maintenance, operations support, while only using a small percentage of computing capacity [9].

- **Growing awareness of IT's impact on the environment**

Carbon emissions are proportional to energy usage. In 2007 there were approximately 44 million servers worldwide consuming 0.5% of all electricity. Data centers in the server-dense U.S. use more than 1% of all electricity [10]. Their collective annual carbon emissions of 80 metric megatons of CO_2 are approaching the carbon footprint of the Netherlands and Argentina [15]. Carbon emissions from operations are expected to grow at more than 11% per year to 340 metric megatons by 2020. In addition, the carbon footprint of manufacturing the IT product is largely unaccounted for by IT organizations [15].

1.3 Implementing Green Computing Strategies

Transitioning to green computing has involved a number of strategies to optimize the efficiency of data center operations in order to lower costs and to lessen the impact of computing on the environment. The transitioning to a green data center involves a mix of integrating new approaches for power and cooling with energy-efficient hardware, virtualization, software, and power and workload management [10].

- **Data center infrastructure**

Infrastructure equipment includes chillers, power supplies, storage devices, switches, pumps, fans, and network equipment. Many data centers are over ten years old. Their infrastructure equipment is reaching the end of its useful life. It is power hungry and inefficient. Such data centers typically use 2 or 3 times the amount of power overall as used for the IT equipment, mostly for cooling [10]. The obvious strategy here has been to invest in new data centers that are designed to be energy efficient or to retrofit existing centers.

- **Power and workload management**

Power and workload management software could save $25-75 per desktop per month and more for servers [50]. Power management software adjusts the processor power states (P-states) to match workload requirements. It makes full use of the processor power when needed and conserves power when workloads are lighter. Some companies are shifting from desktops to laptops for their power- management capabilities.

- **Thermal load management**

Technology compaction in data centers has increased power density and the need for efficient heat dissipation. Power use by ventilation and cooling systems is on par with that of servers. Typical strategies for thermal management are variable cooling delivery, airflow management, and raised-floor data center designs to ensure good air flow, more efficient air conditioning equipment, ambient air, liquid heat removal systems, heat recovery systems, and smart thermostats [10, 39].

- **Product design**

For example, microprocessor performance increased at approximately 50% CAGR from 1982 to 2002. However, performance increases per watt over the same period were modest. Energy use by servers continued to rise relatively proportionally with the increase in installed base [13]. The shift to multiple cores and the development of dynamic frequency and voltage scaling technologies hold great promise for reducing energy use by servers. Multiple-core microprocessors run at slower clock speeds and lower voltages than single-core processors and can better leverage memory and other architectural components to run faster while consuming less energy. Dynamic frequency and voltage scaling features enable microprocessor performance to ramp up or down to match workloads. Moving beyond microprocessors, the energy proportional computing concept takes advantage of the observation that servers consume relatively more energy at low levels of efficiency than at peak levels [3]. Therefore, the goal is to design servers that consume energy in proportion to the work performed. Since microprocessors have more quickly acquired energy-saving capabilities, it is expected that CPUs will consume relatively less energy than other components. Therefore, it will be necessary for major improvements in memory, disk drives, and other components to reduce their power usage at higher levels of utilization. Energy proportionality, which promises to double server efficiency with the potential for large energy savings for data centers, should become a primary goal for equipment designers [3].

- **Virtualization**

Virtualization has become a primary strategy for addressing growing business computing needs. It is fundamentally about IT optimization in terms energy efficiency and cost reduction. It improves the utilization of existing IT resources while reducing energy use, capital spending and human resource costs [30, 37]. Data center virtualization affects four areas: server hardware and operating systems, storage, networks, and application infrastructure. For instance, virtualization enables increased server utilization by pooling applications on fewer servers. Through virtualization, data centers can support new applications while using less power, physical space, and labor.

This method is especially useful for extending the life of older data centers with no space for expansion. Virtual servers use less power and have higher levels of efficiency than standalone servers [3].

Virtualization technology was originally developed by IBM (as CP/CMS in the 1960's) to increase the utilization efficiency of mainframes. More recently the concept has been applied to x86 servers in data centers. With the use of a hardware platform virtualization program called a hypervisor, or virtual machine monitor (VMM), multiple operating systems can run concurrently on a host computer. The hypervisor controls access to the server's processor and memory and enables a server to be segmented into several "virtual machines", each with its own operating system and application. For large data centers, server usage ranges from 5-10 percent of capacity on average. With virtualization, server workloads can be increased to 50-85 percent where they can operate more energy efficiently [3]. Less servers are needed which means smaller server footprints, lower cooling costs, less headcount, and improved manageability.

- **Cloud computing and cloud services**

As Internet-based computing centralizes in the data center, software technology has advanced to enable applications to be used where and when needed. The term "cloud computing" refers to a computing model that aims to make high-performance computing available to the masses over the Internet [35]. Cloud computing enables developers to create, deploy, and run easily scalable services that are high performance, reliable, and free the user from location and infrastructure concerns [31]. The "cloud" has long been a metaphor for the Internet. When combined with "computing" the definition turns to services [23].

As cloud computing continues to evolve it has increasingly taken on service characteristics. These services include utility computing, software as a service (SaaS), platform as a service (PaaS), and infrastructure as a service (IaaS).

• Utility computing: The first cloud services were developed by companies such as Amazon.com, Sun, and IBM that offered virtual servers and storage that can be accessed on demand. This is often described as an updated version of utility computing—essentially virtual computing capacity where users pay for what they use when they need it. Early adopters used this service for supplemental and non mission-critical needs. This model could be extended to include virtual data centers as a virtual resource pool [23].

• **SaaS**: This implementation of cloud computing delivers applications through a browser interface to thousands of customers using a multitenant architecture [17, 23, 34]. Salesforce.com is perhaps the best known of the SaaS companies with applications in sales force automation, CRM, human resources, and supply chain management. More recently, Google has adopted a SaaS model for its GoogleApps and Zoho Office [23]. The benefits for customers include: no upfront investment in infrastructure, servers, or software licenses; reduced operating expenses, end-to end business processes integrated with services anywhere/anytime; dynamically scalable infrastructure, SLAs for composite services, mobile device and sensor control, access to leading-edge technology, and less environmental impact (34].

• **PaaS**: An outgrowth of the SaaS model, PaaS delivers development environments as a service [23]. The model provides the required resources to support the entire life cycle for developing and delivering web applications and services over the Internet. Developers can essentially create their own applications as a service that will run on the provider's platform and are delivered to their customers from the provider's servers. Leading PaaS companies are Force.com, Google AppEngine, and Microsoft Azure. The primary advantages are the speed and low cost that can be achieved for development and deployment [46].

•**IaaS:** This cloud offering provides basic infrastructure, such as servers, storage, clients, and networking as an on demand service. Leading IaaS companies include Amazon Web Services, GoGrid, and Flexiscale [43].

• **Total power consumption:** In a recent study, this metric was the most popular with 68% of IT managers specifying its use. The cost of power and the volume of kilowatts used are typically included in the baseline assessment [9]. This metric can be useful in tracking power usage by facility, function, application, and employee. Accountability for electricity usage by IT organizations has been highlighted since it is a cost that can easily be tracked and it is a large part of the IT budget. Making power cost a discrete line item in the IT budget invites action to become more efficient and generate cost savings.

• **Power usage effectiveness (PUE):** PUE is equal to Total Facility Power/IT Equipment Power. IT equipment power is defined as the load associated with computers, storage, network equipment and peripherals [33, 44]. Total facility power is the total power measured at the utility meter. A PUE of 2.0 indicates that data center demand is twice as high as the power necessary to power the IT equipment. A PUE value of 1.0 would indicate 100% efficiency with all power consumed by IT equipment.

• **Data center infrastructure efficiency (DCiE). DCiE = 1/PUE:** This ratio is equivalent to the PUE. In the above example IT equipment uses 50% of the power in the data center. The other 50% is of power demand is typically required for cooling. As IT equipment uses less energy pay as you go, access to the latest technology, faster service delivery and time to market.

1.4 Green Computing Metrics

Power-related metrics currently dominate green computing. Several energy-efficiency related metrics have been proposed to help IT organizations understand and improve the efficiency of data centers. Table 1 presents summarizes the most widely used benchmarks per unit of performance, then less energy is needed for cooling and DCiE will move higher [33].

• **Data center performance efficiency (DCPE). DCPE**
Useful Work/Total Facility Power. This ratio is informed by PUE and DCiE. However, it is much more complex to define and measure "useful work" performance as a standard metric [44].

• **Other energy efficiency benchmarks:** An alternate approach to energy efficiency monitory at the data center level is to build energy efficiency into the initial design of components and systems and to adaptively manage system power consumption in response to changes in workload and environment [36]. These benchmarks include Analysis tool, Energy Bench, SWaP, Energy Star, SPEC Power, and JouleSort.

2. Environmental Impact

• Carbon footprint: Regulations to reduce green house gas emissions worldwide will likely be forthcoming soon as a carbon tax or cap and trade scheme is being considered by the U.S. government and the Intergovernmental Panel on Climate Change (IPCC). Already some businesses are requesting that their partners provide information on carbon dioxide production [6]. One emerging strategy is to purchase electricity from renewable energy sources such as wind, solar, or hydro. Google has adopted this strategy, although the low-cost hydro energy it has tapped into has significant environmental drawbacks that offset its attractiveness long term [20]. The key metric here is the volume of carbon dioxide that is produced by various business processes and products—the carbon footprint.

2.0 SUSTAINABLE IT SERVICES: THE SECOND SIGNAL

Sustainable IT services are essential to business success. There is increasing pressure to adopt sustainable business practices. Sustainable IT services are not only about the first-wave green computing focus on data-center efficiency or how to minimize carbon footprints. It is squarely focused on the long-term importance of IT to the organization, its customers and to society at large—all second-wave sustainability issues. Therefore, sustainable IT is about everything an organization needs to do to ensure that IT services delivers superior value to attain a strong market position and to ensure its ability to survive. It is about aligning IT with business strategy to achieve market-leading business value, customer value and societal value. This will ensure the viability of the IT organization itself. There are several elements that comprise sustainable IT services [7].

- **Service sustainability:** At a minimum, this includes effective and reliable processes for delivering IT services. It is about managing performance and doing what is necessary to keep the service running smoothly such as constant security, systems recovery planning, and keeping versions current [7].
- **Temporal sustainability:** To sustain IT services over time an organization has to start with a clear understanding of the value that is to be created. It must have a strong business case, be responsive to business conditions, and create value for the customer and society, as well as the business [7].
- **Cost sustainability:** This includes acquisition and operating costs such as the choice of low cost hardware and software that also offer benefits such as low power consumption and ensure high levels of resource utilization. Life cycle management and replacement costs are also important consideration [7, 11, 28].
- **Organizational sustainability:** Organizational change is inevitable. Whether it derives from personnel changes or major changes in technology, markets, or mergers and acquisitions, IT services must continue to operate and innovate. Well managed systems with good documentation and training are more able to manage change [7].
- **Environmental sustainability:** In an ecological context, IT services must be able deliver customer and business value while ensuring that the Earth's resources are being used at a rate that ensures replenishment. In essence, the goal for environmental sustainability is for IT services to be able to meet the needs of the present without compromising the ability of future generations to meet their needs [40].

We define sustainable IT services from a total societal value perspective as the aggregate value available to society from the systematic integration and alignment of the individual IT service components for the purpose of creating superior societal value. Therefore, all aspects of IT services must meet societal goals for sustainability while meeting customer and business value goals in terms of economic, environmental, and social responsibility requirements [38].

- **From Business Value to Customer Value to Societal Value**

Business value is the overall benefit for business units and the enterprise as a whole that results from IT solutions or services. Business value is evidenced by increases in revenue or market position that derive from meeting customer requirements, providing customer savings or ROI, and making investments in innovation that advance the industry as a whole [1, 43]. Although this definition does recognize the customer and the industry at large, the overall focus of business value is to provide returns to the company. As such, business value often focuses on short-term, cost-based solutions that can overlook the long-term best interests of the customer, society, and resultantly, the business as well. The first wave focus on green computing, with its primary emphasis on cutting energy costs, can certainly increase business value, while increasing customer and societal value (carbon reductions). However, the short-term focus on costs cannot ensure that benefits to the customer and society will continue to be realized over the long term. A sole focus on creating business value is not sufficient for a sustainable IT services orientation.

Customer value is the overall benefit derived from a product or service, as the customer perceives it, at the price the customer is willing to pay [21, 22, 41]. A focus on customer value requirements forces companies to look to the markets and the customer as the core drivers of business activity. With this external focus, customer value is a broader concept than the mostly inward looking business value. IT service providers must first understand how their customers perceive value in terms of the perceived benefits perceived and the perceived price of the service that delivers those benefits [21]. It is necessary to understand what these tradeoffs are and how they might influence service configurations that can maximize customer value and business outcomes. The power of choice will ensure that those configurations that deliver superior value will also achieve superior business value. However, a short-term focus on customer value, which is the default approach given short product lifecycles and competitive pressures, is not sufficient for a sustainable IT services orientation. Some customers are willing to look at their long-term needs in a societal context, but for most consumers cost and performance are the dominant drivers [9].

The concept of societal value holds that companies should meet their market goals in such a way that enhances the customer's and the society's long-term well being. In that way, customer value and business value will be maximized as well. Societal value calls upon organizations to build ethical, social responsibility, and environmental considerations into their business practices. Therefore, companies must balance profits, customer requirements, and social responsibility in their business models. These goals are often in conflict and successful sustainable IT strategies should provide a roadmap for their alignment [38, 40].

- **Toward a Framework for Sustainable IT Services**

Although the need for the development of strategies to address the environmental sustainability of IT services has been apparent for many years, there is no extant body of literature on strategies or best practices. The issues surrounding the first wave of green computing are clearer and focused on reducing energy costs through new data center designs, architectures, facility and server density, and virtualization. Beyond that, companies are approaching sustainability through a fragmented incremental "greener IT" approach [8].

Cost optimization was the primary emphasis of the first wave of green computing. Problems and solutions associated with green computing are well known. The second wave, which we call sustainable IT, or more appropriately, sustainable IT services, has a much broader focus on the role of IT in the society. The primary driver of sustainable IT is corporate social responsibility (CSR), especially as it applies to firm's impact on the economy, environment, and society at large [52].

3.0 CONCLUSION

Sustainable IT has been a major focus for IT organizations for the past decade as the cost of power for data centers has risen rapidly. The focus of the first wave of sustainable IT initiatives has been on strategies to increase data center efficiency. Therefore, infrastructure, power and workload management, thermal management, product design, virtualization, and cloud computing strategies have assumed primacy in terms of both strategic and tactical focus. The second wave of sustainable IT services is nascent and much more difficult to define and implement. It involves defining the role of the IT organization in an enterprise's overall CSR strategy. It will involve establishing a roadmap and baseline metrics, redesigning business processes, encouraging participation, and adapting the organization's culture to new ways of doing things [49]. IT governance and decision making will likely be substantially impacted.

This paper offered a review of current thinking and suggested factors that should be considered for a sustainable IT strategy. Future research should address the relationship between customer value, business value, and societal value and how sustainable IT strategies will impact each. It would seem that these concepts should be mutually supportive. However, many business professionals view them to be at odds with each other, or at least to involve tradeoffs that may not always be beneficial for the company. More research is needed to fully understand the market impact of a sustainable IT services strategy. Beyond cost savings are there benefits from sustainability oriented business strategies that customers are willing to pay for? Does sustainability for IT services create competitive advantage? Finally, a model for the development and implementation of sustainable IT services needs to be developed. This model will likely involve the integration of the IT organization's sustainability initiatives with the enterprise-level model and throughout the corporate ecosystem.

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Text Mining in Digital Libraries using OKAPI BM25 Model

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Abstract: The emergence of the internet has made vast amounts of information available and easily accessible online. As a result, most libraries have digitized their content in order to remain relevant to their users and to keep pace with the advancement of the internet. However, these digital libraries have been criticized for using inefficient information retrieval models that do not perform relevance ranking to the retrieved results. This paper proposed the use of OKAPI BM25 model in text mining so as means of improving relevance ranking of digital libraries. Okapi BM25 model was selected because it is a probability-based relevance ranking algorithm. A case study research was conducted and the model design was based on information retrieval processes. The performance of Boolean, vector space, and Okapi BM25 models was compared for data retrieval. Relevant ranked documents were retrieved and displayed at the OPAC framework search page. The results revealed that Okapi BM 25 outperformed Boolean model and Vector Space model. Therefore, this paper proposes the use of Okapi BM25 model to reward terms according to their relative frequencies in a document so as to improve the performance of text mining in digital libraries.

Keywords: Online Public Access Catalogs, Relevance Ranking, Digital Libraries, Okapi BM25 Model, Text Mining, Information Retrieval Models

1. INTRODUCTION

The internet and information technology evolution has drastically transformed information development and access, especially in the library sector thus disrupting the functionality of libraries. As a result, majority of the libraries have digitized their content in order to remain relevant and exist in distributed networks [11]; [7]. Users are now using Public Access Catalogs (OPAC) to search and retrieve information from the digital library's database [5]. Khiste, Deshmukh & Awate [8] defined digital libraries as huge collection of electronic information that can be accessed by distributed users from different locations. In their study Dwivedi; Sharma & Patel, defined OPAC as a library catalog that displays a large collection of materials held by a database in which users search to access the desired documents available at a library by using in search terms such as the author, title, subject/keyword, or date of publications of the material [5]; [17].

However, studies reveal that digital libraries are still losing to other online search engines such as Amazon despite the efforts to transform library catalogs from traditional card cataloging to digital cataloging using Open Public Access Catalogs (OPACs). This is so because the results retrieved at the library's OPAC catalog does not satisfy the users need. Kumar & Vohra [9] explains that the majority of OPACs requires exact search terms to perform relevancy ranking otherwise they will display the 'no output/null retrieval in the results section. Others simply rank the results using last in/first out. The most cataloged items will show up ending up not meeting the expectations of the user. The digital libraries' OPAC use the Boolean model for information retrieval which retrieves too many or too little of the documents. These causes havoc to users when searching relevant results. It is therefore in the interest of the researcher, to establish how to improve search capabilities in the digital libraries by implementing the Okapi BM25 algorithm in order to improve relevance ranking in the online public access catalogs (OPACs) before the results are displayed to the user. The Okapi BM25 model is based on the term frequency, length normalization to improve the relevance performance of the digital libraries especially during retrieval.

2. LITERATURE REVIEW

2.1 Digitization

Information and communication technology (ICT) in libraries and many organizations has led to the increase of soft data and digitization of materials [10]. Materials are digitalized to improve their online accessibility, sorting, transmission and retrieval. Digitization refers to the process of converting print media to the digital content for electronic storage, access, and distribution among users [3]. The digitization process has facilitated storage and enhanced ease manipulation of the traditionally digitized content by researchers [25]. The process has further decentralized information storage therefore making information in the digital libraries readily accessible from anywhere anytime around the globe.

2.1.1 OPAC catalog

Online public access catalog is one of the most important tools that contain all the bibliographic collection of documents stored in the digital library database [19]. The frequent use of the internet among the researchers has slowed the usage of the library catalogs since they lack most of web 2.0 features such as relevancy ranking [12]. The huge unstructured and amorphous data available in the digital library databases has on the other hand made it difficult for developers to come up with algorithms for enhancing successful information retrieval that matches the user queries [3]. In their study Kumar & Vohra [9] established that 12.5 % of the library users at Guru Nanak Dev University found the OPAC catalogue to be slow and complicated to use thus they needed help from librarians. Current generations of library users are not satisfied with the results that the catalog retrieves because they display either too many or too little documents in a given search. The recent developments of the newer catalogs by organizations outside of libraries have resulted in vocal criticisms about the capability of digital libraries especially on relevance ranking [1].

2.3 Text mining

This paper adopts the definition of Talib et al [21] that defines text mining as a type of indexing which aims at extracting structured text data from unstructured text data. Text mining process involves gathering, preprocessing, and text analysis of document from various sources. These processes are carried out to ensure user satisfaction when accessing structured data from unstructured databases. Text mining techniques such as information retrieval, classification, clustering and categorization are thereafter used to ensure that data is analyzed and generated correctly [27]. This paper will however focus on the information retrieval (IR) approach since it aims at retrieving relevant data to users from a large library database.

2.4 Information Retrieval Process

The main objective of the OPAC catalog is to retrieve relevant documents from a large library database so as to satisfy the user information need. Information retrieval models are used to perform the matching process between the library database and the user query for retrieval. The three basic processes involved in information retrieval include indexing, query formulation and matching [13]. Indexing refers to the document representation process. Query formulation also known as indexing is done to by unique terms expressed by a user while query evaluation also known as matching process is done to estimate the level of relevance of a document to a given query [4].

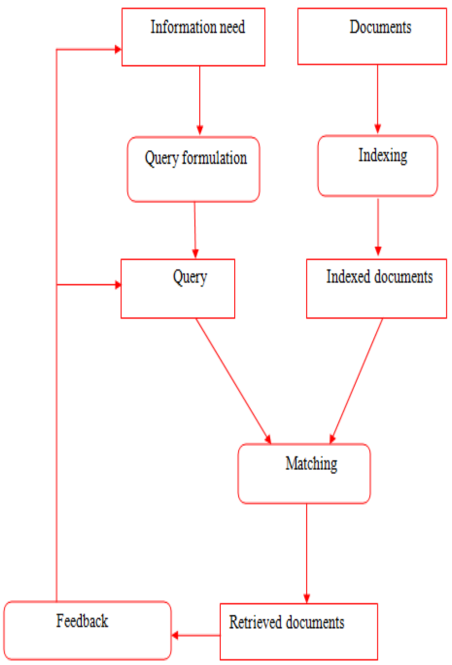

Figure 1 Information retrieval process

2.5 Information retrieval models

2.5.1 Boolean Model

It is an information retrieval model grounded on set theory to determine the prospect of document retrieval. Boolean model is an example of exact match model whereby the fate of the documents retrieval is determined based on the type of information stored in the database [14]. The model uses the logical AND, OR, and Not operators to perform document search in the library databases [23]. The AND operator retrieves results that include all the keywords linked with the operator while OR operator produces results that contain either one or all the keywords used in the user query. The NOT operator retrieves results that excludes the keyword from the user query. The Boolean model is however criticized of lack of relevance ranking when used in retrieval systems such as the OPAC catalog. Boolean model also does not support length normalization of the documents since it does not use term weight such as term frequency and inverse document frequency when retrieving documents from the library database [2].

2.5.2 Vector Space Model (VSM)

This model was introduced to overcome the limitations of Boolean model by assigning weights to term for better matching. VSM presents text documents as vectors to find the similarity between the documents stored in the database and the user query using cosine similarity. Moreover, the model is also used to find exact results with relevance ranking [17]. VSM obtains relevance ranking and information retrieval using document indexing, weighting of the indexed terms using the TF-IDF and finally ranking the documents archives as per the query comparability value [6]. The cosine similarity of the VSM is calculated using the equation 1 below.

$$sim\,(d_j, q) = \frac{d_j . q}{\|d_j\| \|q\|} = \frac{\sum_{i=1}^{N} w_{ij} w_{iq}}{\sqrt{\sum_{i=1}^{N} w_{ij}^2 \sqrt{\sum_{i=1}^{N} w_{i,}^2}}} \qquad (1)$$

Where: d_j represents the total collection of documents, q signifies the user query, $W_{i,j}$ is the i^{th} term of a vector for document j, Wi,q= is the i^{th} term of a vector for query q, and N= is the total number of keywords in a given data set. The model, however, faces some major drawbacks such as poor representation of long documents which is as a result of repetitive use of terms. Moreover, Jain, et al [29], established that the model has low sensitivity to semantics. For instance the word "car" and "automobile" will not give the same match if both words are found in same document. A study by Yulianto et al [2], also revealed that VSM is hard to understand and takes a lot of time to search and match documents before retrieval.

2.5.3 Okapi BM 25 model

The Okapi Best Match 25 (BM25) model is a non-binary model that was developed as part of the Okapi Basic Search System in the TREC Conferences. Okapi BM25 is a probabilistic model that is based on the probabilistic theory. The model is a well-performed term weighting scheme that retrieves its relevant results by incorporating the use of weight term using TF-IDF, and length normalization of a given document [22]. BM25 is a bag-of-words retrieval function that ranks documents according to their relevant results. Okapi BM25 not only considers the frequency of the query terms but also the whole the length of the document under evaluation [26].

2.5.3.1 TF-IDF Weighting of Okapi BM25 Model

In Okapi BM25, term frequency also termed as document frequency shows the frequency of a query term in a document for it to be considered to be relevant. Inverse Document Frequency (IDF), on the other hand, is used to differentiate between common words and uncommon words within a document. The simplest score for document d can be illustrated in the equation 2.

$$RSV_d = \sum_{t \in q} \log \frac{N}{df_t} \qquad (2)$$

Where: N is the total number of documents in a given corpus; df_t is the document frequency of a term.

$t \in q$ is an element of a query.

TF-IDF considers short documents to have more weight than long documents therefore; Okapi BM25 model outperforms TF-IDF and vector space model by taking the average length of each document separately using tuning parameters. Tuning refers to the process by which one or more parameters are adjusted upwards or downwards to achieve an improved or specified result. The values of the tuning parameters are determined empirically using a test collection of documents, queries, and relevance judgments. K_1 is set to 1.2 to control term-frequency saturation since low values result in quicker saturation while high values results in slower saturation. The tuning parameter b is set to 0.75 to control field-length normalization of a document. The Okapi BM25 model calculates the retrieval status value of a given document in order to determine the relevance of a document as shown in equation 3.

$$RSV_d = \sum_{t \in q} \log \left[\frac{N}{df_t}\right] \cdot \frac{(k_1+1)tf_{td}}{k_1((1-b)+b \times (L_d/L_{ave}))+tf_{td}} \qquad (3)$$

Where:

Retrieval Status Value: relevancy scores of a document.

N: represents documents in a given collection.

df_t-the frequency of a query term in a document.

$t \in q$ - t is an element of query q.

t- term

q- query

tf_{td}: signifies the frequency of a term in document d

L_d (Lave): used to calculate the average document length in the whole collection

k_1: tuning parameter set to 1.2

***b*:** tuning parameter set to 0.75

K3 tuning parameter is set to 2 in case the retrieval involves long documents as shown in equation 4.

$$RSV_d = \sum_{t \in q} \left[\log \frac{N}{df_t}\right] \cdot \frac{(k_1+1)tf_{td}}{K_1((1-b)+b \times \frac{L_d}{L_{ave}})) + tf_{td}k_3 + tf_{tq}} \cdot \frac{(k_3+1)tf_{tq}}{k_3 + tf_{tq}} \qquad (4)$$

2.5.3.2 Example of OKAPI BM25 Model

Example query: "president lincoln"

$tf_{president}$,q= $tf_{lincoln}$,q= 1

No relevance information: R= ri= 0

"president" is in 40,000 documents in the collection: $df_{president}$= 40,000

"lincoln" is in 300 documents in the collection: $df_{lincoln}$=300

The document length is 90% of the average length: dl/avg(dl) = 0.9

We pick k1= 1.2, k2= 100, b= 0.75. Hence using the Okapi BM formula illustrated at equation 2.13 the RSV of the query is shown in table 1 below.

Table 1 Retrieval status values of Okapi BM25

$tf_{president,d}$	$tf_{lincoln,d}$	BM25
15	25	20.66
15	1	12.74
15	0	5.00
1	25	18.2
0	25	15.66

The low df term plays a bigger role.

3. METHODOLOGY

3.1 Research Design

This paper used a case study research design to generate solutions for improving information retrieval in JKUAT library. Experimental research was also used to manipulate variables and determine their effect on the dependent variable. This study involves manipulation of text mining technique such as information retrieval to improve the OPAC catalog used in digital library.

3.2 Model Design

A prototype was used to develop this model. Prototype model was selected because it allows development, verification in terms of performance, and reworking on the framework until an acceptable prototype is finally achieved. The prototype processes help to complete a given framework in the area of study. The figure 2 below illustrates the OPAC model design that was used for the development of the model.

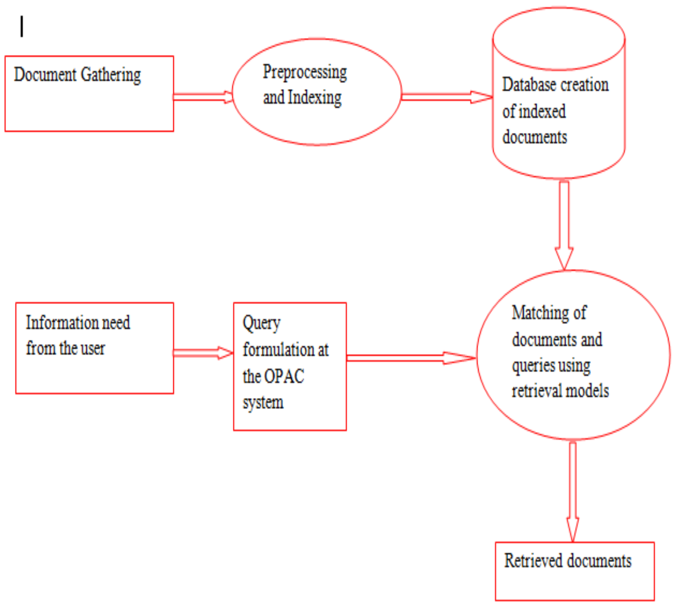

Figure 2 Opac Model design

3.3 OPAC framework Requirements

The front end of the proposed OPAC catalog was implemented using HyperText Markup Language (HTML), Cascading Style Sheets (CSS), Bootstrap, Laravel framework, and JavaScript language. MySQL was used to develop the database while server side programming of the OPAC system was done by Hypertext Preprocessor (PHP).

3.4 Document Gathering

The study utilized secondary data from the Google search engine and other online journals. The collected document were pre-processed using Google to remove inconsistencies such as tokenization, stop words and stemming before the documents were downloaded to be populated to the database. Different search queries were used to collect all the 300 documents that were used to create the database from online journals such as strategic journal of business and change management, scientific research an academic publisher, and International Journal of Computer Science and Engineering Survey among others. For instance, the query "*Text mining and digital library*" was used as a user query using the search engine and resulted in 10 articles were displayed on the first page of the search engine. Seven documents that were found in Portable Document Format were collected uploaded to the database for further analysis shown in table 2. This process was repeated until the collection of 300 documents was achieved.

Table 2 Document gathering

Doc. No	Document Title	Doc. Type	Size	Time (s)
1	Text mining in a digital library	PDF	323.2Kb	(0.47 seconds)
2	Integrating Data and Text Mining Processes for Digital Library Applications	PDF	297 kb	(0.47 seconds)
3	Application of Data Mining Technology in Digital Library	PDF	321 kb	(0.47 seconds)
4	Opportunities and Challenges of Text Mining Hathi Trust Digital Library	PDF	2.0 mb	(0.47 seconds)
5	Library Support for Text and Data Mining	PDF	197kb	(0.47 seconds)
6	Data Mining –A Librarian Overview	PDF	56.9 mb	(0.47 seconds)
7	Integrating Data and Text Mining Processes for Digital Library Applications	PDF	348 kb	(0.47 seconds)

3.5 Entity Relationship Diagram.

The database_item was populated with the 300 documents collected as shown in figure 3. An Entity Relation Diagram (ERD) that was used to create the database.

The database is made up of two entities namely administrator and books. The entities use one to many relationships and therefore, one administrator or a user can add many books to the OPAC system. The user queries the database using either of the attributes of the book entity.

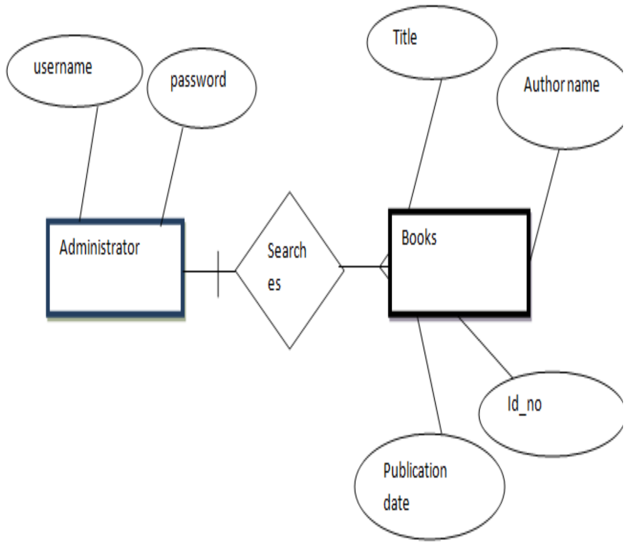

Figure 3 ERD of the Opac database

3.6 Stemming Process

Stemming seeks to reduce different grammatical forms of a word like its noun, adjective, verb, adverb among others and remove various suffixes from a word to get its common origin [24]. This is done to the retrieval models so as to save time and memory space. For example, the words user, usage, using, and usability can be rooted in the word use. The process of stemming helps a retrieval model to have exact matching stems and increase their performance level especially in document retrieval. This can be illustrated in figure 4.

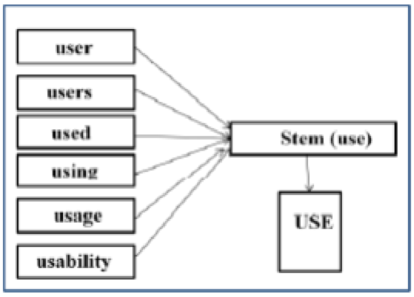

Figure 4 Stemming output

3.7 Routing

All the OPAC framework routes are registered within the *app/routes.php* file. This file tells the php framework (laravel) the URIs it should respond to and the associated controller that will give it a particular call.

3.8 Search and matching process

The user uses the search box that was created at the front end to query the database for the results to be processed by the information retrieval models. Tokenization of the documents is done to remove inconsistencies such as commas, full stops among others. Matching is done before the results are displayed to the user. It seeks to compare the user query against the indexed documents. This result in a ranked list of documents that will be used by the users in search of the information they need. The Boolean Model, Vector Space Model and the Okapi BM25 were utilized for this study. Retrieved results were displayed on the performance basis of each model. The fact that VSM and Okapi BM25 rank their results qualified them to be effective ranking models as compared to Boolean model. The following code was used for search query and matching process

```
//boolean search
foreach($books as $book){
          $keywords = explode(',', $book->title);
foreach($phrases as $phrase){
if(stripos(json_encode($keywords), $phrase) !== false){
if(in_array($book, $items)){
  } else {
array_push($items, $book);
 }
}
}
}
//vector space
$vectoritems = array();
       $books = Book::all();
foreach($books as $book){
$keywords = explode(',', $book->abstract);
foreach($phrases as $phrase){
if(stripos(json_encode($keywords), $phrase) !== false){
if(in_array($book, $vectoritems)){
   } else {
array_push($vectoritems, $book);
                 } }   }
//okapi
          $okapiitems = array();
           $books = Book::all();
foreach($books as $book){
$keywords = explode(',', $book->keywords);
foreach($phrases as $phrase){
if(stripos(json_encode($keywords), $phrase) !== false){
if(in_array($book, $okapiitems)){
  } else {
array_push($okapiitems, $book);
                 }
  }
}
}
```

3.9 Database connection Code

The front end and the back end of the OPAC system were connected to produce the results through the database connection. The following PHP code was used to connect MySQL and select item-database

```
<?php
$mysqli= new ,mysql (“localhost”, “username”, “ password”, “dbname”);
?>
```

When the above code connects MySQL and selects item database the user queries can now be used at the search page to display the results.

3.10 Retrieved Relevant Documents

The improved OPAC catalog is then used to retrieve relevant documents from the database. The retrieved relevant documents are then displayed at the catalog for the users to view, use and compare the performance of each information retrieval models used.

4. PERFORMANCE AND EVALUATION OF RESULTS

4.1 OPAC Results

Once the user has installed PHP software (Xampp) in the computer Apache and MySQL module are turned on as shown in figure 5 below.

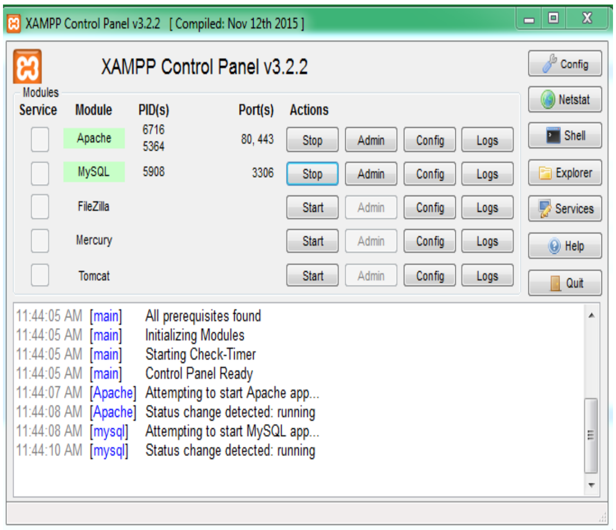

Figure 5 Xampp Control Panel

The user opens any browser and enters the url:http.localhost/opac/public/users/login The following screen will appear for the user to enter his or her email address and a password to access the system.

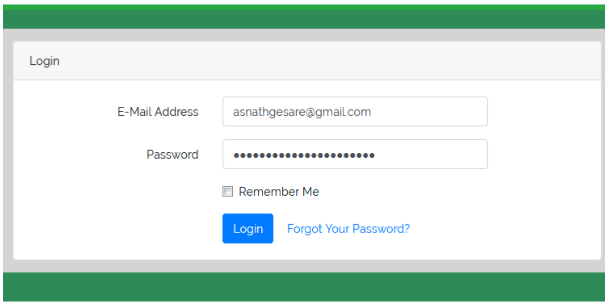

Figure 6 Opac framework

The OPAC framework displays the figure below once the user logs in the details. This can be illustrated in figure 7 below.

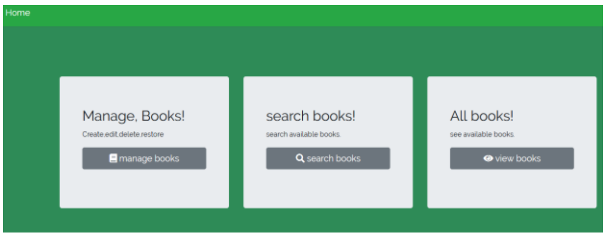

Figure 7 Opac framework search display

When the user hits the search button the following results are observed as illustrated in the figure 8 below

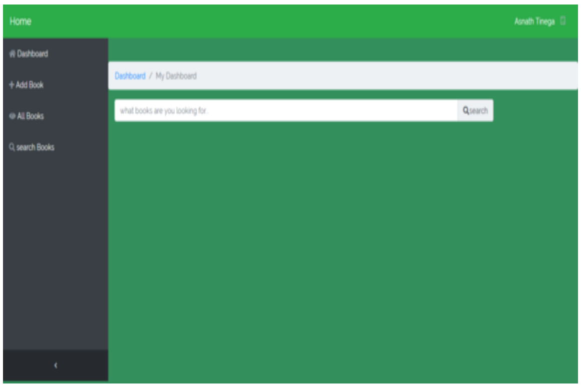

Figure 8 Search Display

When the user searches for example the query "Information System" the three models displayed the following results as shown in figure 9.

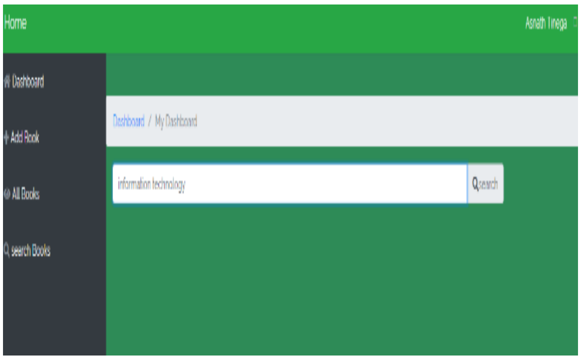

Figure 9 users enters a query" information technology

The results of the search entered by the user in figure 9 results to the retrieval of relevant documents from each model. The first page of the retrieved was screenshot as shown in figure 10. The Okapi BM 25 model retrieved documents by calculating the retrieval status value of each relevant document. Vector Space Model calculates the cosine similarity of each document that was found to match the user query was calculated while Boolean model retrieved just the book title and the author name only.

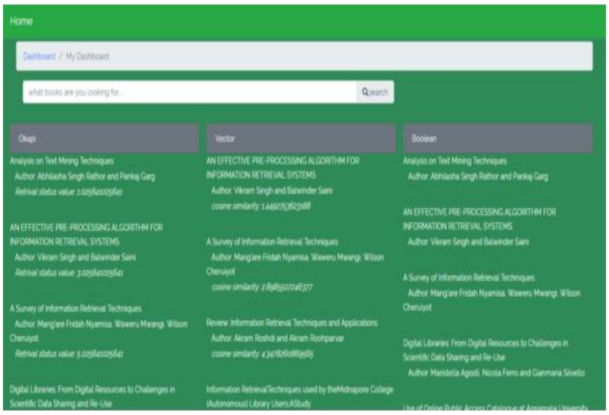

Figure 10 Retrieved documents

4.2 Tests for Performance

Evaluation of the OPAC information retrieval framework performance was done and tested using precision and recall. The Boolean model was left out because it does not retrieve relevant results to the user. Vector space model and Okapi BM25 were tested to proclaim the best model among the two since their retrieval was based on relevancy. This was done using the sample of three queries that was implied on the two models at the same time. The improved digital library's OPAC catalog allowed the users to search the catalog and sort the results by relevance ranking using the three models where the most relevant results are displayed at the top of the page. Precision is the fraction of relevant results retrieved from the total number of documents stored in the library database to meet the information need of the user. Zuva & Zuka [28], pointed out that poor performance of the models displays low values while high performance of the models results with high values. This can be calculated as shown in equation 5

$$Precision = \frac{(relevant\ items\ retrieved)}{(retrieved\ items)} \quad (5)$$

Recall denotes the fraction of the relevant documents in the collection returned by the system for use. This can be calculated using the recall formula as shown in equation 6

$$Recall = \frac{(relevant\ items\ retrieved)}{(relevant\ items)} \quad (6)$$

Precision and recall calculation for query 1: Information Systems

Table 3 Query 1- Information technology

Name of the model	Retrieved documents	Relevant documents	Precision results (%)	Recall results (%)
Okapi BM25 Model	15	11	62.2%	78.57%
Vector space model	8	3	34.4%	21.43%

Precision and recall for query 2: data mining in the digital libraries today

Table 4 Query 2- data mining in the digital libraries today

Name of the model	Retrieved documents	Relevant retrieved documents	Precision results (%)	Recall results (%)
Okapi BM model	9	6	64.29%	66.67%
Vector space model	5	3	35.71%	33.33%

Precision and recall calculation for query 3: Challenges facing the digital libraries especially in information retrieval

Table 5 Query 3- Challenges facing the digital libraries especially in information retrieval

Name of the model	Retrieved documents	Relevant retrieved documents	Precision results (%)	Recall results (%)
Okapi BM model	12	9	54.55%	56.25%
Vector space model	10	7	45.55%	43.75%

5. CONCLUSIONS

This paper's literature review exposes a vocal dissent on the use of OPAC in many digital libraries, especially with its complex search mechanisms. Although recent developments of the search capability of the OPAC have been enhanced, still OPAC is criticized for lack of relevance ranking in its search capability [16]. This paper concludes that Okapi BM 25 model can be used in information retrieval in the digital library's OPAC catalogue. A term with a high relative frequency within a document is more representative and relevant in the document characterization and ranking. Based on this research and analysis, the Okapi BM25 model is proposed to reward terms according to their relative frequencies in a document. From the results obtained, it is clear that the Okapi BM25 model which is integrated with relative term frequency information, document length normalization and tuning parameters significantly outperforms the Boolean Model and Vector Space Model on most of the representative data collections. It is a novel approach to combine the concept of relative term frequency with fundamental weighting functions in probabilistic information retrieval systems to increase performance of the model for retrieval results in the OPAC. The OPAC framework is accurate and applicable according to specified requirements.

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