UNESCO 6TH AFRICA ENGINEERING WEEK AND 4TH AFRICA ENGINEERING CONFERENCE

CONFERENCE PROCEEDINGS

Theme:
"Addressing the SDGs through Sustainable Engineering Development"

ISBN: 978-9982-70-915-6

Hosted by
The Engineering Institution of Zambia in collaboration with
The United Nations Educational, Scientific and Cultural Organisations (UNESCO),
The World Federation of Engineering Organisations (WFEO),
The Federation of African Engineering Organisations (FAEO), and supported
by The Southern African Federation of Engineering Organisations (SAFEO)

Sunday 15th to Saturday 21st September, 2019
Avani Victoria Falls Resort, Livingstone, Zambia

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Foreword

It is our pleasure to present the proceedings of the 4th Africa Engineering Conference held at Avani Victoria Falls Resort, Livingstone, Zambia, on 18th and 19th September, 2019. The Conference was part of the UNESCO 6th Africa Engineering week organised and hosted by the Engineering Institution of Zambia (EIZ) from 15th to 21st September, 2019, in collaboration with the United Nations Educational, Scientific and Cultural Organisations (UNESCO), the World Federation of Engineering Organisations (WFEO), the Federation of African Engineering Organisations (FAEO), and supported by the Southern African Federation of Engineering Organisations (SAFEO).

The theme of the Conference was "**Achieving the SDGs through Sustainable Engineering Development**". This being a 2-day conference, the sub-themes were therefore aligned to the following five specific SDGs out of the 17 SDGs: SDG 4-Quality Education; SDG 5-Gender Equality; SDG 9-Industry, Innovation and Infrastructure; SDG 11-Sustainable Cities and Communities; and SDG 13-Climate Action. The call for papers of the 4th Africa Engineering Conference attracted 64 abstract submissions from countries all over Africa. To ensure a high standard conference, each abstract was reviewed for relevance and quality, and only the accepted abstracts were requested to submit full papers for presentation. Based on the recommendations of the committee of experts, only 38 abstracts were accepted, of which 28 are published as full papers in this Book of Proceedings, covering SDGs 4, 9, 11, and 13. Unfortunately, we did not receive any submissions on SDG 5-Gender Equality; we presume potential submitters opted for the 2nd Women in Engineering Forum that the WFEO Committee on Women in Engineering (WIE) was also hosting along the same UNESCO 6th Africa Engineering Week. We are, nonetheless, hopeful that all participants and other interested readers will benefit from the proceedings and also find something stimulating therein.

We would like to express our thanks to the authors of the technical papers and the EIZ Publications and Editorial Sub-Committee, whose work and dedication made it possible to put together a programme that we believe is very exciting and of interest to the participants. We are grateful to the EIZ 59th Engineering Council and EIZ Secretariat for their facilitating role that enabled us cope with the extra work load and ensure that all the papers were ready for the Conference.

Finally, we would like to thank all the participants of 4th Africa Engineering Conference. We hope it was worth it.

Eng Prof Levy Siaminwe, PhD
Chairperson, EIZ Publications and Editorial Sub-Committee

September, 2019

UNESCO 6th Africa Engineering Week and 4th Africa Engineering Conference, on the 18th – 20th September, 2019, at Avani Victoria Falls Resort, Livingstone, Zambia

Engineering Numbers & Needs in the SADC Region

ALLYSON LAWLESS[1]

Abstract

The shortage of engineers has been a hot topic for decades. Debates rage regarding the numbers available and required to design, manage and deliver both economic and social infrastructure, and to address industrialisation and economic growth. In response to Africa's Agenda 2063, SADC countries have developed the SADC Industrialisation Strategy (2015–2063) aimed at driving industrial development and ensuring economic prosperity (SADC, 2015). Countries have recognised, however, that many of the goals cannot be achieved without developing roads, rail, ports, airports, water and energy supplies, and telecommunication networks.

Acknowledging that engineering skills are key to delivering both economic infrastructure and industrialisation, the SADC Ministers of Science and Technology endorsed an Engineering Numbers & Needs Study to gain a better understanding of the actual numbers of engineers, technologists and technicians in the region and the needs of Member States.

After 21 months of detailed research in all 15 SADC countries, it emerged that there were many challenges that require intervention. The popular view is that there is a shortage of engineers. However, 'doing the numbers' paints a different picture. There are more than enough engineering practitioners in most countries, but insufficient numbers with adequate education, training, experience and appropriate expertise. In recent years there has been a substantial increase in the number of universities and colleges churning out engineering graduates, but few pay attention to the graduate attributes or industry demands. Limited graduate absorption and training is evident, which has resulted in the unemployed graduate phenomenon and impedes the development of expertise. Furthermore, changes in policies and employment models in many countries have resulted in a substantial loss of engineering expertise in the public sector – impacting negatively on the delivery of the engineering infrastructure required to support industrialisation.

The paper outlines practical recommendations in terms of quality education, training, professional registration and the development of engineering expertise and leadership, and the policies and investments that must be in place to grow local economies using local skills.

Keywords: Education, training, professional registration, policies, investment.

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[1]SAICE Professional Development and Projects, P O Box 73285, FAIRLAND 2030, South Africa, Tel: +27-11-4764100, Email: allyson@ally.co.za

1 Introduction

The incongruencies of the industry are well known – debates on too few or too many engineers have raged for years. The SADC Engineering Numbers & Needs studied carried out from mid-2017 to early 2019 yielded a fact that all good engineers already know – a sound structure requires a sound foundation! Unless the standard of education and training from cradle to grave is adequate, competence in engineering can never be achieved.

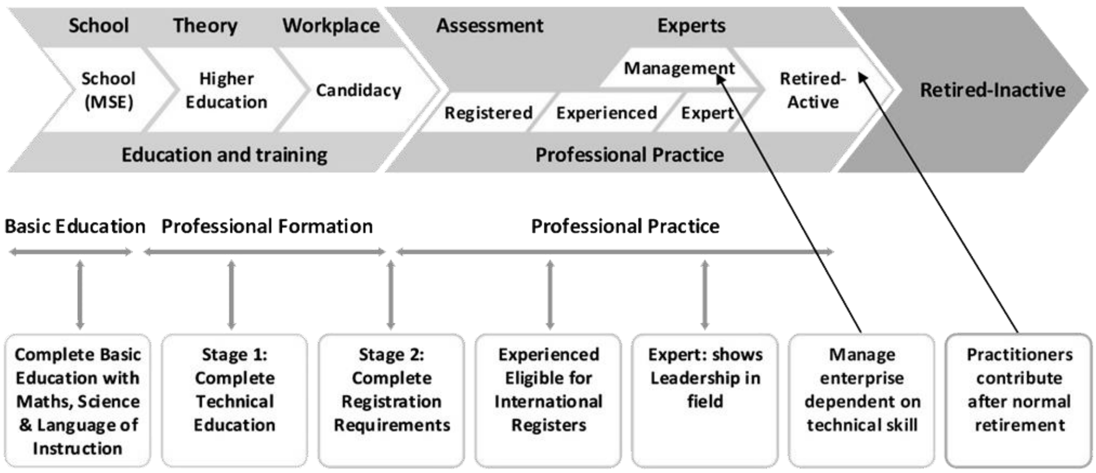

Figure 1: The engineering skills pipeline

2 Developing and harnessing engineering professionals

The engineering skills pipeline is shown in Figure 1. The requirements to succeed are as follows:

- **Schooling:** Demonstrate an aptitude for and grasp of mathematics and science as required by each programme in tertiary education.
- **Theory:** Complete an accredited professional degree or diploma through a university, polytechnic, university of technology or college.
- **Workplace:** Complete a workplace training phase, tackling increasingly complex work, over three or more years, in a community of expert practice under supervision and mentorship.
- **Assessment:** Be assessed through an examination or peer review or both to determine whether the required level of competence has been achieved.
- **Registration:** Be awarded a designation commensurate with the person's education, training and experience.
- **Professional practice:** Work in an environment that values engineering professionals, offers them opportunities to develop as experts or to grow into management and leadership roles, and affords them the opportunity to make technical and strategic decisions.
- **Institutional commitment:** Work in an environment where appropriate staff, systems, processes, support and necessary service providers are in place or may be appointed.
- **Investment:** Work in an environment where investment in planning, development, operations and maintenance of infrastructure, products, systems and/or processes takes place.

Recent graduates are only part of a substantial team of engineering practitioners, each with a different role to play. Conceptualising and designing mega projects require expertise, developed through years of experience, and the confidence to manage and lead change. When employers complain of being unable to find engineers, they are not referring to recent graduates, but to seasoned experts, able to tackle the most complex of challenges. Each of the elements listed above must be in place and standards need to be aligned to allow graduates to grow into strategic leaders.

To ensure alignment throughout the region it is essential that the graduate and professional attributes developed by the International Engineering Alliance (IEA) are adopted and that the complexity levels of the SADC Qualifications Framework are aligned to these standards (SADC, 2018; WFEO, 2018; Manuhwa, 2019). Work is underway to address this need.

3 Elements of the study

Engineering skills are required in all engineering sectors that contribute to the GDP. Figure 2 shows the sector contributions per country.

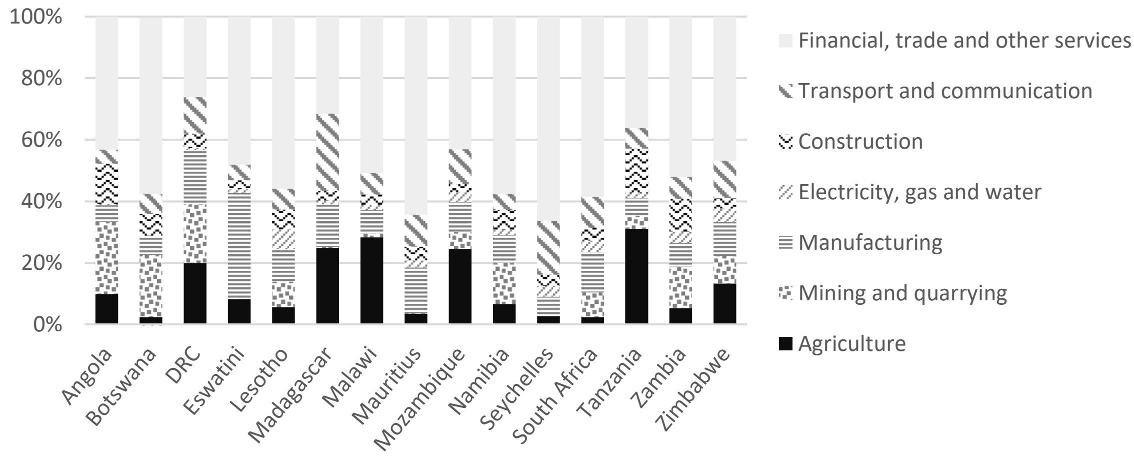

Figure 2: Percentage contribution to the GDP per sector

The study considered the projects planned, the water, sanitation, electricity and other engineering-related SDG targets that must be achieved, the manufacturing industries to be developed or expanded, agricultural and mining developments, and the engineering skills available and required.

Recognising that skills are not static, but rather that there is a flow of skills, it was necessary to determine the current workforce, the demands, inflows from graduation and other sources, and outflows due to retirement, mortality, retrenchments, etc. The research approach was multi-faceted. The research team trawled through at least 350 sets of data, some comprehensive and others sketchy, thousands of papers and articles, and carried out well over 200 structured interviews throughout the region. Telephone conversations, Skype sessions and discussions at many conferences and workshops added to the picture. Engagements with tertiary education institutions, government departments, professional bodies and industry in each country yielded valuable insights.

4 Findings

From early childhood education and throughout the skills pipeline, to the selection of engineering service providers, it was found that opportunities are not conducive to growing tomorrow's engineering leaders or utilising local expertise.

4.1 Secondary education

In many countries, the percentage completing secondary education is limited. As a result, there are inadequate numbers with the aptitude to enter engineering studies. Where the numbers are higher, the quality and subject content of secondary education is often not up to standard. As a result, students struggle with engineering studies and often drop out. The challenges in schools include poor facilities, lack of textbooks and, most importantly, the limited numbers of well-qualified teachers.

4.2 Tertiary education

Due to the ongoing lament from employers about the lack of engineering skills, countries have driven a large increase in tertiary education enrolment and have also encouraged private universities to open and expand offerings in the tertiary space. Gathering engineering graduation data covering several years in order to understand the trends proved almost impossible, but consideration of the data available from 2010 shows that the graduate numbers in the region have increased by almost 80% in the six years, as illustrated in Figure 3. Institutions advise that the numbers have continued to climb and some report that graduations in 2018 were more than double those in 2015.

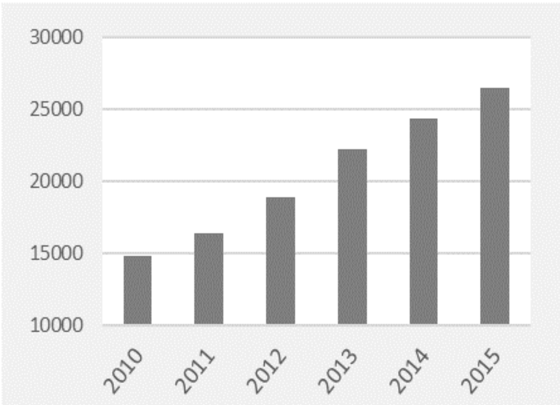

Figure 3: Engineering graduations in the SADC region

The proliferation of tertiary education institutions offering engineering qualifications and the dramatic increase in the numbers studying at existing institutions has had many unintended consequences, including inadequate resourcing, a critical shortage of academics (the student to lecturer ratio far exceeds those of the USA, UK, Europe and many other countries (OECD.stat, 2019), poor quality of graduates and the production of many more graduates than the industry can absorb. The latter has also been recognised elsewhere in Africa (IEA, 2017). The alignment of qualifications requires attention. The content, degree of problem-solving and complexity vary from country to country and this will restrict the mobility of graduates and later professionals in the region, unless graduate attributes are aligned in time. Accreditation processes also vary significantly in the region.

4.3 Graduate training

The claims of engineering staff shortages over decades do not relate to the shortage of graduates and the need to open more universities, but rather to the shortage of experienced personnel. This has come about due to the demise of the formal training programmes that were in place before outsourcing and unbundling took place (Lawless, 2005; Capelli, 2017). The move from permanent posts to contract appointments has also been a contributing factor.

Historically, it was the public sector that planned, designed, developed, operated and maintained infrastructure and their own significant systems, and managed and maintained fleets. Public sector structures were fertile training grounds for recent graduates. Most of the meaningful work on which graduates can be trained today is in the private sector, but companies cannot afford to train large numbers when having to compete and tender at rock-bottom prices. Linking graduates to major public sector construction or manufacturing projects is also proving to be a problem as often the international companies appointed are averse to training local personnel and their staff do not always speak the local language. As experience at work is the primary learning place for engineers, this must be addressed (Senker, 2014).

In Tanzania, recognising the shortcoming in graduate training, the Structured Engineers Apprenticeship Programme (SEAP) was launched in 2003. Guidelines on mentoring, offering structured training and accessing funding were aimed at increasing the number who achieved the competence required for professional registration (Mwamila *et al*, 2004). Mauritius has developed the Youth Employment Programme to address the challenge (MLIRET, 2013) and South Africa has developed a Training Standard requiring service providers to train graduates and apprentices on public sector projects, but sadly this is not mandatory (cidb, 2013). Each have to some extent contributed to an increase in the number of graduates being developed.

4.4 Professional registration

The requirements for professional registration vary from country to country, and in some countries, there is no requirement for engineering practitioners to be registered at all. Without a recognised measure of competence, mobility in the region will be limited.

4.5 Developing tomorrow's leaders

Returning to Figure 1, it can be seen that the end of the candidacy (graduate-in-training) phase is only the beginning of the professional's career. Being assigned increasingly complex work and more responsibility, and continuing to develop through post-graduate or management studies or ongoing research are some of the many continuing professional development (CPD) activities necessary to become recognised specialists, planners, strategists and/or engineering leaders. All too often, after the graduate phase, there is no further development and staff are assigned routine tasks year in and year out. Unless young professionals work alongside experts and are challenged and encouraged to develop, countries will continue to lament the shortage of engineers, as inexperienced staff will not meet their requirements.

There is a fixation about not using foreign expertise or experienced practitioners from minority groups, and all too often recent graduates are paired with such experts and are expected to take over in a very short period. Without adequate meaningful post-graduate experience, young graduates are not equipped to comprehend the complexity of activities carried out by experts. Rather, mid-career practitioners with experience in the same field as that of expert practitioners should be selected as understudies and should be groomed to take over from experts in time.

4.6 The public sector

Four of the six GDP contributors studied rely heavily on government spending, while the success of manufacturing and mining depends on government support and the policies in place. There are several challenges impacting successful development.

- **Engineering professionals:** The numbers employed in the public sector are dwindling because salaries are generally low and conditions are not conducive to technical decision-making. In some countries, there has been a moratorium on employment in the public sector, while in others, the requirement for appointing only professionally registered personnel means that juniors cannot be appointed and developed through the ranks. Without technical structures and skills, the quality of development, or the appropriateness of the solutions selected is often problematic, and the lack of maintenance leads to premature failure.
- **Policies:** Although international service providers may have the skills and resources for large or complex projects, appointing foreign consultants and contractors as a matter of course is unacceptable. Many projects, such as standard school structures, community halls and the like, are well within the abilities of local companies. As part of large projects, small contractors must be trained and where international service providers are appointed, local skills, materials and equipment must be used. In addition, designs, drawings and operating instructions must be made available in the official language of the country and must be checked and approved to ensure that they satisfy local needs.

  As with professional registration, the categorisation of contractors varies throughout the region. In some countries, contractors need only apply for a licence, while in others they are categorised by skills, capital, equipment and past projects, and may only be awarded contracts within their range of experience. The requirements specified in offset agreements also vary significantly, often with limited local development demands being placed on manufacturers entering countries to use local resources.

  Many other policies require review to attract rather than deter investors, but they must include job creation and the development of local capacity and content.
- **Investment:** There are many areas that require increased investment before it will be practical to increase engineering capacity. These include investment in:
  - Expanding economic and social infrastructure, developing trade corridors and enhancing the levels of service
  - Ongoing operations and maintenance
  - Agricultural and manufacturing development
  - Developing sustainable communities.

5 Numbers and needs

Combining engineering workforce estimates and registration data from each country suggests that there are almost 230 000 engineering practitioners in the region, just under 21% of whom are professionally registered, as shown in Table 1. It should be noted that registration is in place in only 12 SADC countries, and in several countries not all categories are eligible for registration.

The number graduating in 2015 represented just over 11% of the workforce, which is a large number to absorb in the absence of meaningful work. Anecdotally, the graduation numbers have increased significantly in several countries since 2015, contributing to the increasing pool of unemployed graduates. The number of engineers is approximately 115 000, which is orders of magnitude lower than the numbers suggested by the OECD.

Table 1: Estimated engineering workforce, registration, graduation and gender statistics for the region

Category	Total in the workforce	Registered		Graduates		
		Total	% of workforce	In 2015*	% of workforce	% female
Engineers	114 579	34 722	30%	9 875	9%	22.0%
Technologists and technicians**	114 281	12 746	11%	15 607	14%	24.7%
Total	228 860	47 468	21%	25 482	11%	23.7%

* Totals are understated as graduation data from some countries is incomplete
** Technologist and technician categories are not recognised in all countries

The temptation is to train many engineers in the hope that they will change the fortunes of the country. However, the numbers required are dictated by many factors. If infrastructure is limited as per the African Infrastructure Development Index (AIDI) ranking (AfDB, 2018a), then there will be little work for engineering practitioners. If the levels of service are basic, then the complexity of engineering work and the numbers required will be low. If manufacturing is limited to low-tech food processing, the demand for engineering skills will be lower than for high-tech processes (Williams *et al*, 2014). If policies do not attract investors and development is limited, there will be little demand for additional engineering skills.

Industrialisation aims to accelerate growth, create employment and improve living conditions. Countries need to examine their plans and develop skills for the sectors identified. Construction has long been recognised for its job creation potential, but must also be used to develop the large number of unemployed engineering graduates and apprentices, small contractors, subcontractors, suppliers and emerging manufacturers. The region needs to roll out infrastructure projects and invest in industrialisation if job creation and poverty alleviation are to succeed.

6 Recommendations

6.1 Secondary education

The number of qualified teachers, teaching methods and material require attention. Consideration needs to be given to harnessing technology and the 'flipped classroom' approach to reach and teach the large numbers currently excluded from quality education and to increase the number successfully completing secondary education. Career guidance and assessment programmes need to be mounted and funding raised to attract those who excel in mathematics to enter engineering studies.

6.2 Tertiary education

- **Rationalisation of tertiary education:** The number of tertiary institutions, the number of students being enrolled, and the shortages of academics and appropriate resources need to be addressed. Investment should be made in strengthening the established institutions rather than opening new institutions, to produce the desired calibre of graduates.
- **Alignment and accreditation of qualifications:** Alignment of qualifications and the development of accreditation standards are important for mobility in the region. A subcommittee needs to be set up under the Technical Committee on Certification and Accreditation (TCCA) to debate graduate attributes for each level of qualification. A 10- to 15-year plan must be developed with milestones for institutions to work towards in order to upgrade curricula, develop capacity and acquire the resources so that they are eventually in a position to offer equivalent qualifications.

6.3 Graduate and professional training

Large national programmes must be reinstituted to develop graduates. A committee composed of employers and professional bodies who have been successful with graduate training should be formed to develop guidelines and suggest funding options, terms and conditions. Professional development beyond registration must also be provided.

6.4 Alignment of registration processes

A subcommittee under the TCCA composed of registering bodies, potential registering bodies, the Southern African Federation of Engineering Organisations (SAFEO) and advisers from the IEA, when required, should be set up to interrogate all Acts, establish best practice, and ensure that all countries adopt one set of outcomes per category and similar assessment processes.

6.5 The public sector

- **Repopulation of public sector structures:** A concerted effort is required to repopulate public sector structures with competent engineering professionals who have decision-making authority, and are able to carry out short-, medium-, long-term and strategic planning, and manage outsourced work. Appropriate inhouse engineering functionality must be reinstated and systems must be setup for developing future generations. Structures, responsibilities, packages and training regimes must be revisited.
- **Alignment of service provider conditions:** The SADC Trade Negotiating Forum (TNF) is focused on the liberalisation of the construction, energy and tourism sectors. The TNF needs to form a subcommittee to look at construction board or council Acts and agree on standards throughout the region for classifying contractors and the type of work they may be appointed to carry out. Harmonisation of training requirements and the use of local conditions of

contract, local labour, materials and equipment should be considered, and a threshold must be set below which only local contractors may be appointed in order to support contractor development and local job creation.

- **Localisation:** The Industrial Development Forum should consider criteria to be included in offset agreements with manufacturers. Agreements should include not only the use of local labour, plant, equipment and developing local manufacturers, but also the training of engineering professionals so that countries will not always be reliant on imported expertise.
- **Investment:** Without investment in infrastructure and maintenance, growth cannot take place (AfDB, 2018b; Esnault, 2018). Major projects must be prioritised and the funds raised, but care must be taken that funds are largely spent on local staff, materials and equipment. Solutions selected must satisfy local conditions, offer value for money and address the needs of as many as possible.
- **Agricultural engineering solutions:** Regional solutions need to be researched and shared to support countries with innovative ideas to assist smallholders to become more productive, become part of the agro-processing value chain and contribute towards national food security.
- **Rural development:** Infrastructure development has largely been focused in urban areas and industrial centres. Rural development and support are essential to grow rural economies and encourage de-urbanisation.
- **Data collection:** Centralised reporting systems need to be considered for compiling reliable and detailed labour, education, professional and service provider information for better planning, reporting and monitoring progress towards achieving targets.
- **Industry liaison:** To give input on the many engineering challenges, a National Engineering Advisory Team, composed of experts nominated by institutions and engineering bodies in each country, should be constituted per country to engage with government as and when necessary. The team should include academics and practitioners from the private and the public sectors.

7 Conclusion

To address the need for experts, substantial initiatives will be required to educate and develop engineering professionals. However, without investments, enhanced levels of service and the appointment of local service providers, additional expertise will not be absorbed. Many regional and national initiatives must be launched as a matter of urgency to address the shortcomings identified, to support job creation, skills and infrastructure development and activities to grow local economies and achieve the industrialisation and Agenda 2063 goals.

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Skills Competition enabled 'Virtual Laboratory systems' for TEVET system Design, Governance and Management.

David C Chakonta[1]

Abstract

Acquisition of the knowledge, skills, attitudes and values pertaining to the work and practice of engineering requires exposure and participation by persons with felt needs and motivation to pursue an engineering career. The Technical Education, Vocational and Entrepreneurship Training (TEVET) is one mechanism by which the engineering capabilities of interested and motivated persons can cultivate and acquire the desired capabilities. Inadequacies of TEVET infrastructure relative to the youth population growth rate, especially in Africa, and is a serious disconnect between the industry actors and TEVET system actors are among the key challenges to sustainable engineering development in Africa. This problem manifests through poor employability attributes of graduates and lack of continuing professional development opportunities for trainers and industry experts, among other things. The foregoing scenario is against a background of policy development and investments in Africa's education and skills development system. Establishment of a skills competition enabled Virtual Laboratory system to guide the design, governance and management of national TEVET systems. Different sub-systems can be arranged or configured to interrogate and observe different Behaviours of a national TEVET or indeed any stakeholder interested in any functional component. Skills competitions are already integral elements of TEVET systems in countries accounting for about eighty percent of the global Gross Domestic Product (GDP). The main elements of a Virtual Laboratory would start with the Learning environments, followed national and international skills competition systems, a post-competition learning review platform, and a targeted Labour market space such as a Regional Economic development area such as a province or a county.

Key words: Skills Competitions, Virtual Laboratory, TEVET system, Optimal Performance.

[1] Tel.: +260 96 6 92 1960; Email: david.chakonta@gmail.com

1.0 Introduction

The dynamic interplay of sustained population growth, rapid technological innovations mainly fueled by individual and collective aspirations for improved quality of life by this growing population, and volatilities in annual weather patterns manifesting in extreme weather is defining and will continue to define the Labour market of the twenty first century in which engineering professionals will be working.

For example, the world population at the close of the twentieth century in 1999, was about 6.1 billion [1]; that of Africa was estimated at 0.79 billion.[2] The projected world population at the close of Twenty-first century in 2099, is about 11.2 billion, representing a growth of about 84 percent; that of Africa is projected to be about 4.4 billion[3] implying that it will grow nearly six times at the close of this Century. This fact has not been lost to Governments of member states making up the United Nations, hence the General Assembly resolution of 2015 which adopted the Sustainable Development Goals (SDGs). At Africa region level, member states of the African Union [4] adopted Agenda 2063 for Africa, whose vision statement was:

"An integrated, prosperous and peaceful Africa, driven by its own citizens, representing a dynamic force in the international arena."

This aspiration has among other things motivated development and deployment of solutions by way of investment resource mobilization initiatives through institutions such as the African Development Bank targeting expansion and improvement in productive infrastructure. The following statements attributed to the President of the African Development Bank [5] attests to this initiative and also highlights that securing food security is another push:

"Africa must industrialize to end poverty and to generate employment for the 12 million young people who join its labor force every year. One of the key factors retarding industrialization has been the insufficient stock of productive infrastructure in power, water, and transport services that would allow firms to thrive in industries with strong comparative advantages."

"To achieve food sufficiency and turn the continent into a net food exporter, Africa must empower smallholder farmers, who constitute 70% of the population and produce 80% of the food consumed in the continent."[6]

The key issue then, is what national level systems for Technical Education, Vocational and Entrepreneurship Training (TEVET), can harness the human capability potential inherent in the 12 million young people joining the African Labour Force population each year? Especially when the work force skill levels have been identified to the lowest in the world by a joint publication of the World Bank and Africa Development Forum. This publication [7] (Orias et.al, 2019) among other things made the following assertions regarding Sub-Saharan Africa Work force skills:

"Sub-Saharan Africa's growing working-age population constitutes a major opportunity to reduce poverty and increase shared prosperity. But the region's workforce is the least skilled in the world, constraining economic prospects." The publication went further asserted that:

"In their policy choices, countries will face trade-offs—often stark ones—that will have distributional impacts and a bearing on their development path. This is the challenge of the skills balancing act in Sub-Saharan Africa."

This paper proposes creation and operation of a Virtual Laboratory system that Governments and national stakeholders can appropriately configure to interrogate and/or study particular aspects of national TEVET system to formulate and deploy required policy and/or technical level optimal solutions. One or a combination of the following national TEVET system Governance and/or Operational performance indicators, will be among the decision factors in any trade-off situation which Governments will encounter:

a) Career Awareness levels and Career preference alignment of children and youths, with medium-to-long term national development goals and objectives;
b) Access and participation;
c) Quality of Learning environment and immersive learner experiences;
d) Labour Market demand responsiveness;
e) Equity and inclusiveness;
f) Stakeholder goodwill and relationships;
g) Sustainable and diversified financing systems;

The idea of considering a skills competition enabled Virtual Laboratory system for TEVET was motivated by an observation that a cluster of countries accounting for over eighty (80) percent of global Gross Domestic Product (GDP), who also happened to be member states of an organization called WorldSkills International, appear to explicitly or implicitly integrated and mainstreamed Skills Competitions in TEVET Classroom and/or Co-curricula activity based Learner experiences.

WorldSkills International owns and operates a WorldSkills Competition system designed to among other things, stimulate and measure skills excellence performance of TEVET learners. The Competition is held every two years, and hosted on a rotational basis by member states. The two-year cycle provides an opportunity to review, test and/or develop new performance standards for skill categories driving all economies. The twenty-four months in between competitions provide opportunities for review of immediate past competition event, drawing lessons therefrom that guide review of professional practice standards in industry, as well as related national TEVET curricula. In between WorldSkills competitions are opportunities for knowledge and experience sharing through national skills competition events, that might also involve conferences and workshops. Guest Competitor participation in national skills competitions of sister member states complements the capacity building initiatives. So once this cycle of one WorldSkills Competition event to the next, is incorporated as integral element of the national TEVET policy, and made operational through appropriate strategies and legislation, the assertion then, is that a "Virtual Laboratory" would have been established and made operational. It means that national level, TEVET stakeholders with guidance and/or collaboration, from Governments, can for example, plan skills standards review or development experiments as part of the national development policy measure, using national and WorldSkills Competition events as operational platforms. This for example means that a country can target to build skills excellence standard capabilities targeting specific value chains, and/or economic sectors, associated with the natural resource endowments of a Regional Economic Development area such as a district, province or a county.

The age range of TEVET learners eligible to participate in WorldSkills is between fifteen years and twenty-two years for the majority of the skills categories, and up to twenty-five years for a few skills.

The origins of the WorldSkills Competition system and WorldSkills International trace back to a national skills competition held in Spain in 1947 [8], which from 1950 attracted competitors from Portugal and grew from then onwards to a strength of eighty-two as at June 2019. Africa's contribution being eight; that is: Egypt, Ghana, Morocco, Namibia, South Africa, Tunisia, Uganda, and Zambia.

1.1 Definition of Key Terms

1.1.1 Skills Competition

A Skills Competition may be defined as a test of human or animal ability under set rules, conditions, and related performance standards that are mutually agreed in advance, and are binding on the participating parties.

1.1.2 Virtual

According the Collins online Dictionary, the word "virtual" refers situations that "indicate that something is so nearly true that for most purposes it can be regarded as true." [9]

1.1.3 Technical and Vocational Education and Training (TVET)

Member states of the United Nations, Education, Scientific and Cultural Organization (UNESCO) during the 2015 General Conference, adopted a Recommendation on Technical and Vocational Education and Training (TVET) which among other things defined TVET:

"*TVET… is understood as comprising education, training and skills development relating to a wide range of occupational fields, production, services and livelihoods. ….. TVET, as part of lifelong learning, can take place at secondary, post-secondary and tertiary levels and includes work-based learning and continuing training and professional development which may lead to qualifications. TVET also includes a wide range of skills development opportunities attuned to national and local contexts. Learning to learn and the development of literacy and numeracy skills, transversal skills and citizenship skills are integral components of TVET*." [10]

For UNESCO member states such as Malawi and Zambia, the national policies have included "Entrepreneurship" essentially to highlight the fact that TVET by default prepares, and should prepare students to pursue one or both of the following career pathways:

a) Salaried Worker Career pathway;
b) Self-Employed Entrepreneur Career pathway;

1.1.4 Laboratory

The Merriam-Webster online Dictionary has defined a Laboratory as "a place providing opportunity for experimentation, observation, or practice in a field of study" [11]

1.1.5 Optimal Performance [12]

The Cambridge online Dictionary defines "Optimal" as: "…the best or most effective possible in a particular situation";

3.0 Methodology Outline

Methodologies that have been used to develop the idea of a Skills Competition enabled Virtual TEVET Laboratory have been desk research in job situations, as well as direct observations through activities and/or roles that have included the following:

a) Various TEVET systems development initiatives and projects, while occupying the respective positions of Director Development *(ie. March 2003 – July 2012),* and Director

General *(ie. August 2012 – September 2017)*, of the Technical Education, Vocational and Entrepreneurship Training Authority (TEVETA), Zambia;

b) Board member of the National Council for Construction (NCC), Zambia which essentially introduced skills competitions in Zambia's TEVET system. The initiative started with a Bricklaying skills competition on in 2008, with decision having been made in 2007;

c) Director observations through participation in various events of WorldSkills International;

d) Observation of Finland's 2017 national skills competition;

e) Organizing skills Competitions for Secondary School pupils in the pilot cohorts of the Secondary School Vocational Education and Training system (ie. May 2017)

f) 2010 and 2011);

g) Desk Research

4.0 Key Findings and/or Observations

4.1 Plausible Correlation between WorldSkills Competition participation and GDP per Capita growth.

About eighty (80) percent of the global GDP is attributed to a cluster of countries that have in some way integrated and mainstreamed skills competitions as part of the TVET learner experience; these competitions have in turn been affiliated to the WorldSkills Competition system operated by member states of WorldSkills International. Table 1 illustrates some indicative correlations between WorldSkills Competition participation by some countries, and respective growth in GDP per Capita. It can be observed the tiger economy countries are among those that have adopted and integrated skills competitions as a strategic tool for economic growth and national development. The USA provides a best practice example of using school-based Career clubs, which provide Work Based Learning simulations in school settings, as well as mechanisms for introducing and inducting young people into their careers. It was reported that 1965 was the year when Vocational Industrial Club Inc. of America was established. This is what was later on transformed into SKillsUSA. USA joined WorldSkills International in 1973. 2018 was the reference year when the cumulative number of SkillsUSA Chapter members (ie. students and Advisors) exceeded 13.5 million [13] or 8%[14] of the civilian Labour Force population from establishment in 1965

Table 1: WSC participation and GDP per Capita Growth relationship patterns

S/n	World Skills International Member state	WSI Joining or Reference Year	Reference Year GDP per Capita (US$)	2016 or Reference year GDP per Capita (US$)	GDP per capita Percent Growth	Comments
1	Hong Kong	1997	27,330.00 [15]	43,737.04[16]	60.03	2016 the reference year
2	Singapore	1993	18,302.33 [17]	55,243.13 [18]	201.84	2016 the reference year
3	South Korea	1966	133.00 [19]	27,608.25 [20]	20,658.08	2016 the reference year,
4	Chinese Taipei (i.e. Taiwan)	1970	396.00 [21]	22,561.00 [23]	5,597.22	2016 the reference year
5	Japan	1961	563.59 [24]	48,167.99 [25]	8,446.64	2011 is the reference year

5.0 Regional Economic Development area focused Skills Competition enabled Virtual Laboratory platforms for TEVET system Performance study[2].

The operational arrangement or configuration of a Skills Competition enabled Virtual Laboratory system for TEVET performance study, could for example be focused on stimulating growth in GDP per Capita of a particular Regional Economic Development area such as a District, Province or County is shown in Figure 1. The initiation of the Experimentation cycle would start with the Learning and Career Exploration Environments defined by approved national TEVET curricula, in which relevant industries would have had an input with regard to setting learning content and related learning outcome standards. Learning Outcome performance standards could for example be pre-defined at Curriculum and Qualifications Descriptor stage, using the "Criterion Referenced Assessment principle. This implies that performance criteria for say Pass, Credit, Merit and Skills Excellence are pre-determined, and incorporated in the four value creating activities or processes making up the Learning and Career Exploration environments; these activities are as follows:

a) Career Exploration

b) Classroom based learning

c) Career Club based Learning *(i.e. involving simulation of Work Based Learning and Skills Competitions*)

d) Assessment and Certification *(i.e. Inclusive of Skills Competition based **Recognition of Prior Learning (RPL)** Assessments)*

Career Club based simulated learning activities facilitate selection of learners that can participate initially in national skills competitions, and if successful then proceed to participate at the WorldSkills Competition. After the apex competition which is the WorldSkills Competition, a competitor/learner who gets one of the four medals, awarded under the WorldSkills Competition system would have performed far above national curriculum requirements. Table 2 illustrates the performance level standards of national TVET curricula, and the skills excellence standards of the WorldSkills Competition system, which can act as references if supply of internationally competitive skilled persons to a Regional Economic Development area is the study focus.

***Table 2: Comparison of performance descriptors for national TVET curricula and WorldSkills Competition Skills Excellence standards (Source:** Jenny Shackleton – Skills Assessment Adviser, WorldSkills International, (2017))*

Competence: the ability to:	**Excellence: the ability to:**
Perform routine tasks as trained	Perform routine and exceptional tasks
Respond satisfactorily where the demands and context are clear	Respond satisfactorily or better where the demands and context are ambiguous
Perform satisfactorily under control and supervision	Respond satisfactorily or better without control or supervision
Perform satisfactorily in predictable circumstances	Respond satisfactorily or better in unpredictable circumstances
In a competition: performance of this nature should achieve at <u>least 10%</u>	***In a competition: performance of this nature may achieve <u>up to 90%</u>***

[2] Adapted from original Concept Design by David C. Chakonta – Skills Excellence and Careers Ltd. Zambia (2017)

The Post Skills Competition Learning and Innovation system would be the platform for reflective learning, archiving the acquired learning as a country, and developing dissemination plans through national skills competitions, Continuing Professional Development (CPD) Activities as well as Curriculum and Qualification Descriptor review or development. Students exposed who have participated in the various stages of competitions starting with in-house Career Club based skills competitions, through national to WorldSkills Competitions, will then at some stage enter the Regional Economic Development Labour market space with internationally competitive skills performance standards. If this entry is based on deliberately agreed human capital development experimentation plans and targets, adjudicated through relevant Skills Advisory Groups (SAGs), it is feasible to continuously grow the talent pool of internationally competitive skilled persons in a province or a county. Figure 2 illustrates the framework which can be used to observe and evaluate progressive growth of the required talent pool with each WorldSkills Competition cycle.

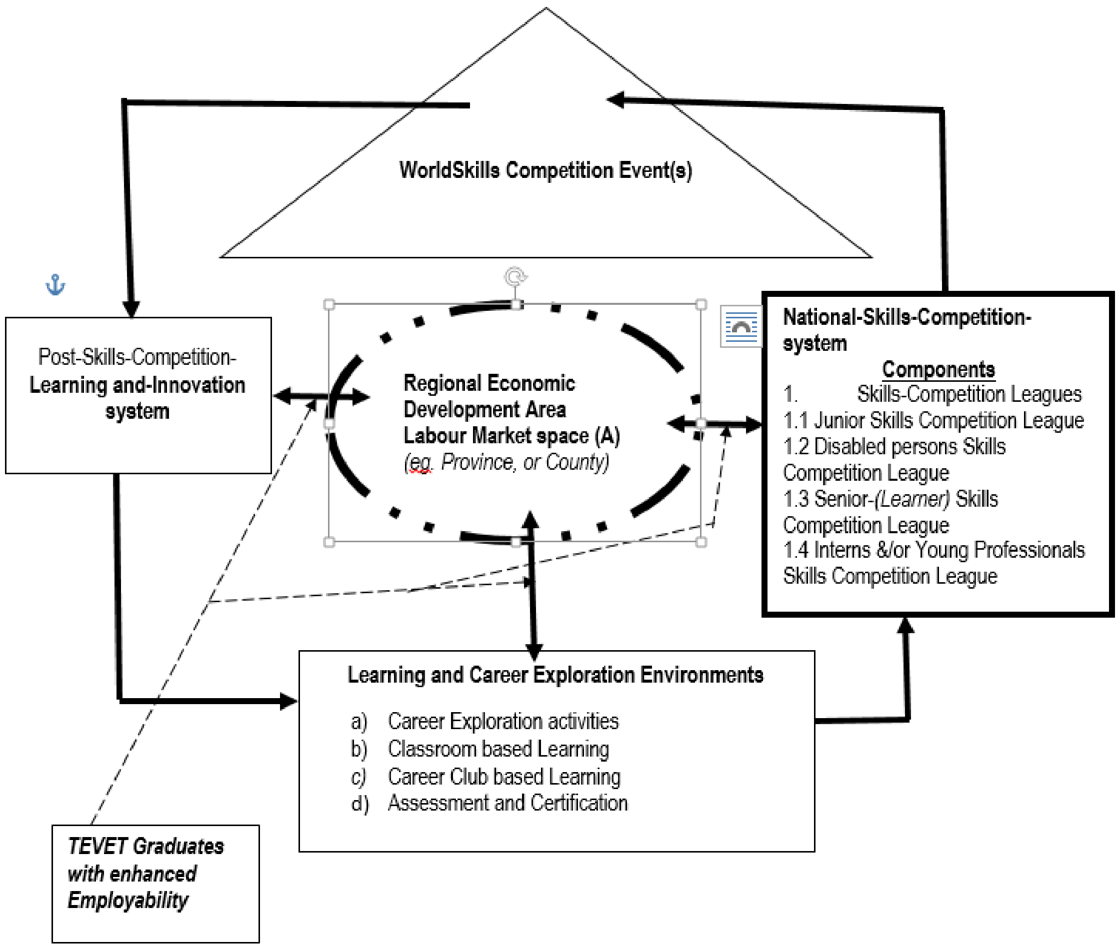

Figure 1: Regional Economy focused Skills Competition enabled Virtual TVET Laboratory system framework

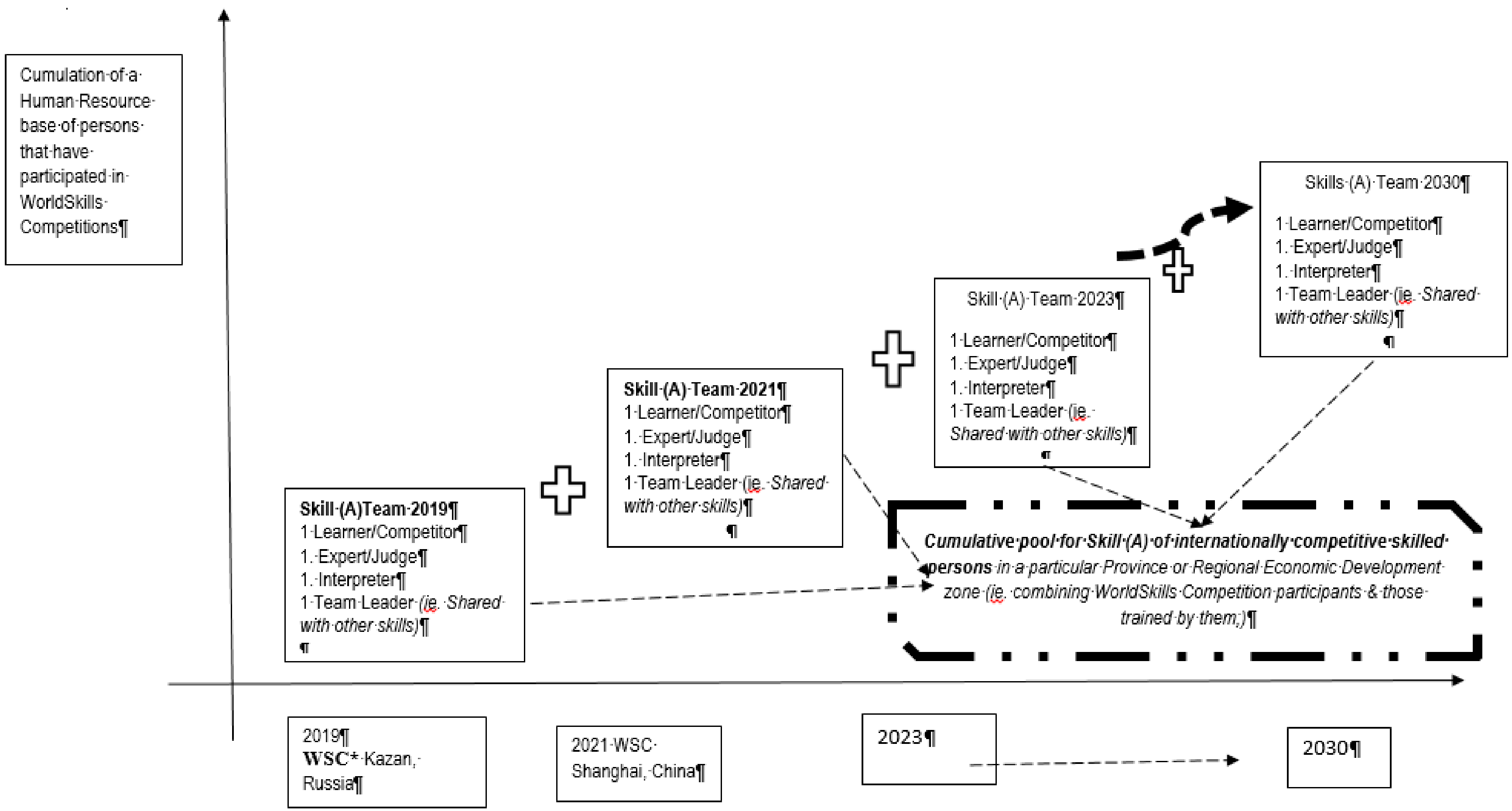

Figure 2 Cumulative number of persons exposed to the WorldSkills Competition standards for Skill (A) in a specific Regional Economic Development zone WSC - WorldSkills Competition*

6. Virtual TEVET Laboratory Platform for monitoring and developing Learning Outcome Standards for Career Club based Work Based Learning simulations[3]

No economy can balance the social demand for TEVET with available enterprises and vacancies for industry practical training. This example as illustrated in Figure 4, illustrates how use of Career Clubs, might be operated in tandem with Production Units, that will be structured through Learn-and-Work Teams, for Work Based Learning simulations.

The starting point are Standard Work Activity Tasks associated with the national curriculum. This would provide a base to escalate performance through Career club based Entrepreneurship and Innovation projects in which learners are compelled to engage with real local customers. Participation in national and WorldSkills Competitions would then enable them to escalate their performance levels to international trade competitiveness.

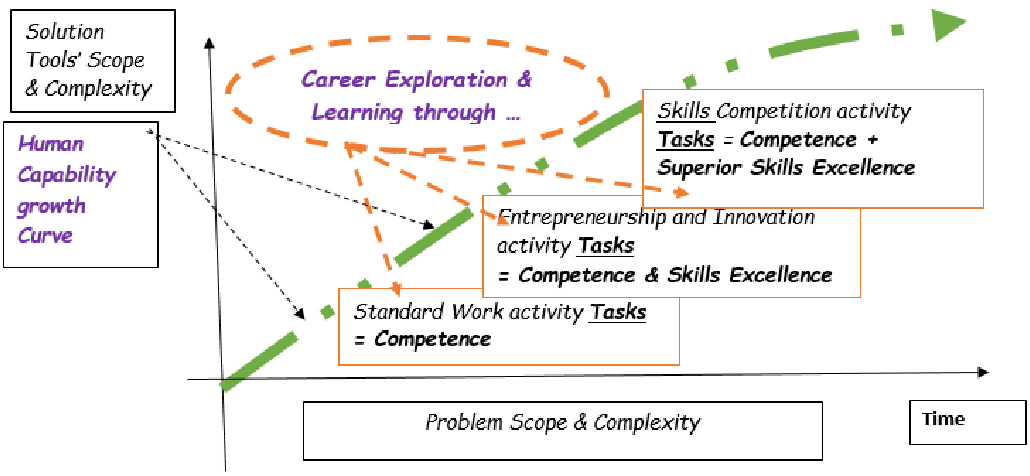

Figure 4: Career or Skills Club based Work Based Learning Simulations

7.0 Conclusion

The interplay of sustained global population growth, rapid rates of technology innovations, combined with climate change volatilities are creating situations where Government policy making and deployment environments are being pressured for trade-offs. This for Sub-Saharan African for example, resulted in sub-optimal outcomes of investments made to improve education and skills development systems. One plausible reason for this development has been the absence of a coherent and easily configurable Laboratory system to undertake required experiments, observations, and controlled environment practices as part of systems development activities. The paper has proposed creation of a "Skills Competition enabled Virtual Laboratory System" that can be configured by any interested party to interrogate elements of interests at both policy and technical levels of a national TEVET system; with the WorldSkills Competition system owned and operated by member states of WorldSkills International as a key enabling element.

[3] Designed by David C. Chakonta – Skills Excellence & Careers Ltd. , Zambia (2018)

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Strategies for Responsive Engineering Curricula: A Framework for Zambia Technical Education and Vocational Training (TVET)

Daniel Noah Mwale[1]

Abstract

Developing a responsive engineering curriculum is a complex process. A responsive curriculum addresses the rapid changing needs of students, bridging the gap between knowledge and theories on one hand and contextual, continuously changing realities of societal needs on the other. The apparent mismatches between industry and national development needs and the outcomes of the engineering education system in Zambia points to a potential lack of responsiveness of the curricula on the part of TVET A and TVET institutions. TVET institutions need to be agile and change their approach to suit the needs of the modern student and emerging societal needs. The paper first identifies characteristics of a responsive curriculum and its development based on literature, and assesses their relevance in the conception of a strategic framework for developing responsive curricula. The paper also illustrates the important role of TVET A, in facilitating an enabling framework for collaboration between professional regulatory bodies (The Engineering Institution of Zambia), TVET institutions, industry, and societal needs. The paper does not seek to provide a panacea for challenges in engineering curriculum design in Zambia , but rather offers a valuable case for future initiatives and themes for further discussion with regard to creating responsive engineering curricula that better responds to current and future needs of TVET institutions, students and the Zambia n society.

Keywords: Responsive curriculum, curriculum, engineering education, Curriculum development, TVET.

1. INTRODUCTION

Technical and Vocational Education Training (TVET), research, and innovation play a key role in social cohesion, economic growth, regional, and global competitiveness. The Smart Zambia Master Plan envisions "a prosperous and globally competitive knowledge-based developed country by 2063" (Republic of Zambia: 2017). Given the desire for Zambia to become knowledge-based, TVET has a crucial aspect of driving socio-economic and cultural development. At the same time, an increasing demand for skills and competences requires TVET to respond in new ways. Issues of quality and relevance of general education in general and

[1] Daniel Noah Mwale, Chief Executive Officer, Khaedan Professional Services,
Email: dnmwale@hotmail.com

engineering education in particular have remained elusive in Zambia. [2]Access to TVET is an opportunity for TEVETA and TVET institutions to make use of increasingly diverse experiences to responding to diversity and growing new expectations for TVET requires a fundamental shift in its provision; it requires a more student-centred approach to learning and teaching, embracing flexible learning paths and recognising competencies gained outside formal curricula and a responsive curricula. After the TEVET policy of 1996, Zambian TVET institutions have become more diverse in their missions, mode of educational provision and cooperation, digital learning, and new forms of delivery. The curriculum therefore requires to be responsive to these emerging issues and disruptions in TVET.

The role of curricula is crucial in supporting TVET systems and institutions in responding to these changes while ensuring the qualifications achieved by students and their experience of TVET remain at the forefront of institutional missions. Achieving diversification, and industrialisation in Zambia, will require human capital that has functional skills and qualifications that support the development of practical skills in science, technology, engineering, and mathematics (STEM). TVET can therefore play a significant role in contributing to the delivery of highly trained human capital that can efficiently drive sustainable national economic diversification and industrialisation. There are, however, several constraints that Zambian TVET faces such as poor quality of skills training, and skills mismatch caused by the peripheral role played by industry and engineering regulatory bodies in the development and execution of engineering training through the TVET curricula (Republic of Zambia 2017:99).

The purpose of this paper therefore is to provide a framework for the development of responsive engineering curricula in the Zambian TVET environment.

2. THE CONCEPT OF CURRICULUM

The concept curriculum has been differently defined by different scholars. These definitions are dependent on their different ideas of teaching, learning, and the functions of TVET institutions and the types of products they expect from learning institutions.

Curriculum can be defined as a plan for instructional guide, which is used for teaching and learning to bring about desirable behaviour change in the learner. This definition refers to the formal curriculum, which is planned ahead of time, bearing in mind the characteristics of the curriculum recipients, the philosophy, and goals of training, the environment, the resources, methods of teaching, and assessment procedures. It is the road map to attainment of the goals of education.

The definition of curriculum as an organised sequences of learning and teaching experiences designed for the training of the learners is related to the above definition. It is a course of studies offered in an institution for the training of students in order to get a diploma, a certificate, or any other forms of academic awards. Learning experiences are embedded in courses taught to the learners in learning institutions. The learning experiences are student oriented, goal oriented; and they can be physical or mental activities, observable or unobservable (Offorma, 2002). Some authors link curriculum content to learning experiences (Tyler, 1971). Wheeler (1978) distinguishes learning experiences from curriculum content, he perceives the latter as the activities engaged by the learners and the former as the knowledge they are made to interact with. Learning experiences are the means while the content is the end. Curriculum content is made up of the subject matter, body of knowledge, topics, ideas, concepts, symbols, facts, and reasons, presented to the students (Offorma, 2002).

Curriculum is a programme which includes programme of studies, programme of accomplishments, and programme of direction. The curriculum is a plan incorporating a structured series of intended learning outcomes and associated learning experiences, structured into a sequence and generally organised as a related series of units, modules, or subjects.

The different stages of curriculum development originate from the activities of the innovative curricular movement which began in the late 1950s, and stressed the responsibility of professional curriculum centres in the introduction of educational changes. This movement was influenced by the guiding theories, of Tyler (1950) and later of Walker (1971) in these centres a strategy of centralisation was adopted. The centres topped down their materials curriculum development which acted as a feedback source (Connelly, 1972). In the 1970's, the Centre's attention was mainly on formulation and development and less on the implementation (Eden, 1979). However, in recent years, there has been discontent with the level of knowledge in the classroom despite the new curriculum. This has led to a mounting realisation of the necessity to scrutinise the effective application of new curricula by teachers and students in TVET institutions (Goodlad, 1977). One of the main assumptions drawn from these studies is that, while external centralised curriculum development bodies are valuable for attracting skilled personnel, have access to various sources of experts and can organise the necessary resources for the construction of high quality materials, they also suffer from one serious disadvantage: their detachment from the classroom.

3. MODELS TO CURRICULUM DEVELOPMENT

The purpose of this paper is not to give a detailed account of the various approaches in curriculum development but rather to give insight about the general approaches to enhance the understanding of responsive curriculum. A few relevant approaches or models are discussed briefly.

3.1 Tyler's Model

Tyler's model for curriculum designing is based on the following questions (Tyler, 1971):

- What educational experiences can be provided that is likely to attain these purposes?
- How can these educational experiences be effectively organised?
- How can we determine whether these purposes are being attained?

The model is linear in nature starting from objectives and ending with evaluation this model evaluation is terminal it is important to note that (Tyler, 1975):

- Objectives form the basis for the selection and organisation of learning experiences
- Objectives form the basis for assessing the curriculum
- Objectives are derived from the learner contemporary life and subject specialist

According to Tyler (1971), evaluation is a process by which one matches the initial expectation with the outcomes

3.2 Taba's Model

The Taba's model (1962) is based upon the curriculum development process similar to Tyler's but introduced additional steps and called for more information to be provided for each of them. The model is:

Diagnosis of needs Formulation of objectives

- Selection of content Organisation of content
- Selection of learning experiences
- Organisation of learning experiences

Determination of what to evaluate and the ways and means of doing it.

3.3 Wheeler's Model

Wheeler's model (Wheeler, 1967) for curriculum design is an improvement upon Tyler's model instead of a linear model, Wheeler developed a cyclical model of evaluation. In Wheeler's model is not terminal. Findings from the evaluation are fed back into the objectives and the goals, which influence other stages.

- Wheeler contends that:
- Aims should be discussed as behaviours referring to the end product of learning which yields the ultimate goals one can think of these ultimate goals as outcomes.
- Aims are formulated from the general to the specific in curriculum planning.
- This results in the formulation of objectives at both an enabling and a terminal level.
- Content is distinguished from the learning experiences which determine that content (Wheeler, 1967).

3.4 Kerr's curriculum model

Most of the features in Kerr's model (1968) are similar to those in Wheeler's and Tyler's models. However Kerr divided the domains into four areas, namely objectives, knowledge, evaluation, and school learning experiences. What should be noted about this model is that the four domains are interrelated directly or indirectly and that the objectives are derived from the school learning experiences and knowledge (Kerr, 1968; Pandey, 2015). In Kerr's model, the objectives are divided into three groups: affective, cognitive, and psychomotor. The model further indicates that knowledge should be organised, integrated, sequenced, and reinforced. This model is based on the following questions:

- What is the purpose of the curriculum?
- How should the knowledge be structured?
- At which levels should the aims function?
- What are the roles of the educators and students in the curriculum process? (Pandey, 2015).

4. RESPONSIVE CURRICULUM

Engineering lies at the interface between science on the one hand and society on the other. It is concerned with the systematic application of scientific and mathematical principles towards practical ends for the benefit of people. Traditionally the emphasis in engineering education has been on the scientific side, with students given a thorough grounding in the basic scientific and mathematical principles underpinning their discipline. However, the constraints on engineering problem-solving today are increasingly not technical, but rather lie on the societal and human side of engineering practice. These changes require new approaches within the curriculum and by promoting active learning and encouraging students to experiment and be more creative, e learning is one of an important number of strategies for achieving the paradigm shift that is required.

There has been demand on engineering education relating to its objectives and organisation and engineering education has come under increasing pressure to consider these developments in its curricula and training methods. The factors that should inform responsive curriculum include economic, science, society and the student.

Traditional conceptions of curriculum remain influential to date (Tanner and Tanner 2007), progressive engineering educational perspectives are emerging. These perceptions recognise that teaching is not about treating students as empty vessels that can be filled with information and takes into account the non-linear character of both learning and teaching.

Accordingly, curricula are re-conceptualised as approaches of thought, guided experience, and as the reconstruction of knowledge and experience that enables the student to cultivate intelligent control of subsequent knowledge and experience. This entails that curricula should be capable of preparing students to meet the skills demand for the future situations, which they might not have necessarily encountered in learning institution. This view is supported by Schubert (1986) who advances the requirement for curricula to fit precise contexts and that subsequently, curricula are continuously in the being created to respond to the ever changing circumstances. Similarly vein, Peters (2000) stresses the significance of flexibility arguing that the curriculum must no longer be made uniform and fixed for long periods. He suggests that it should be variable and flexible to current needs. It must be related not only to individual learning requirements, but to the challenges and demands of experts and anticipate future trends. These authors suggest that curricula need to be relevant, flexible, diverse, and integrated (Taylor 2000) to provide the required skills sets needed to address current and future challenges.

In this paper, the term ‘responsive curriculum’ is used to refer to a flexible and adaptive curriculum that links and removes the gap between theories in engineering, learning and universal knowledge and the more contextual, continuously changing and demanding realities of everyday life and the world of work on the other.

Literature on responsive curriculum design and development stresses diverse requirements for reacting to changing student needs, including interdisciplinary (McFadden et al. 2011), the need to base teaching and learning on problems in the field and the importance of simultaneously developing students’ competencies to accomplish tasks required of such students in practice.

Other literature further stresses the methods relevant for making curriculum responsive. Some authors address the need to involve relevant stakeholders, even beyond the institutions, at all stages of curriculum development (Taylor 2000); others authors suggest that curriculum development starts with identifying current needs of the professional field as a basis for evaluating existing curricula (Paulsen and Peseau 1992). Some also emphasise the centrality of faculty in the curriculum development process and the need for involvement of expert support (Wolf and Hughes 2007). In the Zambian context, the literature on the many characteristics for creating a responsive curricula and specially, how the development process can guarantee that the curriculum meets the requirements of a responsive curricula is not available. This paper will therefore contribute to filling the gap.

From the discussion above, a number of distinctive characteristics of responsive curriculum development have been identified. These include attributes related to curriculum design, implementation, and evaluation. The processes of responsive curriculum development are repetitive and are not linear progression from one stage to the other (Pandey, 2015). They involve all-embracing debates and critical thinking on relevant and appropriate curriculum content then delivery methods (Wolf and Hughes 2007) in which previous decisions are reviewed and revised (McFadden et al. 2011). While traditional curriculum design is often completed within three to six months (Pandey, 2015), responsive curriculum development processes generally require much longer time. Developing a responsive curriculum is a learning process for curriculum developers as it abhors the 'business as usual' attitude by all players. Accordingly the responsive curriculum design process requires a robust internal institutional mechanism for learning and growth. Curriculum evaluation is a continuous improvement-oriented rather than judgement-oriented (Paulsen and Peseau 1992).

The responsive curriculum development processes involves all relevant stakeholders outside the host departments or institutions. Stakeholders may be from relevant industry and are experts in their fields who may not necessarily be members of faculty to direct curriculum development (McFadden et al. 2011; Smith-Sebasto and Shebitz 2013; Taylor 2000; Wolf and Hughes 2007). Stakeholders outside the training institutions, such as

ex-students, practitioners, and employers are also involved to ensure the curriculum links with the world of work (Barradell and Peseta 2016; Taylor 2000). The purpose and extent of engagement of these external stakeholders varies according to disciplines and availability of such experts. Often, they are consulted as a source of information during needs assessment (McFadden et al. 2011; Pandey, 2015). Other times they review curricula (Pandey, 2015)). Rarely, they are made part of responsive curriculum development teams, where they participate in decision-making on curriculum content Paulsen and Peseau 1992). Within a responsive curriculum, courses are rarely taught by individual faculty members. Instead, a team of teachers work together to deliver a course and this includes the involvement of external actors in order to link learning to the real-world (McFadden et al. 2011). Linking learning to the world of work is one of the unique attribute identified.

All processes of curriculum development require leadership, commitment of a team leader to guide the process. Responsive curriculum development requires a leader who is highly motivated and an expert about ensuring the responsive character of the curriculum by facilitating the engagement of other members of the institution in the field, sometimes from different disciplines (Patterson, 2007).

5. STRATEGIES FOR RESPONSIVE CURRICULUM FOR TVET IN ZAMBIA

The following discussion explores the strategies and their implications for responsive curriculum in Zambia's TVET:

5.1 Strategic Stakeholder Engagement

The engineering curriculum should be designed to meet the needs of industry, the employers, and the labour market. It is therefore, necessary to identify specific groups or users for the curriculum being developed and arrange consultation with them. It is important that these groups be consulted, so that these groups own the curriculum, see it as meeting their needs, and consider it to be labour market demand driven. In some countries the initial approach for curriculum development/ revision is initiated by industry groups.

5.2 Creation of Career Pathways TVET to University

The curriculum developers need to consider the options available to engineering students for career opportunities and avenues available for higher education/vertical mobility. For example the engineering student after graduating from TVET may proceed to additional training, self/wage employment or a diploma/first degree programme. Alternative pathways and articulation possibilities/opportunities are key elements of successful engineering curriculum. Recognition of prior learning as practiced in some countries may provide an incentive for career pathways in engineering education.

5.3 Strategic Research and Development engagement

Successful engineering curriculum should be based on valid statistical data, collected from a wide range of sources, and analysed in line with the rationale and objectives of curriculum development. There should be mechanisms in place to provide the necessary data, back stopping and professional support for engineering education curricula. There is a need to establish an infrastructure to collect, analyse and disseminate the necessary research information to form the basis of engineering curriculum development.

There is a need for setting up of a research data bank which can be accessible by TVET institutions. Some research fields can include:

- Graduate surveys
- Analysis of employment market trends
- Demographic data
- Emerging engineering trends

5.4 Developing Expertise in curriculum development in TVET Institutions

Relevant TVET curriculum is the real key to the process of providing knowledge and skills to learners. Expertise in curriculum development and its implementation is the most important prerequisite in providing a competitive edge.

5.5 Change Management and Societal Resistance

It is generally accepted that engineering education is a traditionalist process and not willingly open to quick changes (Evans and Henrichsen. 2008). Teachers in overall like to remain with old curricula and teaching practices. Institutional managers of change often show apathy towards curriculum change. This is emphasised by poor responsiveness about change processes on the part of the society as a whole which also includes parents and learners.

5.6 Policy Support and Priority

For appropriate and applicable responsive engineering curriculum, it is necessary to have government support in policy formulation. Government needs to appropriately prioritise engineering education.

5.7 Economic and policy Adaptability

The economy and society need an education system that is more responsive in the sense of being able to adapt but also to lead by shaping the transmission of knowledge and producing leaders who can facilitate adaptation. Hence the real challenge for the TVET system is to determine the skill sets and disciplines that drawn on most heavily by society and the economy at any point in time. TVET institutions then have to ensure that they impart the highest possible level of knowledge and basic skills possible in that skills set or discipline. This requires a very close understanding of the surrounding society and the economy. In fact the institutions have to be deeply entrenched in that society and economy.

5.8 Institutional Disciplinary Adaptation

Institutional responsiveness can only be achieved in a situation in which disciplinary enquiry and rigour is not compromised. This necessitates a focus on disciplinary responsiveness. Economic, social, institutional, and cultural responsiveness must be supported by rigorous and systematic approaches to knowledge development and dissemination in TVET curricula. A distinctive aspect of TVET institutions is their adherence to formal and principled procedures for assessing knowledge claims.

5.9 Instructional and learning responsiveness

Ensuring that curricula are designed and delivered in a manner that is pedagogically sensitive to students from diverse educational and cultural backgrounds presents complex and demanding challenges for TVET institutions. Responsiveness in this sense entails approaches to the design of curricula, instructional strategies, methods of assessment, and approaches to student support that take the characteristics and context of target student groups seriously.

6. CONCLUSION

TVET institutions should, in drawing on national resources to fund their activities, keep clearly in mind the national development agenda and interests which are bound to weigh with societal stakeholders, and with those considerations in mind seek to present these stakeholders with a coherent picture of what the TVET institutions are doing, and seek to do, for the Zambian society.

Significant to re-establishing their relevance to society is the need to ensure that TVET institutions are responsive to the country's development agenda and that they produce graduates in sufficient numbers with the necessary skills to enhance national competitiveness and productivity in a national, regional, and global context. However, it would be irresponsible of TVET to narrow its focus to merely responding to labour market requirements and it is thus essential that curriculum responsiveness is viewed as a multi-dimensional concept with economic responsiveness as a subset of other equally important imperatives such as technological, social, institutional, cultural, disciplinary and pedagogical and learning responsiveness.

In conclusion, Zambian TVET institutions are confronted with a variety of challenges in enhancing curriculum responsiveness, however, success in responding to these challenges will only help to advance their presence and guarantee that they thrive as vibrant contributors of the much needed knowledge generation, relevant skills and dissemination in an industrialised economy.

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Development through Entrepreneur driven STEM education for children

Dunstan Chola[1]

ABSTRACT

As we now live in the 4th Industrial Revolution where the disruption to business models, how we work and the infrastructure requirements is evident. Further, due to the convergence of **B**usiness, Medicine Technology, Engineering, Technology, Arts and Law (BMETAL), there is virtually no career that's being spared in these changes. The World Economic Forum in their report (The Future of Jobs) have stated that the skills required to thrive now and in the future cut across job types. Evident too is that government driven education programs, especially in developing countries, simply don't have the curriculum or disposition to develop these skills early enough in children aged between 4 and 15. This is a problem that needs to be solved and thus presents an opportunity for entrepreneurs that are willing to seize the moment. This paper looks at the current situation and describes education programs that can deliver 4th Industrial revolution skills at various stages of child education and how entrepreneurs can seize on this to solve the problem. The focus is describing programs that target teaching 4th industry revolutions skills to children between the age of 4 years and 15 years without which a majority of these children will not be prepared for the jobs of the future thus threatening guarantees provided by SDG 8, 10 and 17. It also presents an overview highlighting Franchises as one method that entrepreneurs can use and particularly looks lists how one Franchise's study programs seems to be a good fit in its ability to deliver these skills across this entire age group.

The paper concludes by asking governments to embrace the delivery of such education programs in schools and also urges entrepreneurs to invest in the business of teaching such and other STEM programs to children in order to secure their meaningful participation in the future work place.

Keywords: Skills, Entrepreneur, STEM, education, Children

1. Introduction

The educational needs of the fourth industrial revolution are not to be ignored if only because, as seen in the past, each industrial revolution before has brought forth new impact on the type of education required and how that education is delivered. Those individuals and countries that have responded favourably to the education demands of each industrial revolution have ended up

[1] DVS INNOVATIONS LTD; P.O BOX 310229, Lusaka; +260965459352; dunstanchola@gmail.com

acquiring monopoly of talent, etc together with the attendant economic and social benefit ahead of those that fail or refuse to respond.

While the World Economic forum and other studies have described to us the skills required in the future work place and the fact that 65% of children entering school today will work in jobs that do not exist, we are not acquiring those required skills at the speed fast enough to fully take advantage of the demand for those skills. In fact government schools in most developing countries are mainly delivering STEM education at a slow pace and in a manner that seems to be failing to impact a good number of children, especially those children that are not naturally predisposed to STEM. Questions can be asked about whether the STEM education being taught now it adequate to deliver the required skills early enough in our growing children or if indeed we are teaching them in the right way. Further it seems we are waiting too late to teach technology to children in the right way

We need some innovation (curriculum or otherwise) for each of our unique children, communities or indeed countries in order to meet this challenge. Entrepreneurs seem to be best suited for this and the environment must be expanded in order for entrepreneurs to find their niches and deliver on these requirements to as wide a number of children as possible.

2. Status Quo

STEM education curriculum in Zambia is prescribed by government and delivered in a consistent format and method across most (if not all) schools countrywide. It can however be argued that out of the four areas in STEM, only Science and Mathematics is actually taught in our schools neglecting Engineering and to a large extent Technology. There also appears to be a problem in the effectiveness in the delivery of science and Mathematics going by average results being achieved by learners in Zambia.

Table 1. Average scores in science and Mathematics. (Source: ZEEP Baseline Survey Report)

Province	Mathematics Learners Mean Scores in %			Science Learners Mean Scores in %		
	Girls	Boys	Total	Girls	Boys	Total
Muchinga	28.0	28.3	28.1	33.3	32.7	33.0
Northern	31.4	33.7	32.6	42.4	46.1	44.3
Luapula	34.1	34.4	34.2	42.5	47.4	44.9
Southern	30.3	30.6	30.4	35.9	35.4	35.6
Eastern	32.2	33.4	32.5	38.2	40.6	39.2
Copperbelt	32.4	29.6	31.1	43.4	38.8	41.3
Northwestern	28.8	31.0	29.9	34.4	35.7	35.0
Central	29.7	28.0	29.0	34.9	34.3	34.4
Western	34.2	33.5	33.8	38.4	37.9	38.1
Lusaka	30.4	32.0	31.1	37.6	40.0	38.6
Overall	**31.2**	**31.4**	**31.3**	**38.2**	**39.1**	**38.6**

Reviewed documents would appear to suggest that there are some problems in STEM education delivery or simply in developing the required skills through current circumstances (teacher shortages, limited practical lessons, etc) of STEM. These problems are manifest in the low average grades in science by learners, career choices of secondary school leavers and the aptitude of most school leavers that get to choose Science and Engineering careers. The examination council of Zambia reports for recent years show that a large number of pupils are not grasping concepts in certain subject topics, lacking in critical thinking, failing to interpret diagrams, exhibiting low problem solving skills and failing to apply knowledge to real life situations.

This is not really a problem currently because a large number of careers do not require these skills. However, it will soon become a problem as these children graduate and start working because most workers of the future will in one way or the other be custodians of technology such that it will be impossible for those workers to ignore STEM subjects just like it will be impossible for Engineer types to ignore humanities. Artificial intelligence, coupled with analytics, IoT, ability to estimate human cognition in medicine and agriculture, drones, etc will require people who today do not care about technology (Lawyers, Doctors, Pharmacists, Auditors, etc) to depend on it for their own career survival or indeed to be competitive.

Children between 4 and 16 years old in advanced economies are now learning new STEM subjects like synthetic biology, coding (low level programming), robotics, virtual reality, etc and are being exposed to group work, Playful learning, Project based learning, high quality STEM teachers, 3D Printing, Artificial Intelligence etc. These are the areas in which opportunities exist for entrepreneurs to exploit and these are being achieved in various ways across the world and Africa cannot afford to remain behind on this.

3. Solutions and Opportunities for Entrepreneurs

3.1 Project based learning, Playful Learning and Learning by Making.

It is true that there are those of us that are naturally predisposed to learning STEM in the formal classroom situation and our concentration in those environments will still be keen. However there are some among us who cannot learn any STEM concept in such environments.

Graham Brown-Marlin in his paper, “Education and the 4th Industrial revolution (2017)”, argues that to solve some limitations of classroom teaching, every STEM subject must have a sibling of an applied or practical nature. This means giving children practical problems to solve that depend on their understanding of theory in order to accomplish the practical task. To complement this stance is Mitchel Resnick (Professor of Learning Research) who has concluded that, learning through play is an enduring experience that boosts student confidence to grasp theories, design their own products and look forward to attending their next class. It is an area that remain unexploited in Zambia although it is loosely implemented mostly in nursery schools albeit without a structured learning objective behind those implementations.

Many other authorities agree with these statements which lead us to believe that entrepreneurs can seize this opportunity by creating practical study programs (maybe as after school programs) in interested schools at a fee. A simple market survey conducted for Lusaka show very promising financial rewards that are worth a commensurate investment. It is also possible now for one such entrepreneur to skip the research and design stage of such programs and instead buy readymade programs, tools and delivery methods as a Franchise thus cut on time and deliver immediately to meet global standards of those that have already been at such programs for a long time.

3.1.1 A General Look at Franchise Education

There are many Education Franchises that can be adapted to teach STEM in Zambian schools for the ages between 4 and 16. The beauty with any franchise is that, as an entrepreneur, you do not need to invest into a research and development team since the franchisor will employs such people for you so that you can concentrate on delivering on what your client wants solved. Many type of franchises exist and education is not left behind. We present below those franchises that we have had a look at just to show a bit of what is out there in the education sector.

Table 2: List of some franchises available in the STEM education sector.

Franchise Name	**What it Teaches**	**Investment**
Young Engineers	STEM Enrichment (Automation, Robotics, Engineering, Coding)	$20,000 - $42,000
Kumon	Enhances Maths and English	$1,000-$10,000
STEM for Kids	STEM Enrichment (Automation, Biomedical Engineering, Virtual Reality)	$20,000 - $52,000
Sylvan Learning Centers	STEM Enrichment	$15,000-$40,000
Mathnasium	Custom Math Tutoring Services	
Muzhinda Hubs	Coding, application development	

For any of these Education franchises, the entrepreneur will be equipped with manuals, tools, management support, updates, etc that will make delivery of the selected programs easier with less headaches. The catch is one has to pay royalties to the franchisor in perpetuity in order to continue enjoying the franchise.

3.1.2 An overview of Young Engineers Franchise Study Programs

Young Engineers is a Global Franchise from Israel that operates in 43 countries and is endorsed by Harvard University to improve student concentration improvement of interest in science subjects by those that would normally not be interested. It provides unique study programs for children aged 4 to 15 years old that teach, mathematical principles, the laws of physics, engineering (including programming), teamwork and collaboration in an entertaining way. These programs have been proven to improve concentration, creativity and logical thinking in those children. The programs are generally delivered as an ongoing after class program on selected days of the week.

Some of the programs created by YE Franchise for different age groups are presented in Table 3.

Table 3: An overview of study programs created under the Young Engineers Franchise

Target Age	Study Program Name	Program Objectives
4yrs – 6yrs	BIG BUILDERS PROGRAM	• Nature and Environment • Basic Scientific Concepts • Creative and independent thinking • Developing self-reliance • Developing Problem Solving • Teamwork and group play
6yrs – 9yrs	BRICK CHALLENGE	• Motor and Spatial Skills • Planning and Time management skills • Interpersonal skills • The laws of physics • Develop sense of self reliance
9yrs – 12yrs	GALILEO TECHNIC	• Creative thinking • Problem Solving • Laws of Physics • Develop self-reliance • Interpersonal Skills • Teamwork
7yrs – 11yrs	ROBO BRICKS	• Introduction to Robotics and Computer Science • Problem Solving • Critical and creative thinking • Self-reliance and self confidence
12yrs – 16yrs	ROBOTICS	• Coding Skills • Advances Algorithmic thinking • Engineering perspective • Teamwork
5yrs – 13yrs	ALGOBRIX	• Algorithmic thinking • Coding and Robotics • Multi-threading • Mechanics • Teamwork • Problem Solving
6yrs – 10yrs	ALGOPLAY	• Algorithms • Functions and parameters • Conditions and Loops • Multithreading • Debugging

3.2 Private STEM schools and Introduction of New STEM

Well run private schools are generally in very high demand and therefore a good way of delivering STEM education that meet global standards within Zambia at a premium to the entrepreneur.

As stated above, new STEM now includes subjects that are not being taught in the Zambian curriculum but must quickly be learnt by our children in order for them to be ready for the future. Government schools are also struggling to attract enough, let alone retain, high quality STEM teachers simply because of the nature of governments as well as the practice of STEM teachers to stop teaching lower grades (and even leaving the teaching profession) once they study further.

An entrepreneur in the Education sector can surmount these challenges and reap financial rewards in the process.

It is possible to open private schools that do not need to follow the Zambian curriculum thus opening an opportunity to offer STEM education exactly as offered in countries that are at the edge of developing future skills using old STEM or new STEM. Such a school is free to offer subjects featuring Robotics, Programing, Biotech, Genomics, etc using a private school and get affiliated to examination authorities that currently recognise these new frontiers of early child education.

A Facebook research we conducted showed that 87% of our target respondents (Zambians living in Lusaka and Copperbelt province of Zambia with kids in the age group 4-16), would be willing to switch their child to a well-run private school even if the new school charged up to twice what they pay at the current school if this promises to give their child a clear advantage in the future job market. This suggests a large market that must further be researched for any such private schools that are able to communicate their offering in a clear and specific manner.

4. Conclusion

It is clear entrepreneurs can assist drive future proof STEM education in Africa by seizing on the many opportunities and circumstanced at the moment. One way is introducing special practical STEM study programs (or purchasing STEM education franchises) whilst the other is establishing special private schools that deliver cutting edge STEM education focusing on new STEM areas and also employing and retaining high quality STEM teachers in those schools from anywhere in the world. Governments alone will not do it in good time because of various challenges highlighted as well as the fact that some means of delivering the required STEM education can only be championed by Entrepreneurs. To achieve scale, many entrepreneurs need to enter this space while government on the other hand must also embrace this if only to also use is as a test mechanism for change that they might need to implement in the main curriculum.

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Engineering Industrial Practical Skills Transfer: The Role of the School of Engineering at the University of Zambia

Sebastian K. Namukolo[1], Ackim Zulu[2]

Abstract

This paper reviews the current ongoing practical engineering industrial short courses programme offered in the School of Engineering at the University of Zambia, with a view of making improvements and revisions of the current courses, introduction of more courses and devising means of measuring success outcomes as a strategy of effective engineering skills transfer to the Zambian industry. The roots for the existing lag in the response of the education systems in developing countries to changes in technology are traced, together with an outline of the development of electronic technologies. The observed Zambian industrial skills gap that has increased in recent years has been occasioned by the fast technological advances in the ICT industry that now requires new skills in the installations, utilization, protection, maintenance and repair of equipment at all levels of application and usage (industrial, commercial and household). This engineering skills gap that affects most developing countries, compounded by lack of manufacturer's representation, has affected national productivity output resulting in economic growth slowdown. The paper discusses the identified skills gap and a challenge brought about by knowledge deficiency and suggests and outlines a roadmap in addressing the problem by the provision of intensive theory and practical based short industrial relevant courses as a means of transferring the required engineering skills. It also suggests upgrading and improvements of the current industrial short courses being offered and proposes the introduction of additional new ones in line with modern applied technology industrial trend, and suggests the implementation of success measurable evaluation outcome strategies.

Keywords: electronic technology, ICT, industrial skills, knowledge deficiency, short courses, skills transfer, skills gap.

1. Introduction

Engineering technology, as other human endeavours, has been developing over time. Two types of developments are discernible in engineering technology. The first is the dichotomous type that bears landmarks of upheavals in thinking and actions such as occurred over the last four centuries in the transformation of the first industrial revolution in the 18th century to the current fourth

[1] University of Zambia; School of Engineering, Box 32379, Lusaka; +260 211 293792; sebastian.namukolo@unza.zm.
[2] University of Zambia; School of Engineering, Box 32379, Lusaka; +260 211 293792; ackim.zulu@unza.zm.

industrial revolution (Freeman and Louca, 2001). The second type of technology development is the one of evolutionary form, mainly occurring within technology disciplines, and is typified by such occurrences as appeared in the industry of information and technology technologies (ICTs). One characteristic of the change in the second category is that it is predictable, and in the ICT industry, is famously characterised by Moore's law (Schaller, 1997; Mack, 2011). Despite being predictable, the second type of change has appreciable impact on the parameters of labour, business and organization arrangements and ultimately on productivity. This paper shall henceforth use engineering technology development and change as referring to the second type, in the examination of the response of the School of Engineering of the University of Zambia (UNZA) to what appears as rapid changes and developments in Engineering technology.

The developed and industrialised countries appear to have educational and training systems which are well-aligned or matched to the development of technology, whereas developing nations characteristically have corresponding systems that lag the developments in technology changes (Berman et al, 1998). This poses an identifiable challenge to the educational and training systems in the developing world. The School of Engineering has been in existence from 1967, and has experienced a fair share of this challenge in the environment of hostile situations of 1) weak linkages between industry and academia, 2) low capitalisation in education and training infrastructure, and 3) low capacity for technology manufacturing and service provision related to technology. Although the response of the School of Engineering to this challenge appears to be reactive, the School is turning this response into a strategic posture. This paper presents the vision, purpose and development of the Practical Engineering Industrial Short Courses Programme in the Department of Electrical and Electrical Engineering at the University of Zambia as a response to, and acceptance of, the changing technology landscape in the discipline of electrical engineering. This paper is organised to show, in the introduction (section I), the milieu of technology, and reveal the challenges in section II. In section the III, the challenges of ICT technologies are situated, while in section IV, the response of the School of Engineering of UNZA are presented. The paper ends with a conclusion in section V.

2. The problem in context: electronic technology challenges

The Second World War was a poignant period during which the shortcomings in the performance of equipment manufactured in the temperate regions and deployed for use in the tropics came to the fore (Follet, 1956). Following this insight, the subsequent generations of equipment were redesigned with adaptation to the tropical climate, spawning the term “tropicalization”. In the 1980s, it was found that a significant amount of electronic instrumentation equipment for medical facilities and research institutions in Zambia is in an ineffectual state for various reasons. Prominent among these factors for this state of affairs were outright poor installations from the beginning of projects and a lack of skilled manpower for maintenance of the equipment when in service. This is starkly reflected even in the microcosm of the situation in Zambia as captured in a parliamentary committee report of 2016 (NAS, 2016) and an externally constituted study by the World Bank in 2018 (World Bank, 2018). The International Atomic Energy Agency (IAEA) has been one of the leads in recognizing this situation in Africa and subsequently achieving an international agreement of cooperation from 1990 (IAEA, 1990) under which short-term training programmes could be instituted for specialised training of personnel. It was apparent in the IAEA experiences that the key ingredient to the success of the deployment of equipment for medical diagnosis and treatment and that for research and instruction in higher education institutions was a well-trained cadre of manpower. In the sense of being well-trained, the component for updating the skills of personnel following progress in the technology of equipment and for re-skilling of personnel in the face of new technologies is appreciably significant for both the installation and service stages of the equipment.

The IAEA's position has subsequently taken a wider view of the problem of skilled manpower in developing nations of Africa and Asia and include formal training through standard courses in higher education institutions up to postgraduate qualification and research (IAEA, 2019). The widened position has also called in more funding and other partners such as UNESCO, the World Academy of Sciences, the Regional Universities Forum for Capacity Building in Agriculture (RUFORUM) and the Harbin Engineering University. However, the initial approach for focusing on short specialised courses has been so effective that the School of Engineering of UNZA has adopted this approach from the late 1990s to satisfy the need for specialised short-term training of personnel for industries in Zambia.

3. Situating the challenges of electronic technology

It is generally agreed that technology is the key that can lift the developing nations into the status of developed countries. While experts also generally agree that a wide range of factors are at play for solving the dilemma of innovation and uptake of technologies in the developing countries (Cirera and Maloney, 2017), certain key issues emerge and subsist in the application of adopted technologies, more particularly so in developing nations because these regions do not apply the requisite measures and safeguards expected for evolution of technology and changing operating environment. One area of technology where this is acutely apparent is in the modern instrumentation and data processing equipment. The developments and environment in this area are changing on several fronts (NTIS, 1983) of which the pertinent ones are the ones portrayed in the following subsections.

3.1 Reliance of modern technologies on data processing units

The tendency for modern technologies is towards a growing usage of ICT functions. The microprocessor is at the core of these functions. Human activities are now augmented with technologies which employ the microprocessor either as general purpose or application specific. The scope of human activity sectors covered by the use of the microprocessor involves the sectors of domestic, industrial, conveyance, computing and electronics, low-power supplies and supervision, and medical application (Okoro et al, 2013). Nearly every conceivable facet of human activity seems to employ the microprocessor as illustrated in the expanded description of the activities in Table 1.

Tracing the evolution of the microprocessor from 1971 to the present reveals a fascinating route of remarkable developments. Figure 1 synthesises the evolution of the microprocessor from three points of view: 1) electronic technology firsts, 2) generations of the microprocessor development, and 3) key functional issues pertaining to the periods of development. In the first view, the definition of the time of appearance for the major technologies is pinpointed, from the first bipolar junction transistor in 1947 to the usage of very-large-scale-integration (VLSI) of electronic devices in 1976. In the second view, a generations-angle is assumed in which five generations of development from the first generation of the microprocessor in the early 1970s to the current fifth generation are distinct. In the third view, the changing issues of interest in the functionality of the microprocessor the decades from 1970 to 2020 are captured.

Table 1: Microprocessor Applications

Sector		Applications
I	***Domestic***	Appliances: Security: Climate control:
II	***Industrial***	Transport systems of: Road Rail Air Water transport systems Fluid (gas/liquid) pumps Payment systems Temperature control Computer servers Medical devices Vending kiosks Security and surveillance systems Physical and digital access control
III	***Conveyance***	Road: automobiles and trucks Rail: trains Air: aircraft Water: boats and ships
IV	***Computing and Electronics***	Data and information processing units ranging from micro- to super- computing systems Mobile communication devices Home and mobile entertainment devices Operating modes and functions control
V	***Low-power supply and supervision***	Mobile powering of devices
VI	***Medical***	Control and regulation of biological functions: blood sugar, pace-makers, etc

While the resulting computing power is progressively increasing, with the attendant addition of complexity, the microprocessor together with associated peripheries has become more fragile in the operating environment. In admitting the importance of the role of the microprocessor in human activities, it becomes apparent that in some critical sectors there is great need to apply effort to achieve a performance which is continuous and is free from malfunctions and errors. Applications in the sectors of health, critical public services, crucial commercial arrangements and the security industry are at the front of this consideration.

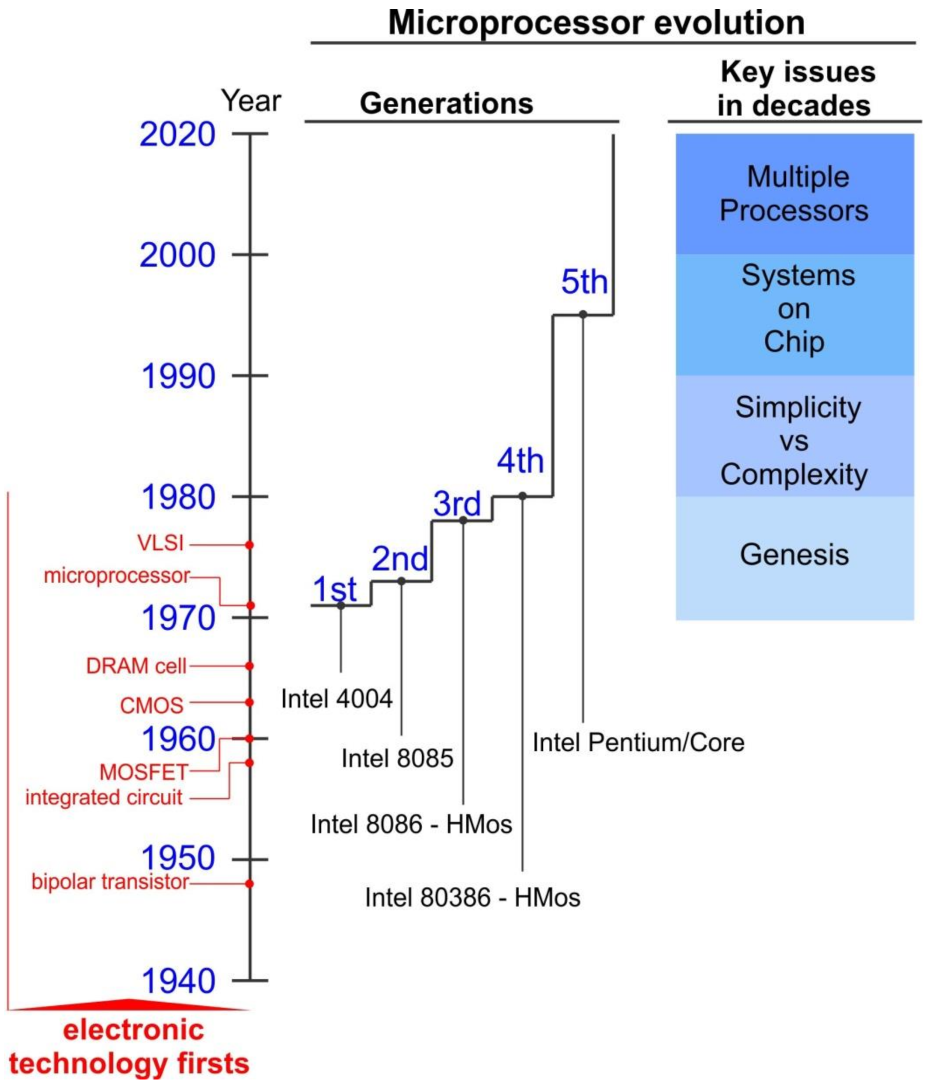

Fig. 1: Three views of the development of the ICT processor

3.2 Mismatch in improvements of device performance and immunity to electrical noise

While older generations so ICT processing devices operated satisfactorily in the existing electronic environment, the situation is not so for new generation devices. The new devices are undoubtedly faster, more powerful with complex logic and higher capacity memory, benefiting from the breakthrough of VLSI. On the other hand, the electrical noise in the environment has increased, resulting from the operation of fast switching semiconductor devices and the extensive use of unconditioned power. A combination of the fragility of the new generation ICT processing devices and the worsening of the operating electrical environment produces a chasm in the operating condition of the new technology. Under these conditions is apparent that there is requirement to apply measures that either improve the electrical environment or protect the new generation ICT processing devices or a combination of the two approaches.

3.3 Increasing power quality issues

The electrical power supply system is meant to supply ac power continuously at the correct voltage and frequency. When any of these requirements is not met, the power supply is deemed to have power quality issues. In the technical consideration, power quality issues are more extensive than the stated requirements in this introduction and are more specifically defined to include the list in Table 2 (Kennedy, 2000).

Table 2: Power quality problems and their effects

Classification		Types	General Causes	Effect/Affected items
I	***Steady-state issues***	interruptions	Breaker and fuse operation due to protection or maintenance	No power supply
		Under- and over-voltages	Load variations; motor starting	Machine life
		Harmonics	Nonlinear loads	Overheating and maloperation of equipment
		Flicker	Motor starting	Irritation
II	***Slow transients***	Sags and swells	Faults	ICT equipment
III	***Fast transients***	Impulses	Lightning; load switching	ICT equipment
		Oscillatory transients	Switching operations	ICT equipment

There is notable effect on ICT equipment by power quality issues of the kind in the classes of transients, which are mainly as the result of power system faults and switching operations. The ICT equipment, being predominantly nonlinear contributes to the generation of power quality problems of the steady-state kind in the form of harmonics. The result of this interplay is an increased power quality problems.

3.4 Response to the problems

In considering the multifaceted issue resulting from the evolution of technology, especially of the ICT form, the general response of has been a resort to regulation, codes, and standards. Such regulations are noticeable in Europe (e.g. The European Union Directive on Electromagnetic Compatibility (EMC)) and in USA (e.g. the Federal Communications Commission regulations on Electromagnetic Interference (EMI)). Both the International Electrotechnical Commission (IEC) and the Institute of Electrical and Electronic Engineers (IEEE) have promulgated numerous standards that address use and operation of equipment and devices, on one hand, and address the conditions of the electrical environment, on the other hand. However, experts agree that the measures of regulations and standards alone can resolve the issues raised. A combined approach of monitoring the electrical environment and taking a proactive stance to address the quality issues which arise in the electrical environment augments the intentions of regulations and standards.

4. Response of School of Engineering

The standard response of the education system to the challenge of the multifaceted position of the increasing fragility of the core electronic devices of technology and the deterioration of the electrical environment in which the electronic technology operates would to progressively review or develop curriculum that takes into account the developing changes. As expressed in the introduction, this approach is followed as a matter of fact in the education institutions of the developing world in the manner already discussed. The situation in Zambia industries was affirmed through audits performed by School of Engineering of UNZA over a number of years since late 1990s.

4.1 Response to the challenge

The approach adopted by the School of Engineering at UNZA is one of immediate response by giving on-demand tailor-made short-term courses targeting practicing professional under Engineering Industrial Practical Skills Transfer programme. Typically, the duration of each course is five days, giving the professional the flexibility of time and cost to update skills for negotiation the challenges described. The programmes, a representative menu as shown in Table 3 for the period 1998-2019, have both a theoretical content and a hands-on practical aspect, so that professional emerge with added confidence to apply corrective measures of mitigating the operating electrical environment and restoring failed equipment.

4.2 Future outlook and plans

It is expected the state of posture of the relationship to changing technology of Zambia will persist for the next ten years. The School of Engineering, as regards electro technology, plans to strengthen and expand its mission to upgrade the skills of the practicing professionals.

Some of the practical actions to apply in the near future to meet this end are included in the list below:

- Establish a centre in the university for short term training of practicing professionals
- Increase linkages with the local industry and professional bodies such as the Engineering Institution of Zambia and the IEEE.
- Organize conferences and workshops
- Involve government organs.

Stakeholders’ endorsements, in addition to understanding their needs, can lead to increasing the suite of short courses in School of Engineering at UNZA beyond the quantity shown Table 3.

Table 3: School of Engineering menu of short courses 1998-2019 for electrical engineering professionals

	Short course	Sector(s) of Microprocessor Application per Table 1
1	Switch mode power supplies	I, II, IV, V
2	Design of off-grid solar power supply	I
3	Design and repair of variable speed drives	II, III
4	Power conditioning earthing and lightning protection	I-VI
5	Design and repair of inverters	I, IV, V
6	Industrial plant automation	
8	Theory, troubleshooting and repair of uninterruptible power supplies	I, II, IV, V
9	Design of a basic SCADA system for industrial and power substation control	I, II
10	Wide area monitoring protection and control	I-VI
11	Reliability, power quality and earthing systems	I-VI

5. Conclusion

Starting from the position that education systems in developing countries are not as well-equipped as those in the developing countries to track the rapid changes in technology, particularly in electronics, a challenge is established for higher educational institutions in the developing world. It has further been realised that certain technologies developed for operation in certain environments does not perform as well as intended when deployed in different environments. A host of factors combine to challenge the operating space of ICT-based technology. As the world marches into the 4th industrial revolution, a growing reliance on ICT in the use of technology is observed. Further, the increase in the performance of the ICT processors seems not to be matched by protection against the electrical disturbances. Crucially, power quality problems are gaining in appearance in the electrical environment and in effect on the ICT technologies.

A multi-faceted approach to the identified challenges is recommended to augment regulations and standards, and involves having arrangements of monitoring the electrical environment to determine the state of affairs and deploying mitigating measures. The standards developed by the IEC and IEEE provide clear guidance on such arrangements.

The School of Engineering of UNZA, being encumbered in the identified situations of higher educational institutions in the developing world, is proactively facing the challenges through purposely-crafted short-term training courses to update the skills of practicing professionals. The short-term courses have been running for nearly two decades and the future plan of the institution is to strengthen and expand this approach using the support of all stakeholders. To this end, the School of Engineering counts on the support of the professional bodies, government organs and the Zambian industry.

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Increasing Efficiency in Wet Scrubbers

Mweene Himwiinga[1], Sergey Yurevich Panov[2], Wezi Nyimbili Nkonde[3]

Abstract

Air pollution, particularly industrial air pollution is currently a serious global problem as over 100 million tons per year of industrial gaseous pollutants and other substances contaminate the air basin leaving many areas unsuitable for habitation of any form. Zambia is no exception to this problem as thousands of its population are exposed to harmful air such as sulfur dioxide, nitrogen oxides and hydrocarbons from industrial activities and some cases have been fatal. This research is aimed at enhancing the treatment efficiency of industrial air pollution control devices namely spray-type scrubbers by combining processes and improving hydrodynamic characteristics of the device. The proposed design for a cost effective, energy efficient wet scrubber for the treatment of industrial gaseous emissions consists of a contact device made up of a chain curtain with the primary purpose of intensifying absorption of pollutant gases. Experiments were conducted in carbon dioxide-water and sulfur dioxide-water systems using a specifically designed laboratory stand. Hydraulic and mass transfer characteristics for the proposed device have been compared with known data and the designed ejector scrubber has been successfully tested under industrial conditions in Zambia and Europe.

Keywords: wet scrubber, gaseous emissions, treatment efficiency, chain curtain, sulphur dioxide.

1. Introduction

The right to a healthy environment is recognized by over 150 states in the world including Zambia. However, this right is being threatened by climate change which is currently a major global problem and is caused by anthropogenic emissions of greenhouse gases such as carbon dioxide, nitrous oxide, methane and indirect greenhouse gases such as nitrogen dioxide and sulfur dioxide. Air pollution is a deadly man-made problem which, according to the UN Report (Boyd (2019)), is responsible for seven million deaths per year of the world's population including 600,000 children. The major type of air pollution in Zambia is industrial air pollution.

[1] Citizens for a Better Environment; Room 66, Afcom House, Obote Avenue, Box 23202, Kitwe; +260955500432; mweenehimwiinga@gmail.com.
[2] The Air Force Academy in memory of Prof. Zhukovsky and Y. A. Gagarin; 133 Marshala Nedelina Street, Box 394052, Voronezh, Russia; +74732264752; su-panov@yandex.ru.
[3] The Copperbelt University; Jambo Drive, Riverside, Box 21692, Kitwe; +260968797823 wnkonde@gmail.com.

Treatment of industrial gaseous emissions from pollutants includes various methods such as absorption, adsorption and thermal burning. Findings by Lazarev (2001) indicate that one of the most commonly used devices for gas treatment include wet scrubbers, particularly, spray-type devices (e.g. Venturi scrubbers). In the modern world, wet scrubbers are considered to be highly efficient and on high demand for dust removal purposes. The operation principle of the device is based on an intensive breakdown of a pollutant gas stream moving at a high velocity (60-150 m/s) by a liquid spray.

Owing to advantages such as low start-up costs at the initial construction stage (water circulation system that does not need treatment), high gas treatment efficiency, highly dispersed dust particle removal and pollutant chemical compound removal, treatment of high temperature gases, design simplicity and ease of use, Venturi scrubbers are widely used in industries and according to various researchers worldwide including Ali, Qi and Mehboob (2012), Venturi scrubbers will remain viable for years to come.

However, notwithstanding the afore mentioned advantages, application of spray type devices for absorption treatment of gases is linked with a few notable disadvantages such as low mass transfer coefficients, low specific productivity per unit volume of device and high energy costs required to create hydrodynamic regimes. According to Goremwikin et. al (2001), these disadvantages prevent a more wide spread use of Venturi scrubbers in complex gas treatment systems.

The objective of this research is to develop a design of a more efficient wet scrubber (spray-type device) by introducing a unique curtain chain as a drift eliminator.

2. Materials / Methods / Design / Methodology

In order to achieve the set objective, a laboratory stand was set up for the chemical treatment of toxic gaseous emissions as shown in Fig. 1. The laboratory stand consists of wet scrubber otherwise known as an ejector scrubber S, fan F, pump P, container C, and manometers M1, M2, gas analyzers GA1, GA2 and psychrometer R.

For measuring gas temperature, an alcohol thermometer (with a length not less than 100mm) was used and attached to the gas inlet. Static pressure in the gas stream was measured using a U-shaped manometer and it was filled with pure water. Pollutant concentration was measured using gas analyzers (Tesno 30) that were installed at the gas inlet and outlet. Relative humidity was determined using a psychrometer with wet and dry bulb thermometers. A digital differential manometer was also used to measure differential air pressure, air velocity and flow rate.

The wet scrubber consists of a cylindrical case unit made up of several sections with a flat bottom and outlet spigots for sludge 6, and treated gas 10, which are integrated into the housing of the contact device consisting of a convergent-diffuser (Venturi) tube 7, and nozzle 8. The drift eliminator component is located in the case unit of the device and consists of chains suspended from a clamp mounted on the lower part of the neck (constriction) of the inner tube using two pins and detachable joints (not shown). Fig. 2 shows a diagram of the wet scrubber.

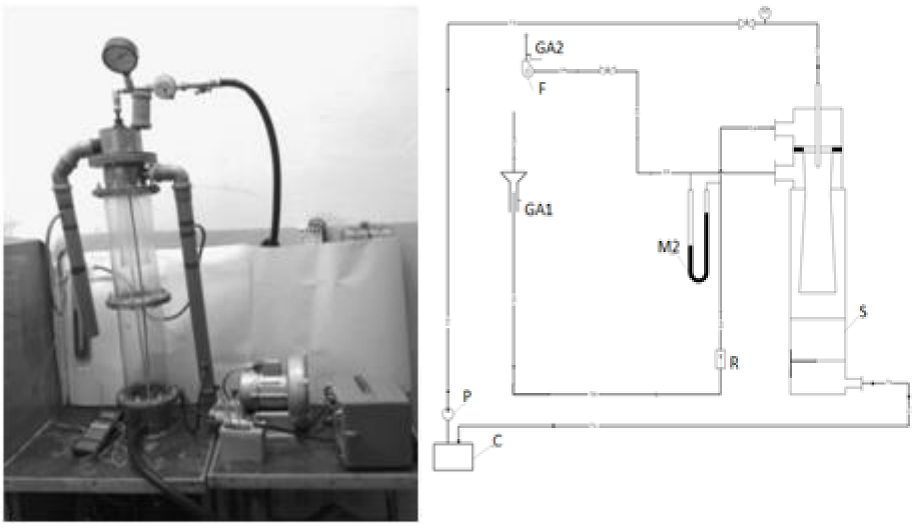


Fig. 1: Photograph and schematic diagram of the experimental unit

The mixing chamber consists of a confusor (upper part of the Venturi tube) which serves the purpose of increasing velocity and houses the nozzle and Venturi tube neck (constriction) where interaction of the sorbent with the harmful gas components takes place as well as coagulation processes. Furthermore, by virtue of a decrease in gas velocity, part of the pressure expended on the creation of high-speed gas is recovered.

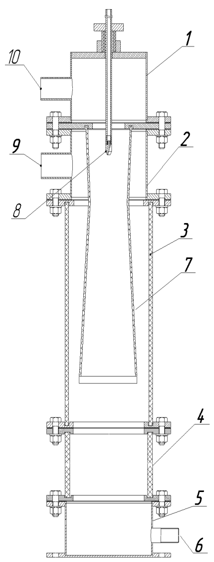
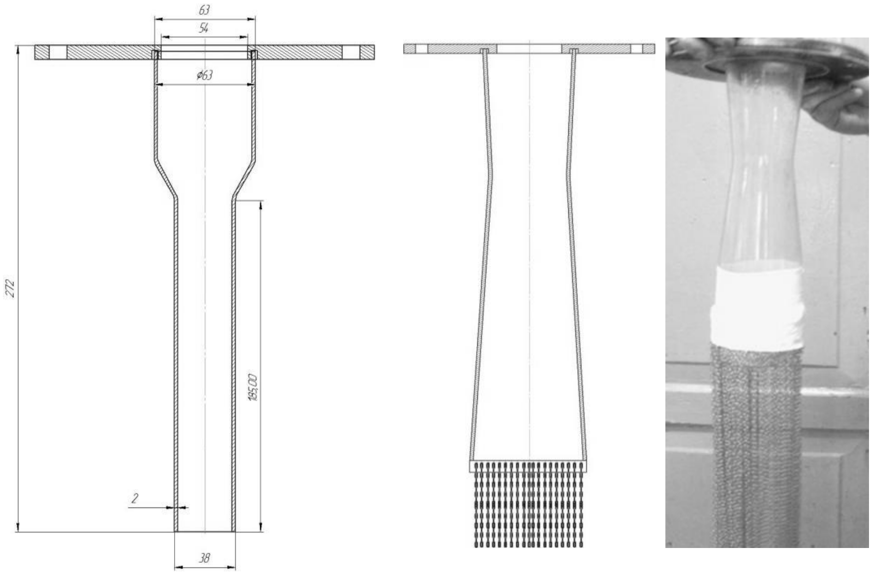


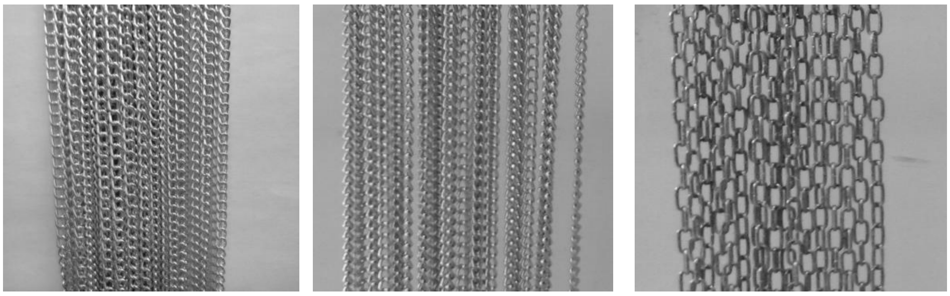
Fig. 2: Schematic diagram of wet scrubber

Pollutant gas is uniformly fed into the device through the gas inlet spigot and further enters the mixing chamber of the wet scrubber constructed in the form of venturi tube (Fig. 3(b)). Experiments were later conducted where the venture tube was substituted and results compared with a tube with an extended neck as shown in Fig. 3(a). The cross section of the confusor and constriction (neck) is designed in such a way as to create conditions for the ejection of gases through impact. A high impact fluid stream flows from the spray nozzle with a high velocity and is broken down into tiny dispersed particles which form up along the cross section of the chain curtain. Three different types of chain curtain were used and compared for this experiment as shown in Fig. 4.



(a) ***(b)***

Fig. 3: Schematic diagram of the tube with an extended neck (a) and schematic diagram and photograph of the Venturi tube attached to the drift eliminator (chain curtain) (b).



(a) ***(b)*** ***(c)***

Fig. 4: Chain curtain types for the drift eliminator. (a) type 1 (6.5×3.8 mm link size); (b) type 2 (7.0×3.5 mm link size); (c) type 3 (10×4.5 mm link size).

Characteristics of these chain curtains can be likened to those of a filter granular packing. The gas stream flows through the chain curtain and gaseous pollutants are captured by the absorbent’s dispersed particles upon collision or contact. Dynamic coagulation of particles occurs. Further, sedimentation of the captured by-product occurs at the bottom of the device as a result of gravitational forces and the by-product is released as sludge through the liquid outlet. Finally, treated air is released through the gas outlet, fan and is emitted into the atmosphere. Pollutant concentration is measured at the gas outlet.

3. Results

3.1 Hydrodynamic characteristics

Hydraulic resistance calculations for the chain drift eliminator layer are based on the definition of equivalent diameter of the channel layer, d_E and element (chain link) diameter, dz. Values calculated for d_E and d_l are given in Table 1 below.

Table 1: Calculation of values for equivalent diameter d_E for the chain layers

Chain link	Porosity of the chain layers, ε	Volume per link, V_0, m^3	Number of links, n, $1/m^3$	Surface area per link, f_0, m^2	Specific surface area, a, m^2/m^3	Equivalent diameter d_E, mm
Type 1. ∅3.8x6.5 mm	0.72	$2.7x10^{-8}$	$2.9x10^3$	$4.27x10^{-5}$	$1.59x10^3$	$1.81x10^{-3}$
Type 2. ∅4.5x10 mm	0.72	$3.6x10^{-8}$	$1.6x10^3$	$5.10x10^{-5}$	$1.40x10^4$	$2.0x10^{-3}$
Type 3. ∅4.5x10 mm	0.72	$5.6x10^{-8}$	$1.4x10^3$	7.2010^{-5}	$1.27x10^4$	$2.6x10^{-3}$

These values are found in the workings of a known formula as expressed by Goremwikin et. al (2001).

$$d_E = \frac{4\varepsilon}{a}, \qquad (1)$$

$$\frac{w_1 \cdot d_E}{\varepsilon \cdot \nu} = \frac{0.45}{(1-\varepsilon)\sqrt{\varepsilon}} \cdot \frac{w_1 \cdot d_l}{\nu}, \qquad (2)$$

Where ε – porosity of the 'chain' layers; a – specific surface area of elements of such a layer m^2/m^3; ν – dynamic viscosity; w_1 – average velocity, m/s.

Considerable attention was given to the hydraulic conditions in the spray-type scrubber. In Fig. 5 below, hydraulic resistance is shown for the three chain types against gas velocity.

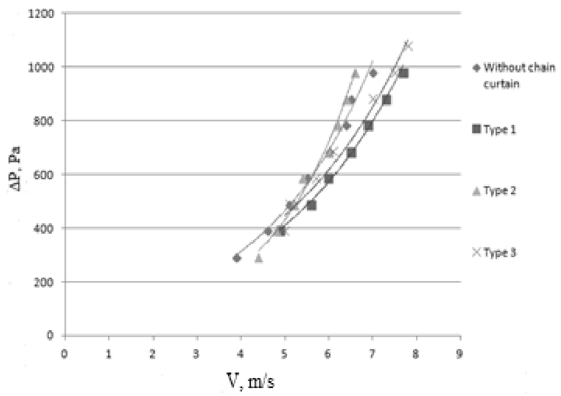


Fig. 5: Hydraulic resistance in relation to gas velocity

During the analysis of the hydrodynamic situation, a phenomenon was observed where there was a decrease in hydraulic resistance by 2 – 5 % (as shown in the graph in Fig. 5) due to the liquid ejection effect. This is because there was a decrease in gas vortex formation as the chain curtain also plays the role of a leveling device. This theory is in line with the principles of aerodynamics as affirmed by Idelchik (1947). Processing of experimental data on hydraulic resistance of the wet chain curtain was done using a criterion equation of the form:

$$\mathrm{Eu} = \mathrm{A} \times \mathrm{Re}_{\mathrm{g}}^{\mathrm{n}_1} \times \mathrm{Re}_{l}^{\mathrm{n}_2} \quad (3)$$

Where: Eu - Euler's criterion, g – gaseous phase, l – liquid phase.

The least-squares method was used to obtain the relationship between Euler's criterion and Reynolds number (Re) in the gaseous and liquid phases.

$$\mathrm{Eu} = 0.03 \times \mathrm{Re}_{\mathrm{g}} \times \mathrm{Re}_{l}^{0.9} \quad (4)$$

Criteria Range being: $\mathrm{Re}_{\mathrm{g}} = 140 \dots 2600, \mathrm{Re}_{l} = 30 \dots 1000$, which corresponded with the gas flow rate $\mathrm{w}_{\mathrm{g}} = 2 \dots 20\ \mathrm{m/s}$. The calculation error between the calculated and experimental values for liquid layer hydraulic resistance on the chain contact device was 8 %.

3.2 Pollutant capture and treatment efficiency

An assessment using carbon dioxide-water experiments was done on mass transfer processes by plotting outlet carbon dioxide concentration against time. Carbon dioxide was chosen for this experiment because of its high solubility in water. The results of these experiments are shown in fig. 5. The graph in fig. 5 clearly demonstrates that using a chain curtain greatly increases gas treatment efficiency (by an average of 30 %) as compared to treatment without a chain curtain. The highest treatment efficiency is achieved when using type 1 (75 %) and the least efficiency – type 3 (60 %).

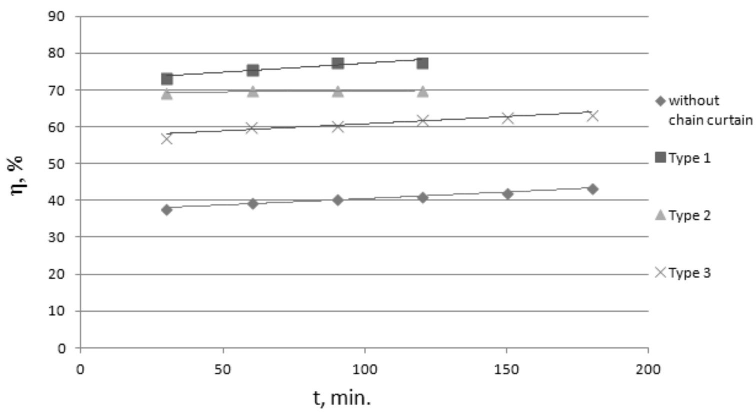


Fig. 6: Gas treatment efficiency for different chain types over time.

t- time, min., η- treatment efficiency, %

The operation of the scrubber was tested in compliance with the absorption method for gas treatment from sulfur oxides. Sulfur dioxide was safely produced in the laboratory from the combustion of sulfur. A chemical sorbent, calcium carbonate which is produced as a by-product in the manufacture of fertilizer at Minudobrenia Plc, Russia (Fig. 7), is used. The following chemical reactions take place in order to neutralize the pollutant gaseous component:

$$CaCO_3 + SO_2 \rightarrow CaSO_3\downarrow + CO_2 \qquad (5)$$

$$CaO + SO_2 \rightarrow CaSO_3\downarrow$$

$$2CaSO_3 + O_2 \rightarrow 2CaSO_4\downarrow .$$

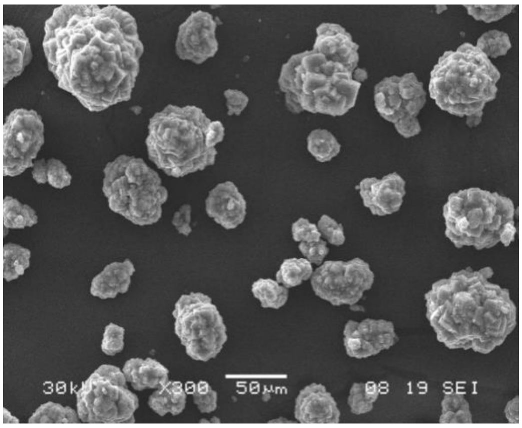


Fig. 7: Microphotography of sorbent ($CaCO_3$), a by-product of fertilizer production

Preliminary results indicate that the stiochiometric inlet ratio of Ca/S equals about 2.0 and SO_2 emissions reduce by 90-95 % (as shown in Fig. 8), significantly larger than the projected 70 - 80 % and subsequently corresponds with the residue concentration of less than 30 mg/m^3. This is explained by the greater degree of pollutant capture and high deposition of the sorbent on the chain curtain (not more than 20 mg/m^3) owing to the sorbent's well developed surface area (Fig. 7).

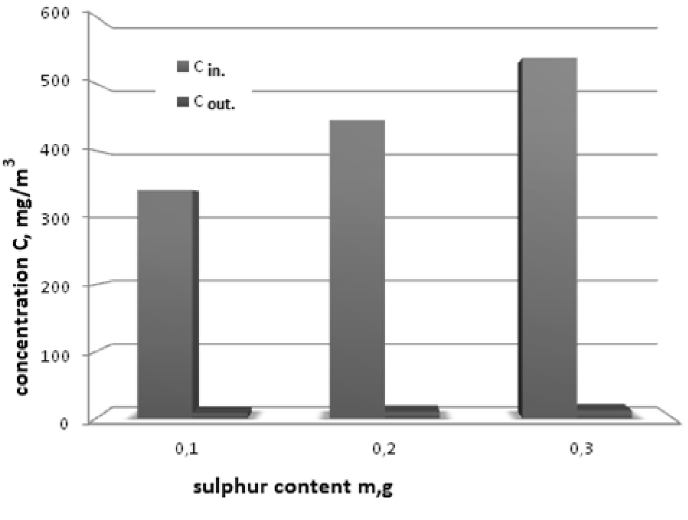


Fig. 8: SO_2 efficiency removal with 10 % sorbent solution

3.3 Mass transfer

In general, the use of the tube with an extended neck turned out to be more effective than the Venturi tube, which makes its usage in industry more promising, as it is simpler in design and set-up. Criteria equations describing the processes of mass transfer in phases are expressed below:

$$Sh_g = f(Re_g, Sc_g) \quad (6)$$

$$Sh_l = f(Re_g, Sc_g)$$

The following equations in generalized variables were derived after processing experimental data:

$$Sh_g = 0.011 Re_g Sc_g^{0.5} \quad (7)$$

$$Sh_l = 0.002 Re_l^{0.688} Sc_l^{0.5}$$

Analysis of experimental data shows good correlation with the data of other researchers as shown in Fig. 9, which validates and entails adequacy of the obtained equations.

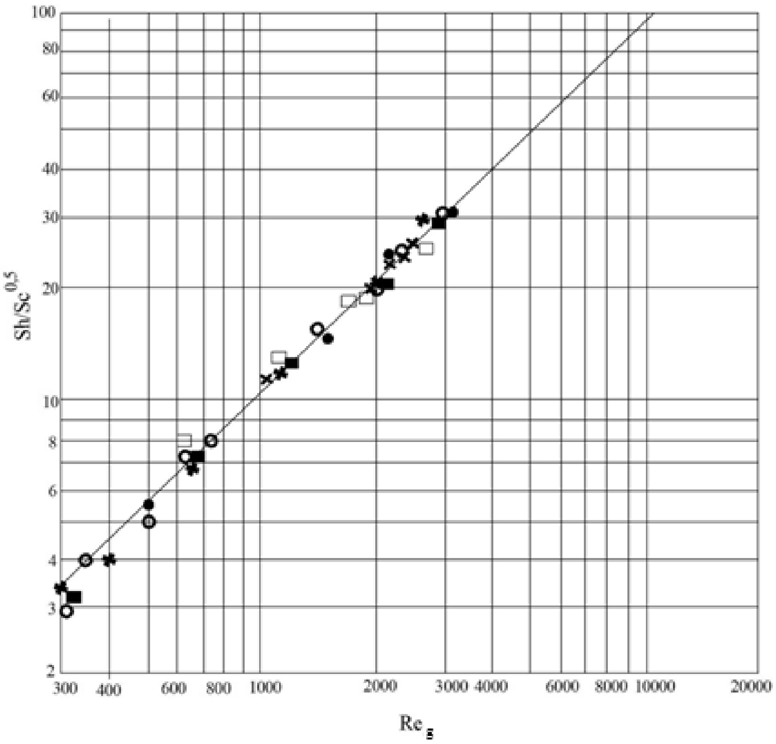


Fig. 9: Comparison of calculated and experimental mass transfer data in the gaseous phase. Experimental data : □, ○, × - tube with an extended neck; ■, ●, ✳ - Venturi tube; ×, ✳ - type 1; ○, ● - type 2; □, ■ - type 3; Line – calculations from formula (7)

An assessment of the obtained results was conducted and a highly effective ejector scrubber (wet scrubber) was designed, patented (Panov, Himwiinga and Zinkovsky (2015)) and successfully officially tested under industrial conditions in Zambia at a brewery plant, in Russia at a tyre recycling plant and in Tatarstan at a sugar processing plant.

The proposed device also increases treatment efficiency without the use of additional equipment, reduces metal and design complexity and the overall cost of the treatment process is reduced as a result of design simplicity.

4. Conclusion

1. A new method for improving treatment efficiency (use of a chain curtain as contact surface for the drift eliminator) in wet scrubbers particularly spray-type devices for industrial gaseous emissions has been proposed.

2. It has been proven through experiments that the use of the chain curtain as the contact surface for the drift eliminator comes in as a more rational solution for treatment devices. Furthermore, treatment efficiency as shown during the experiments increased up to 90 - 95 %.

3. Hydraulic resistance did not increase greatly as would have been expected, but rather, remained at the same level and in other cases, reduced by 2-5 %.

4. Assessment of the obtained results was conducted and a highly effective ejector scrubber (wet scrubber) was designed, patented and successfully officially tested under industrial conditions in Zambia, Russia and Tatarstan.

5. The proposed device also increases treatment efficiency without the use of additional equipment, reduces metal and design complexity and the overall cost of the treatment process is reduced as a result of design simplicity.

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A Review of Wind Resource Potential for Grid-Scale Power Generation in Zambia

Amos Banda[1], Leonard Simukoko[2], Henry M. Mwenda[3]

Abstract

The Zambian electricity grid system has been dominated by hydropower at 96%, 2.1% thermal and 1.7% renewable (Kaluminiana, n.d.). During the 2014/2015 rainy season, Zambia received very low rains which led to reduced electricity production at the two major power plants. In light of this situation, there was a push towards diversification in the power generation mix to achieve a more resilient system. This quest for diversification has led to the inception of grid-scale wind power feasibility studies at ten sites distributed around the country. These feasibility studies intend to establish the availability of the wind resource for grid-scale power generation, this will foresee the development of the wind power industry in Zambia.

This paper conducted a thorough review of the above feasibility studies and gives the current status of wind resource potential for grid-scale power generation in Zambia. The three wind resource assessment projects being undertaken in Zambia have demonstrated that there is wind resource potential in certain parts of Zambia for grid-scale wind power generation. These studies have shown that a Class IV WT with hub height in excess of 117m can be operated sustainably at nine of the ten sites. Further, at least five of the ten sites can operate a Class III WT with a hub height of 130m. Due to economic reasons, this paper proposed a Class III WT with hub height of 130m and maximum rated capacity of 4MW WT for the Zambian wind regime.

Keywords: Review, Wind-Resource, Grid-Scale, Zambia

1. Introduction

The Zambian electricity grid system has been dominated by hydropower at 96%, 2.1% thermal and 1.7% renewable (Kaluminiana, n.d.). The renewables only comprise of solar and small hydro-power plants. During the 2014/2015 rainy season, Zambia received very low rains which led to reduced electricity production at the two major power plants. This led to massive load-shedding in an attempt manage the insufficient power being produced. In light of this situation, there was a push towards diversification in the power generation mix which will be more resilient to climate factors due to the compensating nature of this system.

[1]University of Zambia, Technology Development and Advisory Unit, amos.banda@unza.zm,
[2]University of Zambia, Technology Development and Advisory Unit, leonard.simukoko@unza.zm,
[3]University of Zambia, School of Engineering, Dept of Mechanical Engineering, hm.mwenda@unza.zm

The quest to diversify the power generation mix has led to the commissioning of several power projects such the Maamba Thermal Plant, Grid-scale solar plants and several hydro power plants. This quest for diversification has further led to the inception of grid-scale wind power feasibility studies at a total of ten sites distributed around the country. These feasibility studies intend to establish the availability of the wind resource for grid-scale power generation, this will foresee the development of the wind power industry in Zambia.

This paper is a systematic review of the results from the above studies and gives the current status of wind resource potential for grid-scale power generation in Zambia. The paper discusses the International Electro-Technical Commission (IEC) Wind Turbine Classes in section two, the status of wind resource potential is discussed in section three and section four presents the concluding remarks.

2. IEC Wind Turbine Classes

A Wind Turbine (WT) operates on a reverse principle of a fan in that it uses the kinetic energy contained in the wind to turn propeller-like blades around a rotor. The rotor is connected to the main shaft, which spins a generator to create electricity. WTs comes in different sizes and classes, the IEC has established wind turbine classes to be applied for standardization and certification of wind turbines. These classes are numbered from Class I for highest winds and Class IV for sites with very low winds as shown in Table 1 below.

Table 1: Wind Turbine Classes (Eanest & Wizelius, 2011)

	Wind Turbine Classes				
	I	II	III	IV	S
Vref (m/s)	50	42.5	37.5	30	Values to be specified by the designer
Vav (m/s)	10	8.5	7.5	6	
A/15	0.18	0.18	0.18	0.18	
a	2	2	2	2	
B/15	0.16	0.16	0.16	0.16	
a	3	3	3	3	

The table above has become handy for both turbine manufacturers and wind farm developers with regard to types of turbines. For example, for a site with low average wind speeds of 6m/s, it makes economic sense to install Class IV wind turbines which has low average operating speeds. In addition to winds speeds, the table provides the turbulence survivability of a turbine in each class at a turbulence intensity of 15m/s. The Class S WTs have customized parameters to suit a site that does not fit in Classes I to IV.

3. Status of Wind Resource Potential in Zambia

Zambia is a new market to wind power and there are currently no installed wind farms. The major challenge that has faced wind power development in Zambia is the lack of appropriate and industry standard wind data. The available wind data has been recorded for over 30 years and was intended for agricultural and weather focusing purpose. The Zambia Metrological Department (ZMD) has been the responsible department for recording and analysing the wind data. This data was mainly recorded at 2m heights with later sites measuring at 10m heights such as the one in figure 1 below.

Figure 1: A 10m Met mast in Samfya installed under the SASSCAL program

The later equipment provides better wind data quality compared to the older analogy/manual systems. The later systems are fully automated and record data every 10 minutes on a daily basis, this data is remotely accessed via internet. There are 10 of these systems installed around the country. Wind data collected at 10 meters above the ground indicate speeds of between 0.1 to 3.5 m/s with an annual average of 2.5 m/s (ZDA, 2014). It should be noted that the wind data referred to was not intended for grid-scale wind power generation. It can therefore be deduced that the methods used to obtain and analyse this wind data does not conform to the wind power industry practice. Therefore, this data cannot be exclusively used to determine whether the wind resource is adequate for grid-scale wind power generation, however, it can be used to locate potential sites for detailed feasibility studies.

In the absence of adequate ground measured wind data, a number of meta-data sets can be used to establish the wind resource for any area of interest. These data sets are generated from satellite data and wind data from nearby meteorological stations. The IRENA Global Wind Atlas is a wind map which was generated using meta-data. The IRENA global wind atlas shown in the figure below indicates presence of some areas within Zambia with annual wind speeds of around 7m/s at 80m heights.

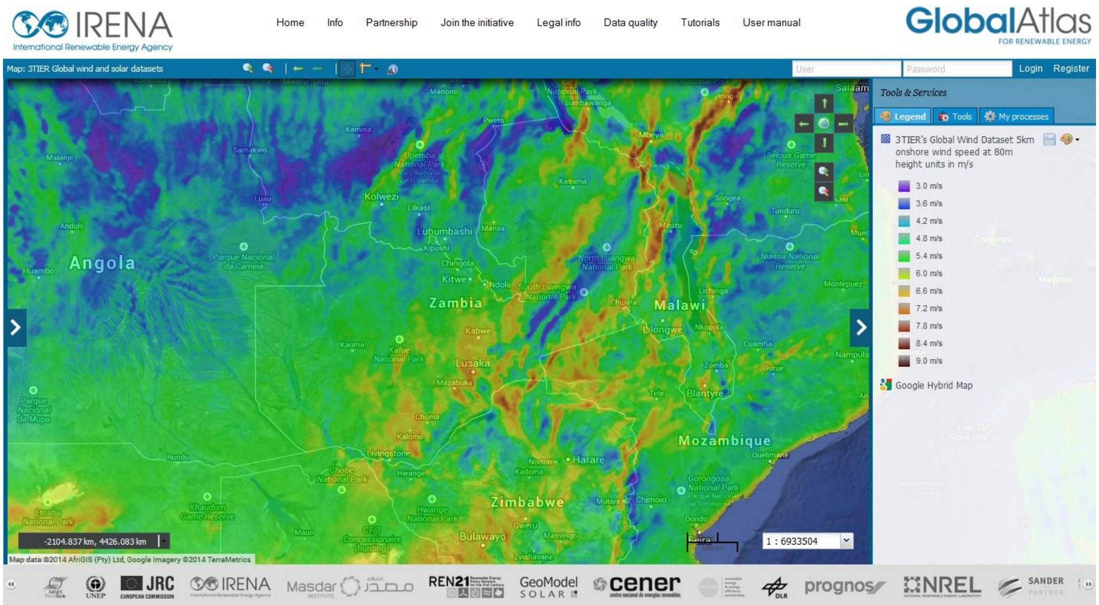

Figure 2: Global Wind Atlas showing wind speed distribution in Zambia (IRENA, 2014)

The wind atlas is generated from satellite data and wind data from meteorological stations on the ground, however, the uncertainty can be as high as 10%, this will impact the accuracy of annual energy production (AEP) estimation, overall risk, and funding. On-site measurement can reduce uncertainty by more than 50% over models derived from satellite data alone (NRG Systems, 2018). It is against this background that the Department of Energy and the World Bank commissioned a project to validate the national wind atlas. The final, validated, peer reviewed output from this project will be the Zambia Wind Atlas, which will be published by the World Bank once the project is completed (DNV-GL, 2016). The findings of this project will help determine viability of wind power development in terms of wind resource.

This exercise involved selection of suitable sites around the country. These sites were chosen such that they represent national coverage at the time of Wind Map generation. The sites with the highest potential for wind power development were given highest priority for this exercise. The selection of the sites was based on the industry practice of taking into consideration various factors such as accessibility, grid connection, wind resource, environmental issues, etc. At the end of a rigorous selection process, eight sites where selected.

Wind resource measurements have been recorded at the eight sites using met masts with measurements taken from November 2016 to January 2018 (DNV-GL, 2018). Note that the data recording is still on-going, the captured period was to facilitate an interim data analysis. Wind data was recorded every ten minutes on a daily basis. This data was run through a software to generate various statistical outputs such as annual average wind speed and frequency wind speed distribution for the measuring period. The annual average wind speed is particularly important as it gives the first indicator of the site's resource potential and can be used to decide whether to continue investigating the site or not. The software was further used to apply long term adjustments to the site measured data so as to predict the annual average wind speed for the project life. To obtain a refined picture of the resource the wind speeds are extrapolated to turbine hub height. The exercise considered a theoretical 4MW turbine with hub-height 130m, therefore, the wind data was extrapolated to 130m and the long term adjustments were applied. Table 2 below shows the annual average wind speeds for the eight sites.

Table 2: Summary of Annual Average Wind Speeds at 80m and 130m (DNV-GL, 2018)

Site	Measured Wind Speed @80m	Long Term Adjusted Wind Speed @80m	Extrapolated Wind Speed @130m	Long Term Adjusted Wind Speed @130m
Choma	6.5m/s	6.6m/s	7.4m/s	7.4m/s
Mwinilunga	6.0m/s	6.0m/s	7.4m/s	7.5m/s
Lusaka	6.2m/s	6.5m/s	7.9m/s	8.2m/s
Mpika	6.2m/s	6.3m/s	7.3m/s	7.3m/s
Chanka	6.5m/s	6.6m/s	7.4m/s	7.5m/s
Petauke	5.7m/s	5.7m/s	6.5m/s	7.0m/s
Mansa	5.8m/s	5.9m/s	6.9m/s	7.3m/s
Malawi	5.8m/s	5.8m/s	6.9m/s	7.1m/s

From the annual average wind speeds shown in the table above it can be deduced that at 80m height eight of the ten sites have Class IV wind speeds, two have wind speeds below Class IV and none have Class III wind speeds. However, at a much higher height of 130 the scenario is different as four site experience Class III wind speeds while the remaining six experience Class IV wind speeds. The long term adjusted wind data at 80m above ground level indicated annual average wind speeds in excess of 6m/s from six of the eight sites, this is adequate to sustainably operate a Class IV WT with an 80m hub height. However, at the same hub height the annual average wind speeds are too low to sustain a Class III WT. The extrapolated wind data for the eight sites indicate that a Class III Turbine with a 130m hub height can operate sustainably in four of the eight sites whereas a Class IV Turbine with the same huh height can operate sustainably at all the sites.

This project is still on going with a final analysis to be conducted at 24months of data collection, the results of the final analysis are not expected to deviate significantly from the interim analysis. The findings of the interim analysis indicate that the potential for commercial scale wind power is available in Zambia.

There are two other feasibility studies which have been conducted in Zambia by different institutions. The final outputs from these studies are feasibility reports on development of wind power at the specific sites. The feasibility assessments in these projects were detailed and took into consideration wind resource, environmental issues, constructability and grid connectivity (Wind Prospects, 2016) (TDAU, 2016).

The aim of the study conducted by RINA on behalf of Kafue Gorge Regional Training Centre (KGRTC) aimed at installing a mast and conducting a feasibility of installing a single WTG at a site within the Kafue Gorge. The proposed WTG is of grid-scale despite that its main purpose will be for training applications. The 60m mast was installed in February and data collection commenced on 7th February 2017.

At the time of the EYA, a total of 13.5months of locally measured data was available for processing. The data was processed in accordance with the IEC guidelines and the results are shown in table 3 below.

Table 3: Summary of Wind Data from KGRTC Mast (RINA, 2018)

Measured Wind Speed @60m	Long Term Adjusted Wind Speed @60m	Long Term Adjusted Wind Speed @95m
4.48m/s	4.52m/s	5.2m/s

The annual average wind speed for this site at 95m agl is below Class IV wind speeds and may not be viable for grid-scale wind power generation. However, it should be noted that if a higher height is considered, the site may experience Class IV wind. The annual average wind speeds obtained in Namalundu indicate average wind speeds of 5.2m/s at 95m above ground level, this is not adequate to sustainably operate a Class IV WT.

A similar study was conducted by Technology Development and Advisory Unit (TDAU) for Rural Electrification Authority (REA). The aim of the study was to assess the wind resource potential in Kasomalunga for possible wind-solar hybrid power generation for an isolated min-grid for the island (TDAU, 2016). The overall intention of the study was to assess the resource potential for small WTs for a 300kW mini grid, however TDAU went a step further to include the analysis for grid-scale WTs. Just like the RINA study, a 60m Mast was installed with anemometers at 40m, 50m and 60m. Two anemometers were installed at 60m and 50m, a barometer and temperature sensor were installed at 4m. The mast was commissioned on 27th February 2017. Figure 3 shows the NRG 60m mast installed at Kasomalunga in Luapula.

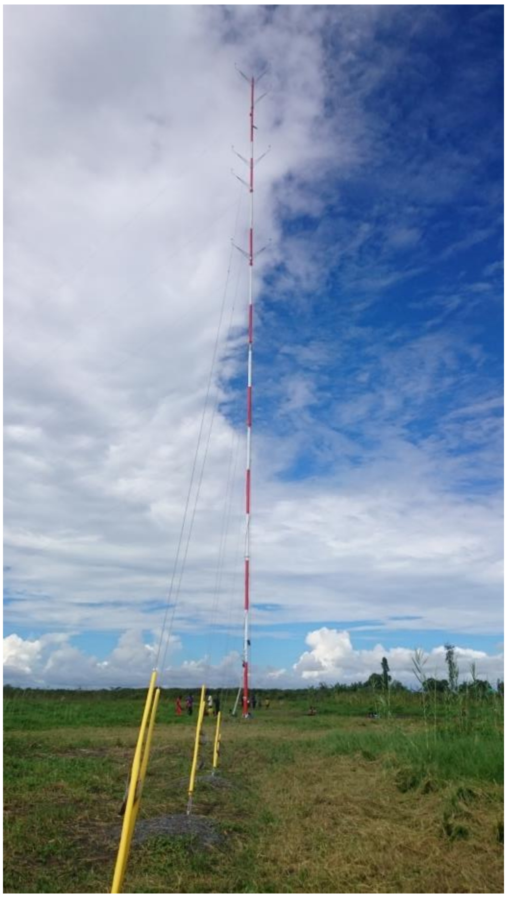

Figure 3: The NRG 60m mast installed at Kasomalunga in Luapula.

At the time of the EYA a total of 12.7months locally measured data was available for processing. The study came up with two scenarios for the EYA, Scenario I included two smaller Vergnet GEV MP200 turbines which would be more practical for the mini-grid. Scenario II included two large Vestas V117 Turbines, this was done to indicate the potential for grid-scale wind power at the site and surrounding areas. The turbines for Scenario I had a hub height of 60m whereas those for Scenario II had a hub height of 116.5m. The data collected from the site was processed in accordance with the IEC guidelines and the results are shown in table 4 below.

Table 4: Summary of Wind Data from Kasomalunga Mast (TDAU, 2018)

Measured Wind Speed @60m	Long Term Adjusted Wind Speed @60m	Long Term Adjusted Wind Speed @116.5m
5.52m/s	5.4m/s	6.8m/s

The annual average wind speed at 60m height for this site are less than Class IV and may not be viable for grid-scale wind power generation, however the wind speeds may be adequate for an isolated system where energy storage is incorporated. When a higher height of 116.5m was considered, the site was found to experience Class IV wind speeds with a possibility of attaining Class III wind speeds if the height is raised even higher. The annual average wind speeds of 6.8m/s at 117m available in Kasomalunga are adequate to sustainably operate a Class IV WT but not a Class III unless at a higher height.

The findings of these projects indicate that there is definite wind resource potential in certain parts of Zambia for grid-scale wind power generation. The above studies have shown that a Class IV WT with hub height in excess of 117m can be operated sustainably at nine of the ten sites. Further, at least five of the ten sites can operate a Class III WT with a hub height of 130m. Despite almost all sites being capable of sustaining a Class IV WT it is more economical to focus only on those which can sustain a Class III WT. According to *LM Wind Power*, there is a clear trend in the market toward more Wind Class III turbines in low wind sites (LM Wind Power, n.d.). The effect of the above situation has resulted in a bias among WT manufacturers to manufacture Class III WTs, this in turn lowers the initial cost of WTs due to economies of scale and competition among manufacturers. In 2010 *Wiley* predicated that larger machines beyond 5 MW should become economically viable with further advances in material and design technology, but a sudden change is unlikely over the next 5-year period (Willey, 2010). This prediction was accurate, as 8 years today the most common turbine sizes for on shore applications are within the 2-4 MW rating. Considering the above explanations, this paper proposes a Class III WT with hub height of 130m and maximum rated capacity of 4MW for the Zambian wind regime.

4. Conclusion

The three wind resource assessments projects being undertaken in Zambia have demonstrated that there is wind resource potential in certain parts of Zambia for grid-scale wind power generation. These studies have shown that a Class IV WT with hub height in excess of 117m can be operated sustainably at nine of the ten sites. Further, at least five of the ten sites can operate a Class III WT with a hub height of 130m. Due to economic reasons, this paper proposed a Class III WT with hub height of 130m and maximum rated capacity of 4MW WT for the Zambian wind regime.

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Characterization of land transformations due to coal mining at Maamba Collieries, Southern Zambia

Susan Sichalwe[1], Bunda Besa[1], James Manchisi[1]and Jewette Masinja[1]

Abstract

In this study, a multifaceted approach involving post-classification change detection method, Remote Sensing (RS), Geographic Information System (GIS) and qualitative methods were evaluated to detect impacts of open pit coal mining on land use/land cover (LULC) and the environment in Maamba, Southern Zambia during 1980-2010. RS, GIS tools and a qualitative approach were used to detect impacts of coal mining on LULC dynamics. The different land use classes primarily settlement, agriculture, water body, forest cover and mining in Maamba coal field area were identified and the impact of land use/land cover change on the environment quantified. The land use/land cover changes were analysed for a period of 26 years from the year 1984 to 2010. The study revealed that settlements increased by 13.97 km^2 (9.8 %) from 1984 to 2010. Cultivated land reduced by 1.47 km^2 representing 1.03%. On the other hand, the water body shows an increase of 0.54 km^2 (0.38 %) during 1984 to 2010. Forest cover shows a decrease of 13.53 km^2 (9.05 %) in the area during the study period. The mining area occupied an area of 3.10 km^2 (2.18 %) during 1984 and 3.60 km^2 (2.52 %) during 2010. This study shows the importance of continuous monitoring of these lands for their effective reclamation and aids urban planners and decision makers to have accurate and up-to-date information as well as help attain sustainable development in the mine. It further demonstrates the effectiveness of a comprehensive approach to study mine impacts on the environment.

Keywords: land use/land cover, remote sensing, mining, sustainable development

1. Introduction

Land as a resource is considered of utmost importance and a source of all material wealth of human beings. Mining of these resources, therefore, is invariably associated with land use and land cover changes (Prakash and Gupta, 1998). In this regard, mining has impacts on the LULC and therefore, earth resource satellite data are critically important and useful for land use/land cover change studies (Yuan et al., 2005). From an environmental point of view, the dynamic process of land use/land cover change is an indispensable concern all over the world, which indicates global environmental change (Ruiz-Luna and Berlanga-Robles, 2003) and this has been

[1] University of Zambia, Box 32379, Lusaka; +260977367725; susan.sichalwe7@gmail.com;
[1] University of Zambia, Box 32379, Lusaka; +260979351754; bbesa@unza.zm;
[1] University of Zambia, Box 32379, Lusaka; +260969822005; jay.manchisi@gmail.com;
[1] University of Zambia, Box 32379, Lusaka; +260977367725; hichikoko.masinja@unza.zm;

recount as the most remarkable regional anthropogenic disruption of environment (Lambin et al., 2003). These changing aspects alter the availability of different biophysical resources including soil, vegetation, water, animal feed and others. Consequently, land use and cover changes could lead to a decreased availability of different products and services for humans, livestock, agricultural production and damage to the environment as well. However, the increased demand for mineral resources has led to increased mining activities and unfortunately let to land use and land cover alterations.

Zambia as a developing country, has over the years experienced an increase in demand for the energy requirement and the coal mining industry is eventually increasing its production to meet the requirement of energy production through thermal power plants, where coal is used for generation of electricity. Zambia's population was at 10.2 million according to the census conducted in 2000 and currently is at 17,609,178 of which 62 percent live in rural areas, (CSO:2000). Population densities are higher in urban areas as compared to rural areas. In third world countries, the livelihood of the majority of the population relies on exploitation of natural resources in a direct manner. As a result, if the population is high, environmental concerns are also high. The Human Development Report for Zambia has shown that there is a strong correlation between poverty and environmental degradation due to poor people's high dependency on exploitation of natural resources for their survival. Population increase in recent years has resulted in an increasing demand for natural resources. On the other hand, Coal production and utilization of coal in Zambia has increased and is confined mainly to the mining industry (54 percent), commerce and industry (37 percent) and the government and service sectors (9 percent) (Sooka and Sikaundi, 2007). However, the contribution of coal to the total energy balance had declined over the years due to operational constraints at Maamba Collieries. However, production has gone up due to fresh investments in the mine after privatization. Proven coal deposits are estimated at over 30 million tons while potential coal resources are estimated to be several thousand tons. In Zambia, all the coal is mined by a company called Mamba Collieries Limited (MCL) in the southern region of the country. Apart from improving the welfare of the local people through employment and cooperate social responsibilities activities, coal mining has caused degradation of the environment such as soil erosion, increased sediment load, acid mine drainage, air and water pollution (Cao, 2007). Besides, considerable amount of solid waste piled in the form of huge overburden dumps, destruction and degradation of forest, agricultural lands, and discharge of effluents from mines into nearby water-bodies are some of the other associated problems that have adverse environmental impact. Continuous monitoring of these lands is, therefore, essential for their effective reclamation and management. However, reliable and timely information on the nature, extent, spatial distribution pattern and temporal behaviour of degraded lands including land subject to mining, which is a prerequisite for their reclamation and management, is generally not available. Therefore, mapping mining activities and evaluating associated environmental concerns are difficult problems because of the extensive area affected and the large size of individual mines. Monitoring and controlling these changes have been more difficult because of the expense and time in producing reliable and up-to-date mapping.

Besides, a successful monitoring approach for evaluating surface mining processes and their dynamics at a regional scale requires observations with frequent temporal coverage over a long period of time to differentiate natural changes from those associated with human activities. In order to meet such challenges, urban planners and decision makers need to have accurate and up-to-date information for the Proper planning, management and monitoring of the natural resources. Remotely sensed data especially satellite data can be effectively used in mapping as well as monitoring of temporal changes in land use/land cover. On the other hand, decision makers should adopt the use of remote sensing and GIS tools as this would enhance identification of areas that are degraded, their rate and extent. In this context, it is essential to scrutinize the effect of mining on land use land cover change to minimize its impact on environment as well as for proper land management and decision making (Bocco et al., 2001, Laskar, 2003, Turner et al., 2003). To ascertain such changes, earth resource satellite data are critically important and useful for land use/land cover change studies (Yuan et al., 2005). Therefore, this study aims at mapping, quantifying and assessing the land use and land cover changes that have occurred in Sinazongwe, Maamba due to mining at Maamba Collieries Southern Zambia.

2. Materials and Method

2.1 Study Area

Maamba town located within Sinazongwe district of Southern Zambia covers an area of approximately 4,964 km^2 (Figure 1). The catchment has a relatively hilly topography, with altitude ranging from 575m to 689m. Maamba is a coal mining town. The town is located about 250 km from the country's capital city, Lusaka, and has a total population of approximately 13 000 residents. Most of it lies in the Zambezi rift valley with a hilly terrain and is about 30 km from Lake Kariba shore (Besa, 2001).

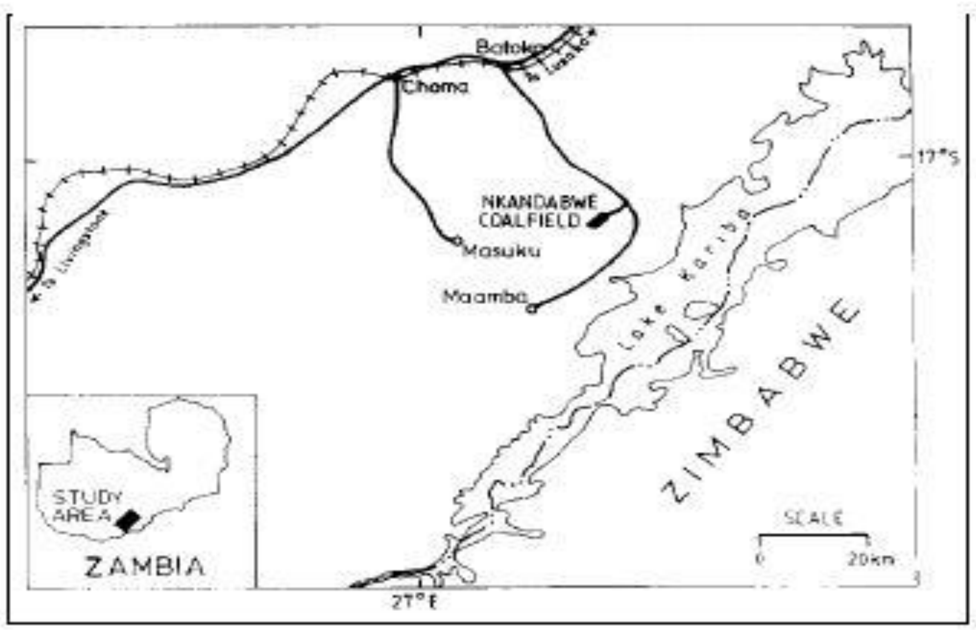


Fig 1: Location of Maamba Collieries Limited

Access to Maamba is by a road that extends southeast from the Great North Road that links Livingstone, Lusaka and the Copperbelt. The mine is 88 km from Batoka. MCL lies within the Siankondobo coalfield comprised of Karoo age sediments, exposed within the current Zambezi

River valley. These coal bearing sediments stretch into neighbouring Zimbabwe. MCL extracts coal from the Gwembe coal formation which comprises lower Maamba sandstone overlain by carbonaceous mudstones. Maamba Collieries was incorporated in 1971 under the ownership of Government of Zambia. Maamba Collieries was mining for high grade coal which was only saleable product and low-grade coal was dumped as waste, resulting in severe environmental pollution. Over a period of time, the company faced challenges, including low production and lack of a capitalization. Various reasons, including poor overall management of the company led to complete stoppage of mining operation. Total Mining Lease Area is 7,876 Ha. The exploration completed area is 1,432 ha. The mine was taken over by Nava Bharat acquisition and MCL has revamped the mine and commenced operations from October 2011, and has produced: 2,701,000 metric tonnes of thermal grade coal; and 2,420,000 metric tonnes of high-grade coal.

The majority of land cover is degraded disturbed woodland. The project area is affected by shifting cultivation practices, burning, and charcoal burning activities. A recent review of irrigable soils indicated that the area required for the mining lease tends to be rocky, with numerous bare back granite outcrops. As a result, the mining lease is generally not suitable for large scale arable farming activities, including irrigation, even though there is a lot of small-scale agriculture activities' taking place especially along the flat land found along the streams in the surrounding areas. Maize fields are common in the area and cultivated for up to five years before planting a drought resistant crop such as sorghum, millet etc. Animal husbandry is limited to the keeping of goats, pigs, chickens, ducks and cattle. Mountains dominate the land so much that land for settlement is only found in isolated pockets. However, most of the habitable land is used for agriculture. There is no manufacturing or any other industry within the mining license area, or within the larger area surrounding the project. Nearby urban areas include Sinazongwe and Choma. Traditionally, men control most of the land. They decide on the use of the land while women have limited say over what to do with the land.

2.2 Sources of Data

In this study, spatial data-sets were obtained from Landsat 7 and Landsat 8 archives from U.S Geological Survey (USGS) and LISS-III satellite images of the year 1984 and 2010 was used and explored through supervised classification in Arc GIS imagine and ground observations obtained from Google Earth. The supervised classification method used is a vital tool in the determination of a statistical relation between the obtained data sets and the ground truth observations (Joshi and Dharaiya, 2018).

2.3 Methodology

2.3.1 Change detection

To obtain changes, all the land use land cover classes were evaluated among the satellite images. Among different classification algorithms, the maximum likelihood was used for supervised classification by taking 50 training areas for five major LULC class categories (10 training points for each LULC class) (Temesgen et al., 2014). The LULC classes include Agricultural Land, settlement area, Water bodies, grassland and forest area as well as Mining area. ERDAS Imagine® 2014 and Arc GIS® 10.2 were used for satellite image processing and LULC change analysis (Agaton et al., 2016). Digital land use land cover classification through supervised classification method was performed for the LULC classification. Recoding method is also done for converting pixel value into a proper class. Area statistics of each land use category is calculated in square kilometres. The rate of change was calculated for each LULC class using Equation 1:

$$Rate\ of\ change\ \left(km^2/_{year}\right) = \frac{LULC_{2010} - LULC_{1984}}{Time\ interval} \qquad (1)$$

Where $LULC_{2010} =$ Land use/Landcover map of 2010, $LULC_{1984}$= Land use/Landcover map of 1984, $Time\ interval =$ Period between 1984 and 2010 in years

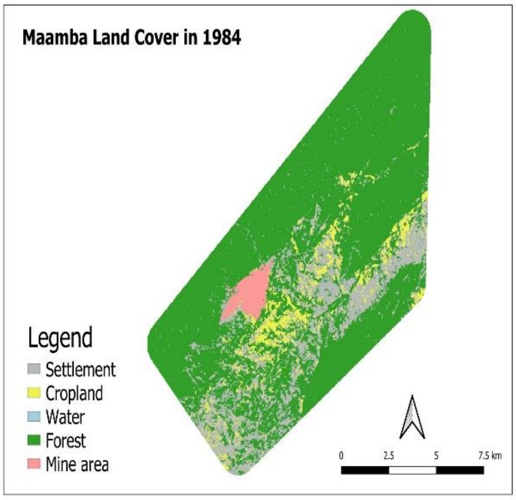
The classified images were edited on the basis of the ground truth data collected from the field and then final classified maps were prepared with assessing classification accuracy using accuracy assessment tool of ERDAS® where LULC maps were used in raster format. By applying random points in accuracy assessment window. Image analysis operations have been carried out using GIS and finally, the changes in various LULC classes are obtained using post-classification comparison method. Error matrix and KAPPA analysis were done for accuracy assessment classification. The final maps were prepared after the ground truth and changes were estimated in GIS. The results obtained were used in order to assess the stress of land use on the ecosystem for the better natural resource management.

3. Results and discussion

The land use/land cover categories delineated in the study area are agricultural land, settlements, forest area, water body and the mining area. Table 1. shows the changes in land use/land cover statistics (in km^2 and percentage) that have taken place during the period between 1984-2010. The results of the land use/land cover analysis are also graphically represented in Figure 2.

Table 1: LULC change in Maamba from 1984 to 2010

Land use categories	**Land use/Land cover (1984)**		**Land use/Land cover (2010)**		**Net Change (km^2)**	**Net change (%)**
	Area (Km^2)	**Area (%)**	**Area (Km^2)**	**Area (%)**		
Settlement	25.35	17.79	39.32	27.60	13.97	9.80
Agriculture	7.23	5.07	5.76	4.04	-1.47	-1.03
Water body	0.02	0.01	0.56	0.39	0.54	0.38
Forest	106.79	74.94	93.26	65.45	-13.53	-9.50
Mining area	3.10	2.18	3.60	2.52	0.50	0.35



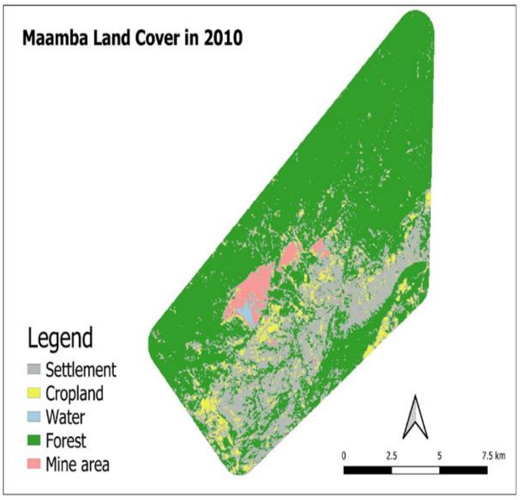


Fig 2: Landuse/Landcover maps for 1984 and 2010 in Mamba

The study depicts that Maamba has undergone a huge change in various land use categories from 1984 to 2010. The land use assessment show that the total area of 142.49 km² in the year 1984 was classified into agricultural land (5.07 %), settlement (17.79 %), water body (0.01 %), forest (74.94%) and mining area (2.18%) as can be seen in Figure 3. While in 2010, not much change was detected in mining area and waterbody; however, agriculture and forest land reduced by -1.03 and -9.50% respectively while the mining area had a slight increase of 0.35%.

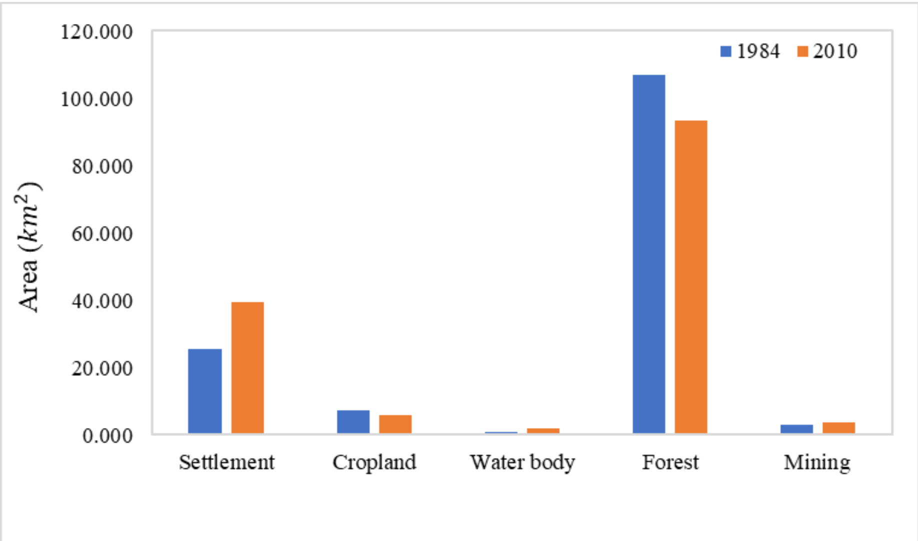


Fig. 3: Changes in LULC between 1984 and 2010

3.1 Settlement

The settlement occupied an area of 25.35 km^2 (17.79 %) during 1984 and 39.32 km^2 (27.60%) in 2010. The settlement shows an increase of 5.1 km^2 (0.70 %) during 1984 to 2010. The increase in settlement area is due to the development of industrial sector which requires residential colonies, industrial buildings, schools, community halls etc and increasing demand for labour work has attracted people from other states to settle in this industrial belt resulting in expansion of villages, towns and cities

3.2 Crop land

Cultivated land is recognized by its yellow tone, smooth - medium texture having non-contiguous pattern with regular - sub regular outline shape. Cultivated land which was 7.23 km^2 (5.07 %) area during 1984 has been decreased to 5.76 km^2 (4.04 %) in 2010. The loss of 1.47 km^2 (1.03%) in the cultivated land has been observed during 1984 to 2010. The development of infrastructure, residential complexes of mining industries and the thermal power plant may result in loss of agriculture land. Development of agriculture is mainly affected by lack of irrigation. The decrease in area under cultivated land is attributed to decline in rainfall which adversely affects the rain fed agriculture as has been verified by rainfall data analysis. The irrigation from the borehole wells is not successful because in the Maamba average ground water level is 125 meters and the mining pits are more than 100 meters deep which can be attributed to the depletion of ground water in the surrounding area which results in the decrease in agriculture area.

3.3 Water body

Water body on the imagery is identified by its light blue to black tone, smooth texture and irregular shape. The water body occupied an area of 0.02 km^2 (0.01 %) in 1984 and 0.56 km^2 (0.39%) in 2010. The water body shows an increase of 0.54 km^2 (0.38 %) during 1984 to 2010. The increase of the water body can be attributed to the fact that Izuma stream is located right in the mining area and due to the mining going on, more ground water is released from the ground into the stream thus increasing the quantity.

3.4 Forests

The forest covered an area of 106.79 km^2 (74.94%) of the total area during 1984 and 93.26 km^2 (65.45 %) during 2010. Dense forest shows a decrease of 13.53 km^2 (9.05 %) in the area from 1984 to 2010 during 26 years. Most of the coal mining activities are taking place in dense forests area because most of the coal resources are located beneath the dense forest region. So the decrease in the dense forest is due to the removal of trees which is the first step of the expansion of coal mining activities, removal of forest for the development of infrastructure for heavy industrialization and increase in the population is another cause because peoples use wood for their livelihood so excessive felling of trees for fuel and fodder.

3.5 Mining pit and Overburden dumps

Coal mining is a very prominent activity in the area for having good reserves of coal. Mining pits are interpreted on the imagery by its pink tone. The mining occupied an area of 3.10 km^2 (2.18 %) during 1984 and 3.60 km^2 (2.52 %) during 2010. The increase of 0.50 km^2 (0.35 %) in the mining pit area has been observed from 1984 to 2010. The increase in the area of overburden dumps is because of huge removal of material from mining blocks which were dumped along the periphery of the plains and forms artificial landscapes.

4. Conclusion

The present study has revealed that considerable land use/land cover changes have taken place in and around the Maamba coal field during 1984 to 2010. Before the start of coal mining and other industrial activities the region was covered with tropical deciduous forests. Coal mining operation on large scale has significantly changed the pre-mining environment scenario. The mining shows increase of 0.50 km2 during twenty-six (26) years which is due to the rapid increase in the coal production, dense forest areas are decreasing but the plantations at overburden dumps under reclamation schemes have also been going on. In addition to mining activity, the industrialization especially the thermal power plant in the surrounding have also adversely affected the land use/land cover, air and water quality of the study area due to the discharge of waste products in the form of ash, smoke and chemical effluents. It may be concluded that the land use/land cover change in the Maamba coal field has taken place due to the rapid expansion of mining and industrial activity during the period 1984 to 2010. This has resulted in the drastic changes in the land cover dynamics of the fragile ecosystem.

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Cobalt and its place in the Fourth Industrial Revolution

Carol Nampungwe[1], Milton Simukoko[2]

Abstract

It is an iconic time of transformation in the history of mankind. A new era of technological revolution has begun that will fundamentally alter the way we live, work, and view the world. On the frontier of this revolution is the advent of technological and digital infrastructure so monumental in its scale, scope, and complexity that it is unlike anything humankind has ever experienced before. Building directly on the third digital revolution, which has connected billions of people through mobile devices and the internet, the technologies of our post-digital world are poised to further change all aspects of the human race. The Fourth Industrial Revolution or 4IR is characterized by a fusion of technologies that is blurring the lines between the physical, digital and biological spheres. Like the revolutions that preceded it, the Fourth Industrial Revolution has the potential to raise global income levels and improve the quality of life for populations around the world. At the forefront of the 4IR are the energy and transport revolutions, Electric Vehicles, Energy Storage Technology, among others. Shrouding the 4IR is the green industrialisation campaign propelled by the "low carbon" theme. If the world has to transition into a low-carbon future and fit squarely – some compelling fundamentals become apparent and imperative -more minerals and metals for renewable energy. This shift will require vast volumes of Copper, Lithium, Cobalt, Manganese and Nickel. Manganese, Cobalt and Nickel atomic numbers 25, 27 and 28 respectively, are integral elements in key technologies of the battery energy storage markets. Cobalt has found newest wider application in the lithium Battery powered Electric Vehicles (BEVs), handheld electronic devices such as Smartphones, iPads and Aerospace Applications.

This paper discusses the cobalt metal and affiliated sister metals, its significance and potential niche in the fourth industrial revolution.

Keywords: Fourth Industrial Revolution, Metal, Technologies, Cobalt, Battery Electric Vehicles (BEVs)

1. Introduction

The First Industrial Revolution started in Britain around 1760.This Revolution used water and steam power to mechanize production. It was powered by a major invention; the steam engine. The steam engine enabled new manufacturing processes, leading to the creation of factories. The Second Industrial Revolution came roughly one century later and was characterized by mass production in new industries like steel, oil and electricity. The light bulb, telephone and internal combustion engine were some of the key inventions of this era. The Second, used electric power to create mass production. The inventions of the semiconductor, personal computer and the internet marked the Third Industrial

[1] Konkola Copper Mines Plc, Private Bag KCM (c) 2000, Fern Avenue, Chingola, Zambia. carolnampungwe1997@gmail.com;carol.lukama@kcm.co.zm
[2] Konkola Copper Mines Plc, Private Bag KCM (c) 2000, Fern Avenue, Chingola, Zambia. milton.simukoko@kcm.co.zm

Revolution starting in the 1960s.The Third, used electronics and information technology to automate production. It is also referred to as the "Digital Revolution".

Now a Fourth Industrial Revolution (4IR) is building on the Third, the digital revolution that has been occurring since the middle of the last century. It is characterized by a fusion of technologies that is blurring the lines between the physical, digital and biological spheres.

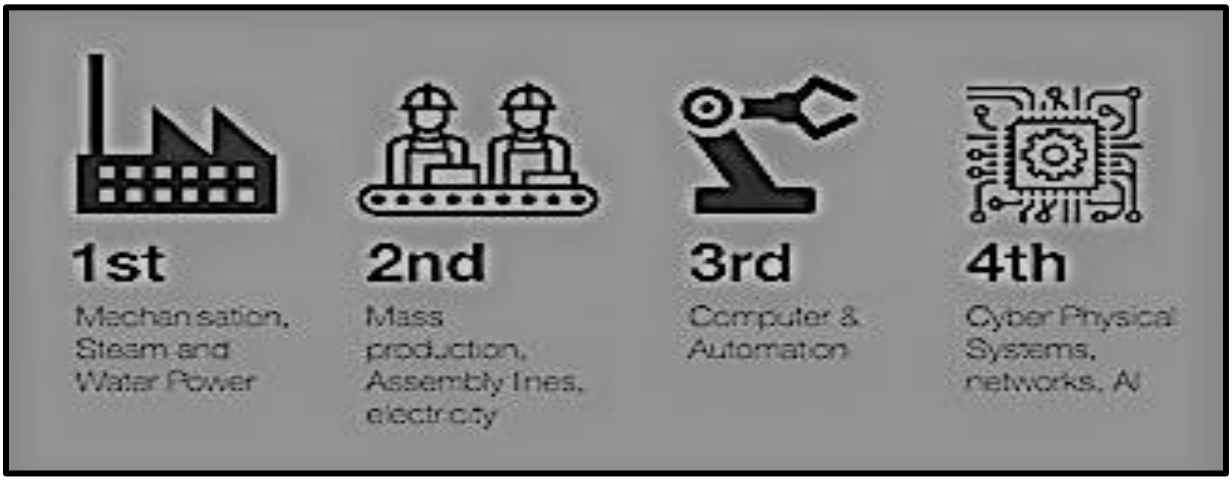

Figure 1: Industrial revolutions (Source: googleimages, noseweek.co.za)

1.1 Fourth Industrial Revolution

It is an iconic time of transformation in the history of mankind. A new era of technological revolution has begun that will fundamentally alter the way we live, work and view the world. On the frontier of this revolution is the advent of technological and digital infrastructure so monumental in its scale, scope, and complexity that it is unlike anything humankind has ever experienced befor**e.**

The Fourth Industrial Revolution describes the exponential changes to the way we live, work and relate to one another due to the adoption of cyber-physical systems, the Internet of Things and the Internet of Systems. As we implement smart technologies in our factories and workplaces, connected machines will interact, visualize the entire production chain and make decisions autonomously. This revolution is expected to impact all disciplines, industries and economies. While in some ways it's an extension of the computerization of the Third Industrial Revolution, due to the velocity, scope and systems impact of the changes of the Fourth revolution, it is being considered a distinct era. The Fourth Industrial Revolution is disrupting almost every industry in every country and creating massive change in a non-linear way at unprecedented speed.

The possibilities of billions of people connected by mobile devices, with unprecedented processing speed, storage capacity and access to knowledge, are unlimited. And these possibilities will be multiplied by emerging technology breakthroughs in fields such as artificial intelligence (AI), robotics, the Internet of Things, autonomous vehicles, 3-D printing, nanotechnology, biotechnology, materials science, energy storage and quantum computing.

1.1.1 The Digital World and Communication

As the world transitions and becomes "smaller" the need for faster means of communication becomes inevitable. The 3rd Industrial revolution birthed the automated world of desktop computers, mobile phones, printers, cameras, radios, DVD players etc, which later evolved into todays 'electronic devices such as smartphones, iPads, Flat screen televisions and other devices to transmit messages with unprecedented processing power and storage capacity.

Billions of people today are connected via mobile devices and electronic communication has developed into an everyday part of millions of people's lives. Content can be shared online and news, has also tended more toward a global bent with less local coverage even from local news agencies. Recently the world has witnessed the emergence of 5G networks.

Fifth-generation wireless (5G) is the latest iteration of cellular technology, engineered to greatly increase the speed and responsiveness of wireless networks. 5G networks are the next generation of mobile internet connectivity, offering faster speeds and more reliable connections on smartphones and other devices than ever before.

Combining cutting-edge network technology and the very latest research, 5G should offer connections that are multitudes faster than current connections. The networks will help power a huge rise in Internet of Things technology, providing the infrastructure needed to carry huge amounts of data, allowing for a smarter and a more connected world.

With development well underway and testbeds already live across the world, 5G networks are expected to launch across the world by 2020, working alongside existing 3G and 4G technology to provide speedier connections that stay online no matter where one would be.

5G will also enable a sharp increase in the amount of data transmitted over wireless systems due to more available bandwidth and advanced antenna technology. With 5G,data transmitted over wireless broadband connections could travel at rates as high as 20 Gbps by some estimates exceeding wireline network speeds- as well as offer latency of 1 ms or lower for uses that require real-time feedback. This means doctors can perform surgery on a patient from one end of the globe to the other in real time.

1.1.2 Artificial Intelligence

Artificial intelligence (AI), the ability of a digital computer or computer-controlled robot to perform tasks commonly associated with intelligent beings. The term is frequently applied to the project of developing systems endowed with the intellectual processes characteristic of humans, such as the ability to reason, discover meaning, generalize, or learn from past experience.

Already, AI is all around us, from self-driving cars and drones to virtual assistants and software that translate or invest. Impressive progress has been made in AI in recent years, driven by exponential increases in computing power and by the availability of vast amounts of data, from software used to discover new drugs to algorithms used to predict cultural interests. Digital fabrication technologies are interacting with the biological world on a daily basis. Engineers, designers, and architects are combining computational design, additive manufacturing, materials engineering and synthetic biology to pioneer a symbiosis between microorganisms, our bodies, the products we consume and even the buildings we inhabit.

1.1.3 Need for Batteries

One of the greatest promises of the Fourth Industrial Revolution is the potential to improve the quality of life for the world's population and raise income levels. The efficiencies and conveniences provided have made our workplaces and organizations become "smarter" and more efficient as machines and humans start to work together. The technologies of the 4IR might even help us better prepare for natural disasters and potentially also undo some of the damage wrought by previous industrial revolutions.

The 4IR has brought about a number of potable gadgets such as smartphones and iPads that require batteries to move along with them at any given point and location. The battery required should store sufficient energy to run as long as the gadget is not connected to a power source, often it entails more than 24hrs and should be rechargeable. The energy storage in such batteries should be as safe as possible thus the need for materials or elements that have energy storage properties.

A number of metals have long been known to have energy storage capabilities. These include cobalt, nickel, manganese and lithium. The most common rechargeable battery has a lithium-ion base. The battery is made of one or more power-generating compartments called cells. Each cell has essentially three components: a positive electrode (connected to the battery's positive or +ve terminal), a negative electrode (connected to the negative or –ve terminal), and a chemical called an electrolyte in between them. The positive electrode is typically made from a chemical compound called lithium-cobalt oxide (LiCoO2). The negative electrode is generally made from carbon (graphite) and the electrolyte varies from one type of battery to another. The ions shuttle between two electrodes (the anode and the cathode) as the battery is charged and discharged thus enabling a novel rechargeable battery system.

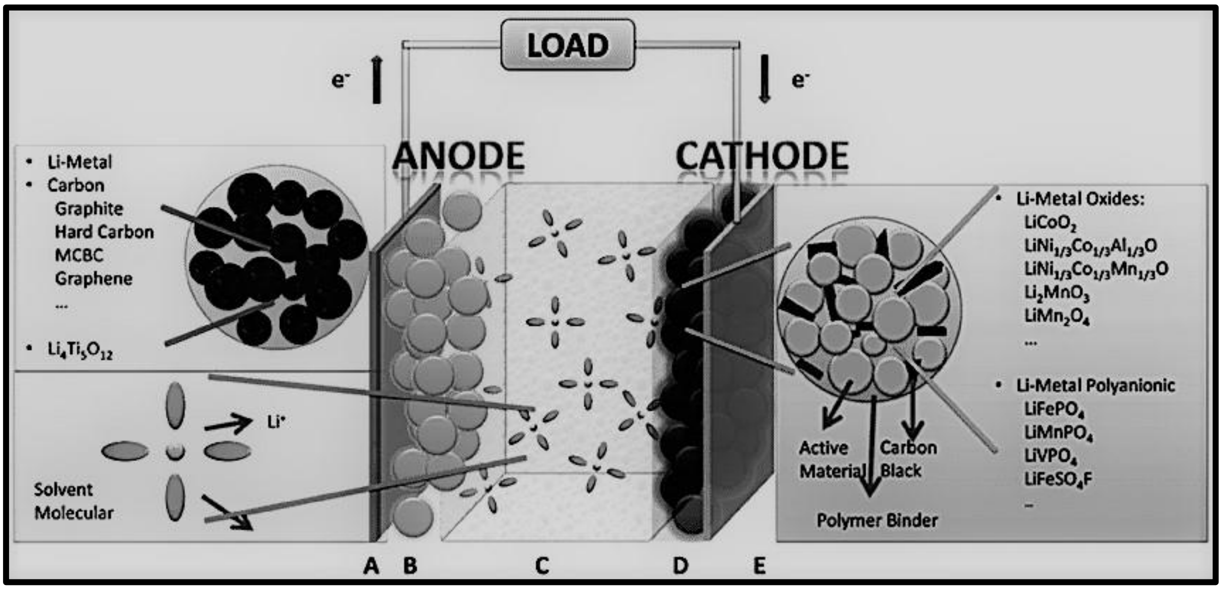

Figure 2: Lithium Ion Battery (Source: googleimages, researchgate.net)

This paper reviews cobalt and its role in the fourth industrial revolution.

2. Metals of the Future

Manganese, Cobalt and Nickel atomic numbers 25, 27 and 28 respectively, are integral elements in key technologies of the Electric Vehicle and battery energy storage markets. Cobalt has found newest wider application in the lithium Battery powered Electric Vehicles (BEVs), handheld electronic devices such as Smartphones, iPads and in Aerospace applications.

2.1 Manganese

Manganese is a chemical element with the symbol Mn and atomic number 25 found in nature in combination with other minerals such as iron. Manganese is a transition metal with important industrial alloy uses, particularly in stainless steels. Steel contains about 1% manganese, to increase the strength, improve workability and resistance to wear. Manganese has recently found its use in BEVs in combination with lithium as Lithium manganese oxide (LiMn2O4). Spinel type LiMn2O4 is attractive for BEVs for low cost, easy production process and thermal safety. Manganese is abundant in nature and well established in the battery industry.

2.2 Nickel

Nickel is a chemical element with the symbol Ni and atomic number 28.Nickel is a hard, ductile, silvery-white lustrous transition metal with a slight golden tinge. Nickel is extensively used for making stainless steel and other corrosion-resistant alloys. Nickel has found application in the electronics of BEVs in more recent years.

2.3 Cobalt

Cobalt is a chemical element with the symbol Co and atomic number 27. Cobalt is rarely found in the Earth's crust as a native metal. It occurs as a by-product of metals such as nickel, copper and lead.

Traditionally cobalt was used to impart blue and green colours in glass and ceramics. Today, cobalt is used in the manufacture of magnetic, wear-resistant and high-strength alloys for the Aircraft Industry and cobalt salts are used in electroplating, in cell phone batteries and other similar mobile devices. It is also increasingly being used in rechargeable batteries for electric cars.

Superalloys are based on nickel, cobalt or iron with large additions of alloying elements to provide strength, toughness and durability at high temperature. Aluminium and/or titanium are added for strength and chromium, as well as rare earth elements like yttrium, are added to improve corrosion resistance. Superalloys are an important group of high-temperature materials used in the hottest sections of jet and rocket engines where temperatures reach between 1200–1400 °C.

Cobalt has also found its use in rechargeable batteries and is the most commonly used due to its better energy storage capabilities.

3. Cobalt Production, Supply and Demand

3.1 Production and supply

The Central African Copperbelt, which runs through the Central African Republic, the Democratic Republic of Congo (DRC) and Zambia, yields most of the world's cobalt. The Central African Copperbelt in particular Zambia and the DRC holds about 80% of the worlds Cobalt. The DRC alone accounted for more than 50% of world production in 2016. World annual cobalt production stood at 114,000 tonnes in 2016 and DRC accounted for 66%. World's annual refined cobalt production was 99,000 tonnes in 2016.

Most of the cobalt mined finds its way to China's refineries and eventually into the Japanese, European and American markets for end product manufacturing.

China has been the leading consumer of cobalt in recent years. China initially purchases the cobalt in raw sulphide and oxide form, before refining it to isolate the cobalt to be used in the process for making cathodes for the batteries powering smartphones and BEVs. Today, China produces more than 80 percent of the world's refined cobalt.

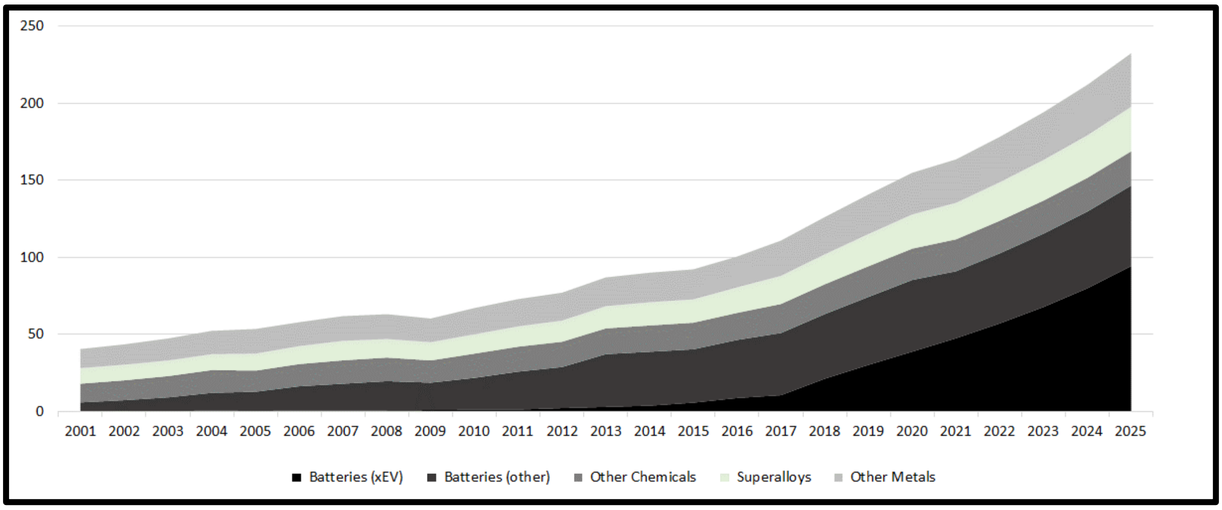

Figure 3-Cobalt production and supply distribution (Source: CRU)

Figure 3 shows that there has been an exponential growth in the Battery Electric Vehicles from 2017 onwards. Batteries production in other sectors fuelled by the 4IR has grown from 2001 through to 2012. Forecasted total demand will exceed 190,000 tonnes by 2025.

China is expected to drive much of the boom on the demand side as it seeks to dominate the electric-car industry, along with an expected boost in sales for the Tesla Model 3 in the United States. Underscoring China's aspirations is the agreement it recently signed with Glencore, the world's biggest cobalt miner, to sell 52,800 tonnes of cobalt hydroxide to China over the next three years. Much of this volume is likely to ultimately go to Chinese electric-car battery company CATL (Contemporary Amperex Technology Co. Limited), which is reportedly the largest battery supplier in the world owing to contracts it has in place with BMW and Volkswagen.

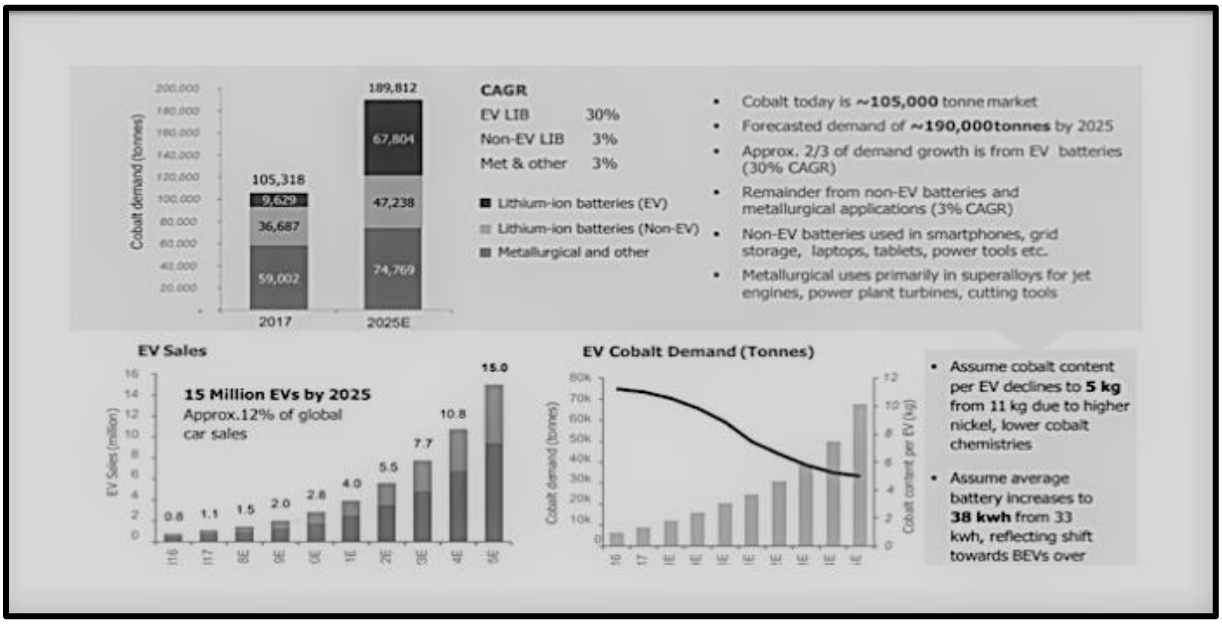

Figure 4-Cobalt demand; current and future projection (Source: cobalt27,provenandprobable)

China is also planning on banning the production of vehicles powered only by fossil fuels, which in turn will push much of the country's car demand towards BEVs. Moreover, it has already launched a Five-Year Plan that involves pressing for up to 15 percent of power to come from non-fossil fuels.

As demand for the metal soars and as supply struggles to keep pace with consumption—a widening supply gap is expected to emerge. According to a cobalt-industry report from Research and Markets, "the global cobalt market will face a tight supply situation in 2017-2021, with the gap of 12,000 tonnes by 2021" as opposed to ~3,320 tonne gap in 2017 representing more than 10 percent of current supply levels.

A veritable craze for rechargeable lithium-ion batteries has been the main factor in boosting cobalt prices, with leading commodities research-house Wood Mackenzie estimating that 49 percent of global cobalt demand was from the battery sector in 2017. Indeed, several notable carmakers such as Tesla, BMW and Volkswagen have made efforts to secure long-term contracts for cobalt to be used in their vehicles' batteries. Each new EV battery uses about 10 kilogram of cobalt which is more than 1,000 times the amount used in an iPhone. Apple has also been a major contributory player in the boom, with cobalt also being a key ingredient of rechargeable batteries used in a variety of home electronics.

The market is set to face further tightening on the supply side, while the electric-car revolution shows little sign of slowing anytime soon. Experts predict that there will be more than 140 million BEVs by 2030 and 900 million BEVs on the roads by 2050.Tony Southgate, Head-Strategic Cobalt Marketing at Eurasian Resources Group (ERG) Kazakhstan, recently forecasted that the cobalt boom "is guaranteed for the next seven to ten years.

Cobalt supply will need to exceed 190,000 tonnes by 2026 to meet demand for Lithium Ion Batteries.

3.2 Growing demand

The bottom line is that cobalt is presently the most important material, from strategic and cost viewpoints to further develop the lithium-ion battery. If an automobile manufacturer or a battery supplier wants to ramp up production, they HAVE to secure future supplies of cobalt.

4. Metal Deployment in cleaner technologies

Over the last 500 years humans increasingly turned to cheaper, dirtier energy sources such as coal and fracked gas for heating, transportation, lighting etc. Non-renewable, or "dirty," energy includes fossil fuels such as oil, gas and coal. Many non-renewable energy sources endanger the environment and human health. Pollutants from burning coal for energy and emissions from internal combustion engines foul the air and contribute to greenhouse gas emissions and global warming.

4.1 The Quest for Renewable/Cleaner technologies

As the world transitions into the future of the Fourth industrial revolution, campaigns on cleaner and renewable energy for the world to go entirely green is the resounding echo in all spheres. The aim is to find alternatives and to reduce the world's dependence on dirty energy sources which worsen air pollution at a time when the world is intent on decarbonising.

In the mobility industry, internal combustion engine cars (ICEVs) ranks as a key mover of economies. There are an estimated 1.5 billion gasoline fuelled vehicles in the world as at 2018.Emissions from combustion engines of vehicles release greenhouse gases like carbon dioxide (CO_2), nitrous oxide (N_2O), and methane (CH_4) which trap heat in the atmosphere .With higher-than-natural concentrations, they produce adverse environmental impacts which lead to global warming, photochemical smog, acid rain, death of forests and reduced atmospheric visibility.

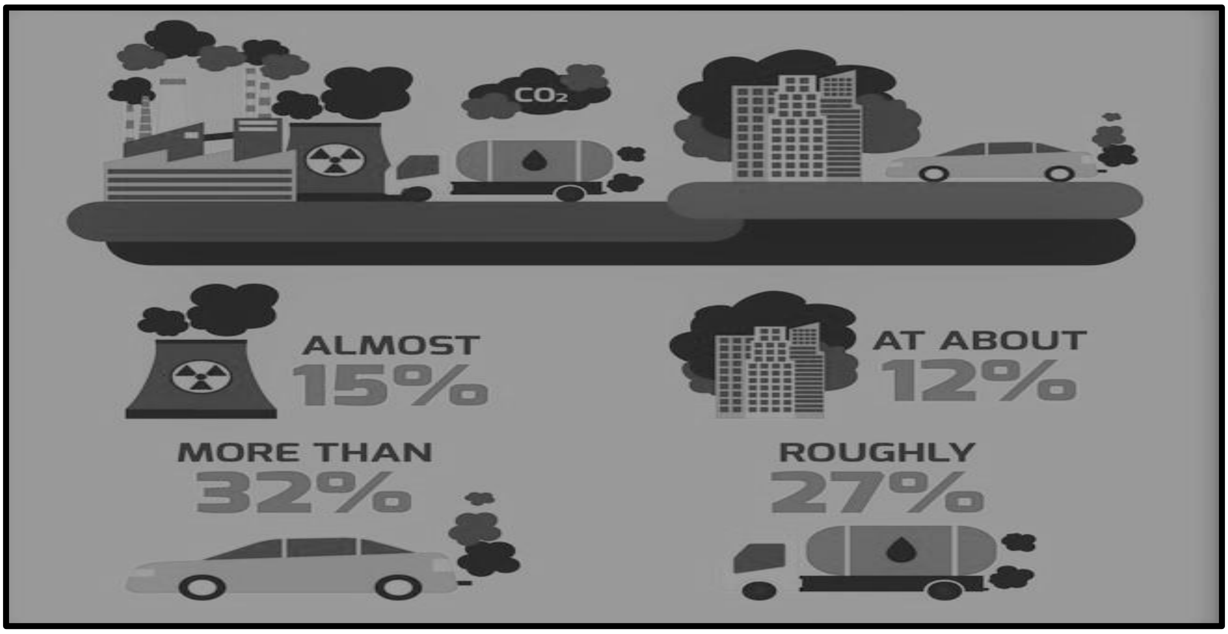

Figure 5: Sources of Greenhouse gas emissions (Source: googleimages, ozeessay.com.au)

The march of climate change, is now a far bigger issue than originally postulated and expectations run high that the greenhouse gas and resource problems should be addressed by massively substituting internal combustion engine cars (ICEV) with battery powered electric cars (BEVs).

Use of lithium-ion battery or Li-on battery vehicles have proved as an environmentally viable option as opposed to internal combustion engine cars (ICEV) relieving the future of burdens of environmental clean-up. This is where Manganese, Nickel and Cobalt, find critical application in the battery energy storage devices. Of the three metals it has been postulated that ***Cobalt stands out as a critical metal in Li-on battery manufacture.***

Cobalt has unique qualities such as, its high energy density which makes cobalt the perfect addition to lithium-ion batteries to stabilize the battery and prevent fires and explosions, while at the same time conserving battery strength and extending battery life.

5. Why the scramble for the once little-known element -Cobalt

Electric Vehicle and portable electronic device used in the Fourth industrial revolution are powered by lithium ion batteries or Li-on batteries. Li-on batteries have a negative electrode made from carbon (graphite), the electrolyte and a positive electrode typically made from a chemical compound called lithium-cobalt oxide ($LiCoO2$).Cobalt containing Li-on batteries have high energy density which means they are able to store large amounts of energy in a small area. This unique quality makes cobalt superior to nickel and manganese thus it is commonly used.

The proliferation of lithium-ion batteries, has spiked the cobalt demand. There are alternative lithium-ion chemistries such as lithium manganese oxide (LMO) or lithium iron phosphate (LFP), which are suitable for applications like power tools and electric buses. However, both these alternatives are not energy dense enough to be used in automobiles or mobile phones, which brings us back to needing cobalt.

While engineers can sometimes find ways to change designs or use substitutes for some elements, cobalt could be tough to replace. There are potential substitutes, but substitution in some uses may lead to losses in performance. So while designing out cobalt can be a possibility, this is not going to happen anytime soon. There is a trend to minimize the use of cobalt by moving from the commonly used NMC111 to NMC 532 and eventually to NMC811, which basically means using more nickel (N) and manganese (M) and less cobalt (C) in the cathode. But automobile manufacturers will be reluctant to reduce cobalt content until they are sure that safety will not be compromised. Cobalt is crucial in improving longevity and safety of Li–ion batteries. The other possibility is to replace cobalt altogether with other materials, but we are at least five years away from being able to do this. Presently, there are no short-term alternatives to using cobalt in electric vehicle batteries.

Even if a technological substitution of cobalt is possible, it will take at least ten years to reach commercial applications .Cobalt is setting out to make its mark in the BEVs arena by displacing other metals to a large extent in many of the cathode formulations, where the bulk of battery metals are used. Cobalt is described as being poised for “a very rapid development" while the world’s researchers and developers are still cracking the cathode formulation code.

6. Looking back to the Future

Krieger said the Fourth Industrial Revolution is different from the third for two reasons: the gap between the digital, physical and biological worlds is shrinking, and technology is changing faster than ever. To support this 4IR, critical metals are needed.

Minerals and metals such as copper, lithium, cobalt, manganese, and chromium are needed for producing solar panels, robots, drones, batteries, wind turbines, smart phones and electric vehicles – the products of the future.

The U.S. Department of Energy says materials used in four clean energy technologies: wind turbines, electric vehicles, solar cells and energy efficient lighting, are critical now. The American Physical Society’s Panel on Public Affairs and the Materials Research Society coined the term “energy critical element” to describe elements that are essential to one or more of the new energy-related technologies. The European Union commissioned a report that identified 14 materials critical to the EU. Only four metals or element groups made all three lists:REEs, platinum group elements (PGEs), lithium and cobalt. So there is absolutely no dispute that cobalt is a critical metal.

Cobalt, is on the radar screens of most investors and researchers given just how important it is to the functioning of a modern economy, in the green movement and in defence applications. Cobalt is going to undergo a massive sea change in perception because it is so much more than an industrial metal. It is the “King of Critical Metals.”

7. Implications for Zambia and the DRC

The Fourth industrial revolution heralds exciting opportunities as metals of the future become critical to both existing and new technologies. Zambian and the DRC house about 80% of the world’s cobalt resource. The 4IR has revolutionised the world with major advancements in communication and the industry as a whole necessitating for more rechargeable batteries with Cobalt as one of the core ingredients. The demand will continue increasing exponentially with demand outstripping supply by 2021. The Cobalt price will continue to be bullish in the short to medium term.

Zambia with its stable political climate offers a better option for exploring the Cobalt refining potential. The Zambian government could also revisit orthodoxy taxation and mining codes to allow for free flow of cobalt concentrates within the Central African Copperbelt to encourage investment in cobalt processing and refining, so the region can be turned into a source for cobalt salts for the growing rechargeable batteries industries. Cobalt's potential niche in the 4IR is inarguably unequivocal and it talks to Sustainable Development Goals(SDG) 9 which addresses industry, infrastructure and innovation.

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Coremaking Simulation an Innovative Technology with Impact for African Foundry Engineers

Farai Chrispen Banganayi[1], Oyombo Dady[2]

Abstract

The development of simulation technologies came with a lot of cost savings through avoiding numerous trial and errors. Simulation of the solidification process has been common in the Foundry industry for the last 20 years. In Foundry Engineering simulation of the coremaking process is a new innovative development. The cores are used to make the hollow section of the castings and are usually produced separate from the moulds. The autonomous optimisation of simulation technologies gives the engineer a variety of options in the design process which will require a lot of time to accomplish if done manually through regular set up of the simulation process. The study evaluated the traditional core making process against making use of core making simulation technologies in an African foundry. In this case we looked into the coremaking process for a rail transmission casting with the aim of reducing a problematic defect on the cores. The use of the simulation technology in trying to solve this problem brought about a number of added advantages in pursuit of responsible consumption and production. The defect was eliminated, lead times were reduced, productivity was improved and material consumption was reduced. This core manufacturing process became more sustainable.

Keywords: Cores, Foundry, Simulation, Sustainable, Development

1. Introduction

The traditional production of sand cores can be a sophisticated process filled with technical challenges that can severely delay production, create scrap and rework leading to increased costs on the finished products (Schneider and Stevenson, 2018). Coremaking gives foundries a capability that no other metalworking process can offer, which is the ability to form external and internal contours, shapes, cavities, and passageways in one operation (Gupta, Aloni and Binzade, 2016). The most common coremaking methods are as follows no-bake, shell, cold box, CO_2, oil sand and hotbox. The more the product designs become complicated to improve efficiencies the more it becomes challenging to make defect free cores that do not compromise the casting's design efficiencies (Schneider and Stevenson, 2018).

[1] University of Johannesburg; Metal Casting Technology Station Institution; Cnr Siemert and Beit Streets Doornfontein 2028;+27115596390; fcbanganayi@uj.ac.za.
[2] University of Johannesburg; Metal Casting Technology Station Institution; Cnr Siemert and Beit Streets

The core making process is seen as a process that generates a lot of gases. This means the core making process is becoming a victim of more stringent environmental regulations. This therefore necessitates the need to optimise the process so as to stay in business whilst abiding to the environmental regulations. In the last few years foundries have been under pressure to improve technologies and processes in order to remain profitable (Gupta, Aloni and Binzade, 2016).

The challenge with the traditional core making methods is that there are based on trial and error. The trial and error methods have huge cycle times and do not adequately address or give you a scientific reason behind the failure of the previous trial. Simulation splits up the real process in detail, according to both time and space. The Engineer is capable of identifying what is happening on which area of the core and at what time from the simulation. This therefore allows for the identification of parameters that affect tool production in advance (Sturm and Wagner, 2014).

Simulation of cores is considered to be very new, though we have had the simulation of metal flow for a long time (Nowacyzk, 2015). Simulation of sand-core production is a new technique for changing tool and process design on the basis of insights into core-shooting and hardening processes based on the basic principles of the process (Sturm and Wagner, 2014). Opposed to physical trial and errors, autonomous optimization using simulation tools provides significantly more choice. Autonomous optimization capacitates foundry engineers to modify several parameters. The optimisation can be performed in the casting design and in the casting process layout, simultaneously and independently from each other, whilst the quality criteria can be individually and quantitatively evaluated (Hahn and Sturm, 2015). Simulation helps to plan, implement and operate stable processes (Nowacyzk, 2015).

Core simulation process needs a number of variables like, core shooting pressure, type of vents, number of vents, nozzles size, nozzle shape. Using the traditional method core box/ patter makers/tooling designers have knowledge on limited variables that will affect the coremaking process (Schneider and Stevenson, 2018). The effects of filling the core box cavity and sand compaction in processes of core production by blowing methods (blowing, shooting) depend on a number of factors. The important factors are: geometrical parameters of cavity and complexity of its shape, number, distribution and shape of blowing holes feeding sands as well as the venting of a technological cavity. Values of separate parameters are chosen according to various criteria, but more importantly they should be adjusted to properties of the core sand to be used (Dańko, Dańko, Burbelko and Skrzynski, 2014). The filling dynamics of a core box are dependent on the flow of air, whilst least compacted area are associated with poor venting (Nowacyzk, 2015).

Changing one process parameter, due to its relationship with other parameters, can have a number of impacts on the rest of the process and can affect the final casting quality in many different ways. This makes it difficult to manually optimize a casting process by evaluating the casting quality based on trial and error, pursuing quality and economic objectives simultaneously (Hahn and Sturm,2015).

2. Approach to analysis of traditional and simulation designs

The core box design prepared from traditional trial and error methods with a problematic filling defect had its design and operation parameters loaded to the simulation software and simulated.

The simulation was evaluated and changes were made to the core box design using autonomous optimisation simulation tools. The best optimised simulation design was then adopted as the new design. The performance of the new design and its core shooting parameters were compared to those of the traditional design from trial and error methods.

3. Analysis of cores from traditional and simulated designs.

3.1 Traditional design core.

Figure 1: Core box traditional from traditional trial and error design with a defected core

Figure 1 shows the core inside the core box with a defect that shows inadequate filling of the core on the two encircled ends in figure1. The practice was then to patch the defect with sand after releasing the core box from the core shooter.

Figure 2: traditional design core box top

Figure 3: Traditional core box design bottom

Figure 2 and 3 show the traditional design core box. The core box was used in the foundry despite its defects. This was most likely the best choice the foundry could rely on after a number of trial and errors.

3.2 Simulation

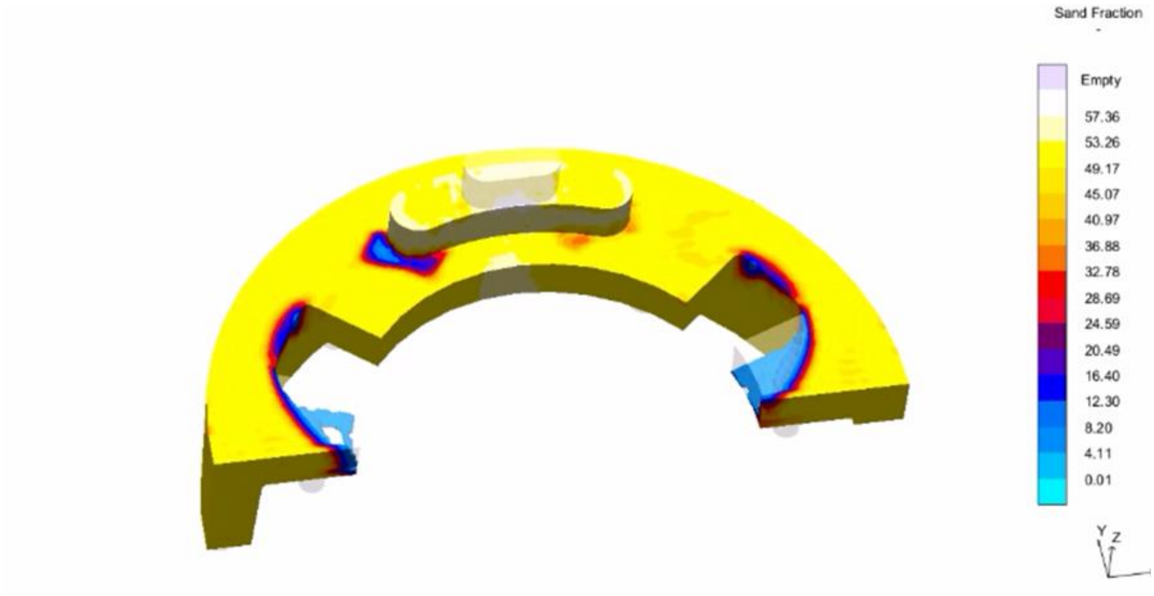

Figure 4: Simulation of the traditional design

The traditional design was simulated under the following conditions

- Original design of core box
- Nozzle central position
- 6 vents
- 1 nozzle

- Silica sand sub rounded
- Phenolic resole sand
- CO_2 gassing
- Core blowing 15 seconds
- Core gassing 15 seconds
- Core shooting pressure 250KPa
- Core gassing pressure 300KPa

The result came out more or less the same giving the same defect in the same area. The simulation showed incomplete filling of the core box. The severity of incomplete filling is represented by the blue, grey and white colours on the simulated drawing as represented by the scale on the right of the simulation drawing.

The autonomous optimised simulation was then carried out to give the results in figure 5 .The ideal design was to change the nozzles positions.

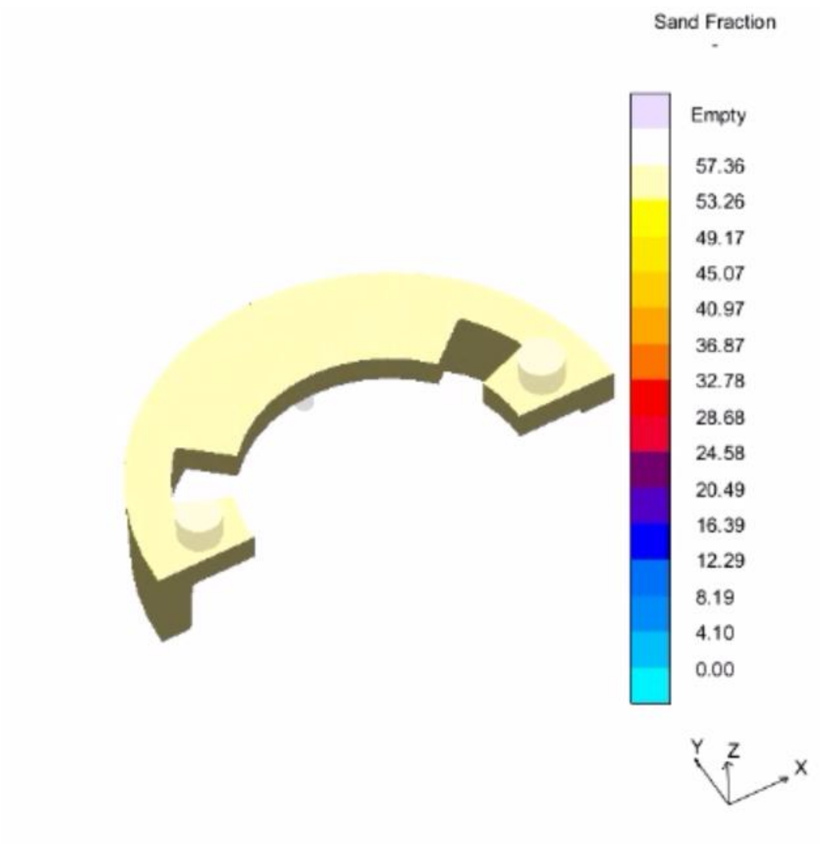

Figure 5: Simulated design

Figure 5 shows the optimised simulated design with a robust defect free core. The optimal core design was achieved with the following parameters;

- Original core design
- Nozzle exterior position
- 6 vents
- 2 nozzles
- Silica sand sub rounded
- Phenolic resole sand
- CO_2 gassing
- Core blowing 10 seconds
- Core gassing 5 seconds
- Core shooting pressure 250KPa
- Core gassing pressure 300KPa

4. Benefits from the core simulation technology

4.1 Benefits for the foundry engineer realised when using core simulation software

The use of core simulation technology resulted in a number of benefits for the foundry engineers in a number of areas. The benefits are given in the subsections to follow.

4.1.1 Improved lead times

Instead of doing a trial an error. The foundry engineer will be capable of producing core boxes for prototypes and production within shorter time periods. This brings about improved competiveness in terms of customer delivery.

4.1.2 Improved productivity

The time for core blowing and gassing have been reduced sue to a more efficient and optimised simulation design. The reduction in times within the core making process results in actual reduction of cycle time. This therefore allows for more cores to be produced within a given shift or day.

4.1.3 Knowledge transfer

The core simulation programme will assist the foundry engineer in understanding the complex interactions between the process variables. This thereby gives the foundry engineer knowledge based on the interaction with the simulation programme.

4.1.4 Accelerated root cause analysis

The foundry engineer is capable of performing root cause analysis on the software programme for core defects that he/she could be experiencing. The simulation programme speeds up the process of identifying the problem.

4.1.5 Reduced costs

The foundry engineer will have a number of savings, from labour time, wood for patterns, CO_2 gas, electricity, and compressed air. This is dependent on the design chosen to make the best quality cores at an economically sustainable cost.

4.1.6 Competitive market advantage

The foundry engineer's prices for castings will eventually become competitive on the market because of the cost savings, lead time and good quality these advantages can eventually lead to more orders.

5. Conclusion

Core simulation is a disruptive technology in the foundry space. The foundry engineer derives several benefits from core simulation technology. The benefits put the foundry in a better position in terms of profits and competitiveness. The savings on materials contribute towards achieving the sustainable development goals. Reduction in trial and errors saves a lot of wood since the majority of the core boxes are made from wood and resin. The same with reduction in gassing time contributes towards reducing greenhouse gas emissions. The benefits attained from simulation of cores contribute towards sustainable development goals under industry innovation and infrastructure SDG 9, responsible consumption and production SDG 12, climate action SDG13 and promotion and sustainable use of terrestrial ecosystems SDG 15. The benefits are seen to be interlinked in achieving certain goals, thus a benefit can contribute towards the achievement of 1 or more sustainable development goals. The innovation and sustainability brought about by simulation technology demands that the foundry engineer adjusts to acquiring key competencies and skills required for production in the future.

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Biomass – Solar PV Micro Hybrid Power Plants in Zambia

Likonge Makai Mulenga[1], SP Daniel Chowdhury[2]

Abstract

Lack of access to safe, clean, affordable and renewable energy in most developing countries has a negative impact on economic growth and development. Zambia is not excluded, about 80% of its population depends on wood/fuel in form of firewood, and charcoal for cooking, whilst candles and kerosene for lighting. Wood fuel is associated with the use of inefficient stoves which increase poverty, health and environmental impacts. With availability of abundant biomass and sunshine hours a month with Potential Energy Output of 5.5kWh/m²/day in Zambia, micro hybrid biomass – solar photovoltaic power plants are thought of to be the energy solution of Zambia. Biogas and Solar energy technologies are feasible to provide such energy system because they can be converted into different forms of energy to provide cooking, lighting and appliance demand. Hence, this research project seeks to integrate Solar Power with Biogas to provide cost-effective production and utilization of energy in rural area of Zambia. This will be done by utilizing local resources, primary data and secondary literature information for system analysis. The production and utilization efficiency will be determined using MATALAB/Simulink with homer Pro simulation to design the systems components and to analyse the financial feasibility studies of the developed system respectively based on the system configurations, conversion and model combinations. The hybrid power project will eliminate battery storage and inverters, which have proven to be the most expensive part in the solar power solution. Biomass will produce biogas to provide energy in the form of heat for cooking and excess biogas will be converted into electricity which will be synchronized with solar to provide power for lighting and electric appliance demand. This paper focuses on why micro hybrid power plants are essential in Zambia and what is needed to sustain the same as an economic option using local resources.

Keywords: Solar, biogas, hybrid, local resources, affordable.

1. Introduction

Access to clean, safe, affordable and sustainable renewable energy supply is one of the greatest challenges facing humanities in many developing countries because of poverty. The energy consumption patterns of poor people mostly from traditional energy (biomass) and fossil fuels likely add to their misery and worsen their poverty. Renewable energy development would allow poor people to have a better life. An estimate of 2.5 billion people in developing countries relies on traditional biomass (Neto, et al., 2010; Louie, et al., 2015) and fossil fuel for cooking and

[1] Konkola Copper Mines Plc; Nchanga Concentrator Engineering Department P/B 2000©, Chingola; +260977450580; likobus@yahoo.com.
[2] Tshwane University of Technology; Electrical Engineering Department Staarsatillerie Road P/B X680 Pretoria 0001; +270713519332; Spchowdhury@gmail.com.

lighting. The traditional biomass supplies over 90% of household energy need in many of developing countries (Lam & Felix, 2011). The burning of biomass releases pollutants that are currently estimated to cause more than 1.6 million annual deaths globally from which 400,000 deaths are in Sub-Sahara Africa (SSA) (Lam & Felix, 2011). These deaths are always among the children and women which clearly shows the link of biomass directly or indirectly to millennium development goals (MDGs) including environmental sustainability, reducing child mortality and gender equity. It is expected that one third of the world's population will still rely on these fuels until 2030 (iea, 2012; PASA, 2007). Most of women and children's valuable time and effort is spent to collecting fuel wood instead of education, income generation or leisure. For instance, in sub-Saharan Africa, women spend 3 to 5 hours collection time per head-load due to long distances of where the fuel wood must be collected from. This will need 6 to 15 hours per week (SNV, 2010). Deforestation too results due to cutting down of trees for charcoal production and fire wood consumption in the end causing environmental damage.

Zambia is among developing countries in Sub-Saharan Africa whose main source of energy is wood fuel (firewood and charcoal). The rural areas, which account for 64% of the population, live below poverty line and 36% of the population lives in urban area (Central Intelligence Agency (CIA), 2013). Although poverty is mainly pronounced in rural areas, 56% of Zambian urban residents are poor and only 47% of the urban population has access to electricity (JICA and MEWD, 2009). Wood fuel is the main and essential source of energy in Zambia. It plays a vital role in the Zambia's energy mix and basic social and economic welfare of many people in the rural and urban areas today and it is very critical in development and realization of the 2030 vision because of its direct link between wood fuel consumption and poverty including environmental sustainability and gender equity. The cutting down of trees for charcoal and firewood utilization always result into depletion of trees. This leads to environmental degradation causing vulnerability to climate change impacts (Department of energy MEWD and ENERGIA, INGSE, 2012)

In this article, micro grid power plant for a Zambian rural community is evaluated in general based on expected electricity demand from the current scenario. Two cases are evaluated; a reference case with a solar photovoltaic and a review of biomass-solar hybrid power plants of already proved studies. The article describes the country overview, its energy need, the available energy resources and the required technology. On this basis, system energy balance is presented, technical and economical evaluations of the results are discussed.

2. General profile

Zambia is a landlocked Sub-Sahara Africa country, with an area of 752, 614 square kilometres located in the Central Southern Africa (JICA and MEWD, 2009). It shares boarders with Democratic Republic of Congo (DR Congo) and Tanzania to the North; Zimbabwe and Botswana to the South; Malawi and Mozambique to the East; Namibia to the South-West and Angola to the West. The population is about 17,000,000 people (i.e. 2019 estimates). There are more than 2.4 million households in Zambia according to the Living Conditions Monitoring Survey Report 2006 and 2010. It is one of the most urbanized countries in Sub-Saharan Africa, with about 36% of the population living in urban areas (REEP Policy Database , 2012). The level of Literacy rate, adult total (i.e. the percentage of people between the ages of 15 and above) is 71% and that of entire population is 80.6% (Central Intelligence Agency (CIA), 2013). Zambia has almost the same favourable uniform climate throughout the country with average temperatures from 15°C to 27°C (Oxford, et al., 2008).

In addition, Zambia is situated at the latitude of 8 to 18 degrees south of the equator, with an average sunshine of about 6-8 hours per day that have high solar radiations rate of 5.5kWh/m2 throughout the year. However, the country's solar energy potential has not been exploited. Zambia's vast land area of 750,000 square kilometres has enormous potential for biofuel plants growth for generation of bioenergy. Furthermore, the country has an ideal plateau landscape, which offers some locations where there is potential for wind energy exploitation. This wind energy as a potential area for power generation has not been exploited due to few studies on wind and lack of wind atlas amongst other reasons.

2.1 Energy balance

Zambia's total primary energy supply is 7, 856ktoe and the following are resource percentage contributions; biomass 80.9%, hydro 11.3%, crude oil 6.6%, petroleum products 1.05, electricity exports 0.2 and coal and pits 0.01% (iea, 2012).

2.2 Energy consumption

Zambia's total annual energy consumption is 4.5 mtone (iea, 2012; JICA and MEWD, 2009) with wood fuel meeting the bulk of the energy needs followed by electricity, petroleum products, and coal. The total demand in Zambia currently exceeds internal generation because of the booming mining sector. Zambia is faced with the challenge of satisfying the demand of more than 80% (REEEP Policy Database - SERN for REEEP, 2012) of its population for modern forms of energy. There has been lack of investment in power generation and transmission infrastructure that has led to deterioration in the power network. Since 2008, 450MW is unavailable from the countries generating infrastructure, leading to peak period deficit of 280MW (REEEP Policy Database - SERN for REEEP, 2012). Since 2015, there is an energy crisis in Zambia which has resulted in an increase in load shedding countrywide to meet the balance of supply and demand. The following contact information may be provided as a footnote for all authors of the paper: current employment affiliation; postal address, telephone number and electronic mailing address.

2.3 Household energy use

The main major use of household energy is cooking, heating and lighting and this is mainly from wood fuel followed by electricity, which is largely used by those in the urban areas. The utmost task that Zambia faces is to provide sufficient and reliable sources of energy to uplift the living standards of its rural populace as well as those in urban but with no electricity access.

2.3.1 Cooking

Only 16.7% of Zambian households have access to electricity of which only 2.6% (SNV and Hivos, 2012) is used for cooking. Firewood is the most used fuel, stated by 60% of households. In rural areas they use 88% of firewood and 8% in urban areas (Department of energy MEWD and ENERGIA, INGSE, 2012). Charcoal is the one commonly used in urban areas than in rural areas; 53% and 10% respectively (Department of energy MEWD and ENERGIA, INGSE, 2012). Out of all these households using firewood, 1.7% rural households and 2.2% urban households buy firewood. 6.6% of rural households and 51.1% of urban households buy charcoal. Overall, households in rural areas have free access to firewood apart from areas with scarcity wood; resulting to them to firewood. Women and children are mainly responsible for collecting firewood. It is estimated that women spend an average of 2.48 hours per day collecting a head load of wood. The countries average of daily fire wood consumption is 12.5kg (SNV and Hivos, 2012). This amounts to 4,562.5 kg of firewood per household per year. Similarly, the records from surveys in the capital city of Zambia named Lusaka, a household consumes approximately 1300kg per year (3.56kg daily) (M & M, 2013). This charcoal is produced from approximately 8tonnes of non-renewable biomass think branches.

2.3.2 Lighting

In Zambia, 27.2% households use kerosene/paraffin as a main source of lighting energy. The other households use electricity 21.6%, candles 26.0%, diesel 3.6%, open fires 5.2%, torches 11.0%, solar panels 3.3% and other energy sources 1.4%. In rural areas, kerosene/paraffin is the usually used as source of lighting energy for 37.1% of households; this number of kerosene/paraffin use is higher in Luapula and Northern provinces at 68.5% and 45.8% respectively followed by diesel (M & M, 2013). Since fossil fuel cost much, especially in rural areas, those that use kerosene/paraffin and diesel for their lighting energy can be substitute it with biomass-solar hybrid technology. Energy sources for lighting vary according to poverty status. Non-poor households had the largest use rates of electricity at 44%, while the moderately poor had 6%, and the extremely poor had only 1% (SNV; Khatiwada, E, 2012).

3. Renewable energy micro hybrid technology

Renewable energy sources have very exciting potential for electricity production and use in many sectors. However, productive use of energy is very crucial to develop valuable economic activities in communities without access to electricity.

In Zambia they remain insignificant in terms of contribution to the total national energy supply. These sources include: solar (thermal and photovoltaic); mini/micro-hydro; biomass (agricultural produces and wastes, forestry waste, industrial/municipal organic wastes, energy crops & products and animal waste); geothermal, and wind.

Wood, petroleum and hydropower endures to be the major energy sources, there is need to explore other sources of energy. The National Energy Policy protected potential of renewable energy sources is shown in Table 1. It summarizes the opportunities and resource availability for the utilization of renewable energy sources and technologies. Solar, wind and biogas have excessive potential but much of the focus in this article is on solar – biomass hybrid project.

Table 1: shows availability and utilization of renewable sources in Zambia.

Renewable Energy Source	Opportunities	Resource Availability

Solar Thermal Electricity	Increasing Rural electrification rates Back up supply Lighting, refrigeration and entertainment	6-8 sunshine hours a day Potential Energy Output 5.5kWh/m²/day
Biomass Combustion and gasification	Electricity generation	50 million hectares – woodlands, Agro Waste, Forest Waste and Sawmill Waste
Biomass Bio-methanation (Biogas)	Electricity generation Heating cooking and lighting	Animal, municipal, Industrial Waste and Waste water
Biomass Extraction, processing for transport	Ethanol for blending with gasoline to replace leas as octane enhance	Sugar cane, Sweet sorghum Jatropha
Geothermal	Electricity generation	80 Hot springs
Wind	Water pumping and maize grinding	Average 3m/s Specific areas with averages of 6m/s

3.1 Biomass potential

Estimation possibility of utilizing electricity generated from biomass in the micro-grid, from both the potential of manure for biogas production and the potential and solid biomass have been investigated. It is found that the potential of solid biomass is much higher than that of manure (Marte, et al., 2014; Zvinavashe, et al., 2010). Estimation of the solid biomass is based on the land and type of crop fed into the digester.

3.2 Solar potential

In Table 1, the potential energy output from sunshine is 5.5kWhr/m2/day for 6-8 hours a day. This is proven to be reliable for communities that have been supplied with the solar home kits and a micro-grid energy stations installed in Chingola (Louie, et al., 2015) and Siavonga, Zambia.

4. Design consideration

Design of a micro-grid in a specific location takes a lot to be considered as the needs differs from community to community. The investment cost of renewable energy sources is still not affordable especially in countries like Zambia where renewable energy considerations are low. This means there is need to consider use of available resources in specific location where the project is to be established to reduce the cost of energy and to increase sustainability.

4.1 Biogas

Biogas is a renewable energy resulting from biomass. Most of the Zambians are substance farmers who grow crops like cassava, maize, sorghum, wheat, groundnuts, bananas, oranges, have mango trees in their yards or nearby their homes and many other crops for consumption and sale in case of surplus. Residues and surplus from the above can be used to produce biogas. This biogas can be used direct for cooking, heating and produce electricity to supplement during the season of the year when solar is at its lowest capacity. In addition, effluent from the anaerobic digesters provides fertilizer to help farmers have more yields (M & M, 2013). Livestock are also available in homes especially for people in rural area and those on farms. Cattle, chicken, goats and pigs are greatest animals one would found in many of the Zambian households as these are used as source of incomes for rural people and contribute to crop production by supplying manure. More than 310,000 households have cattle in Zambia, individual head sizes of 9 for small-scale farmers, 17 for medium-scale farmers and 66 or more for large-scale farmers (SNV; Khatiwada, E, 2012). These are the recorded cattle per household but in rural areas you would find a family having more than one cow at household. Especially in southern province and north western province almost every household have cattle and chicken (PASA, 2007; SNV and Hivos, 2012).

4.2 Solar

Solar power is mostly economical to be used for lighting, entertainment, and refrigerator, hammer mill, sawmill and water pumping. It is also a daytime income generating activities like solar irrigation, Cottage industries, Husking mills, Sawmills, grinding mills (for spice) and powering rural marketplace enhance the productive use of solar power as this power does not include the cost of storage system or cost of fuel. Day load also work as cost reduction potential (Neto, et al., 2010; Marte, et al., 2014; Louie, et al., 2015).

4.3 Selection of Technology:

Different technologies of micro-grid power system are available throughout the world. The cost of the technology matters as this influence the price of energy. Figure 1 shows relevant considerations of designing micro-grid in context of rural communities in Zambia.

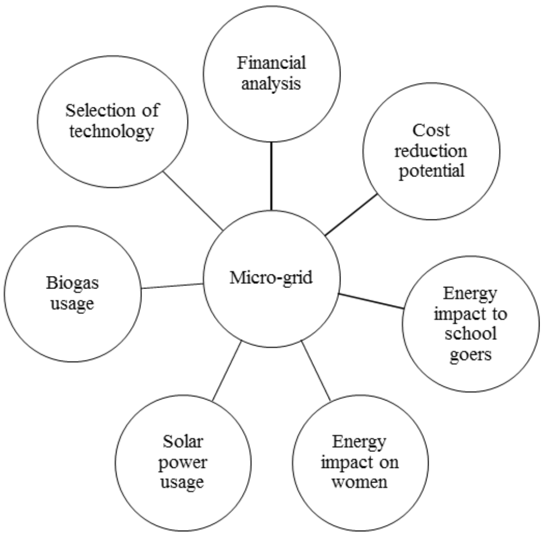

Figure 1: Micro-grid design considerations

Site survey for baseline planning, load demand assessment, technical design and financial analysis are always important steps to take successful community energy project.

5. Survey results

In Zambia, the need to energy usage for lighting, entertainment, phone charging, refrigeration and cooking is for both in urban and rural areas. There are some parts of the country where the national grid has never been since their existence and people in such areas have no idea about the cost for establishing power station.

Survey has been done in two different provinces of Zambia namely Filibaba community a pre-urban area in Chingola, Copperbelt province, Shikwakala community a rural area in Lukulu, Western Province.

Filibaba community is 23km from Chingola city. It is a farming settlement area and community people bring their farming produces to sell in the city. Majority have phones which they charge at a fee of $ 0.2 when they come to the city. For **Shikwakala** community is about 210km from Lukulu city. This community has no source of energy apart from **Mayukwakwa** refuge cape which is about 17km from this community that has thermal power for United Nation officials for office usage. The same thermal power is unreliable as it all depends on the availability of diesel and even if the diesel is available it only works for 4 hours per day. At the time of research Lukulu town was connected to the thermal power that used to come on at 06:00hrs in the morning and goes off at 18:00hrs in the evening daily.

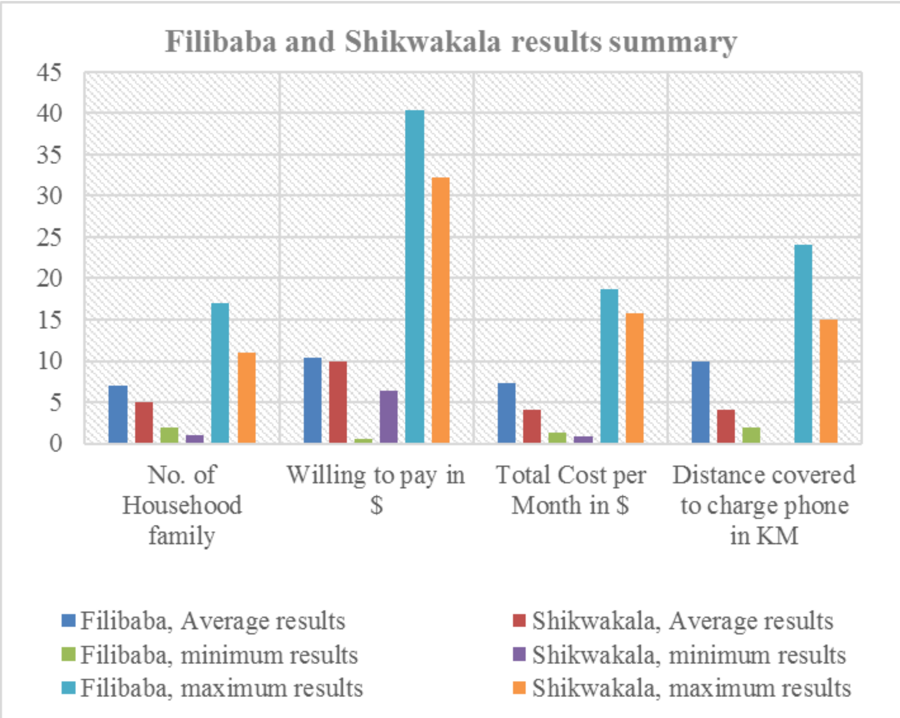

Figure 2: Summary of survey results of Filibaba and Shikwakala 80 households of each community.

From the survey, out of 80 households in Shikwakala, only 28 had mobile phones. These phones only got to be charged when the owners go either to Lukulu or Kaoma town cities to get their salaries at the month end or for business. Only a small number of people used to charge their phones once or twice a week.

Figure 2 shows average, minimum and maximum survey results from Filibaba and Shikwakala communities where solar micro energy station and solar home systems have been implemented. From the survey results, it is seen that the average household family for Filibaba community is 7 while for Shikwakala community is 5 with maximum household family of 17 and 11 respectively. The maximum total income spent on lighting and fossil fuel for Filibaba community is $18.71 per month while in Shikwakala community is $16 per month. Both communities were willing to pay for electricity with $40.32 for Filibaba and $32 for Shikwakala. Both communities had an average willing to pay of $10.

After evaluation of survey results; solar home systems and solar micro energy system were implemented. The two models are welcomed by the communities and there is need to design a sustainable and affordable renewable energy system to meet community energy requirements.

5.1 Solar home systems

Two types of solar home systems were introduced.

1. Solar home system that comes with solar panel, battery, lights, phone charger and accessories.

2. Solar home system that comes with solar panel, battery, TV or radio or both, lights, phone charger and accessories

5.2 Solar micro energy system

The solar micro energy system designed for Filibaba project is 1.8kW supplying two churches, two homes, phone charging, a deep freezer for cold soda selling and security lighting. This was a pilot project in 2015 and has seen other projects implemented in Siavonga, Zambia in 2016 and 2017.

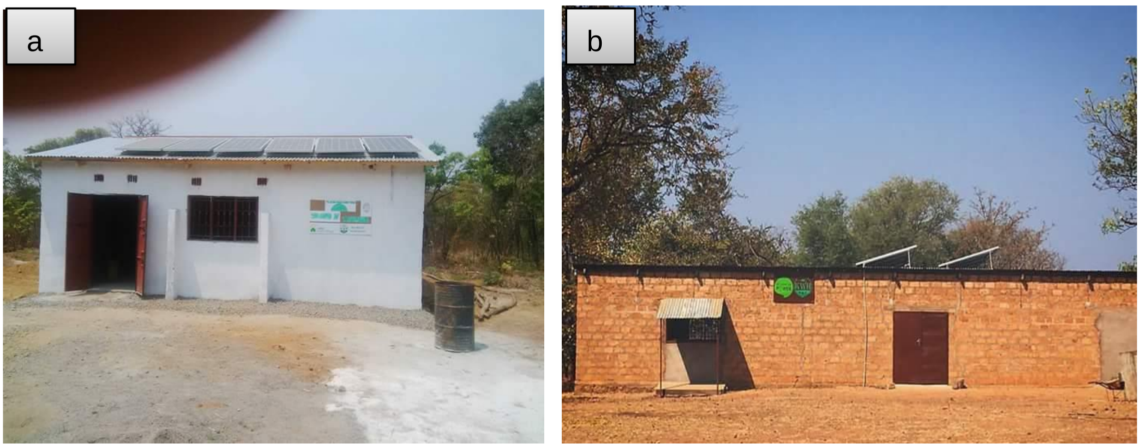

Figure 3: (a) 1.8KW, Filibaba and (b) 2. 56KW, Munyama

6. Results and discussion

Research has reviewed that solar PV micro power plant alone does not meet consumer energy demand and is not affordable. Biomass-solar micro hybrid power plants are reliable and give optimum power requirements (Tucho & Nonhebel, 2017). The inclusion of biomass generator will reduce solar PV modules requirement to meet the ratings (overall size of the system and there will be no interruption of power supply during the rain and cold season. The solution would help to meet power demand during peak hours.

With the deficit of electricity in Zambia, biomass-solar PV micro hybrid power plants will help to eliminate energy crisis the country is now facing. The biomass bring in other added advantages such as the resources are readily available in Zambia, effluent from biogas plant will be used as fertilizer, part of the methane (biogas) will be used for cooking this will help to reduce health related diseases from using wood fuel, women and girl child will have more time to do other household chores and go to school respectively other than going to fetch fuel wood. Figure 3 shows some of the benefits from biomass.

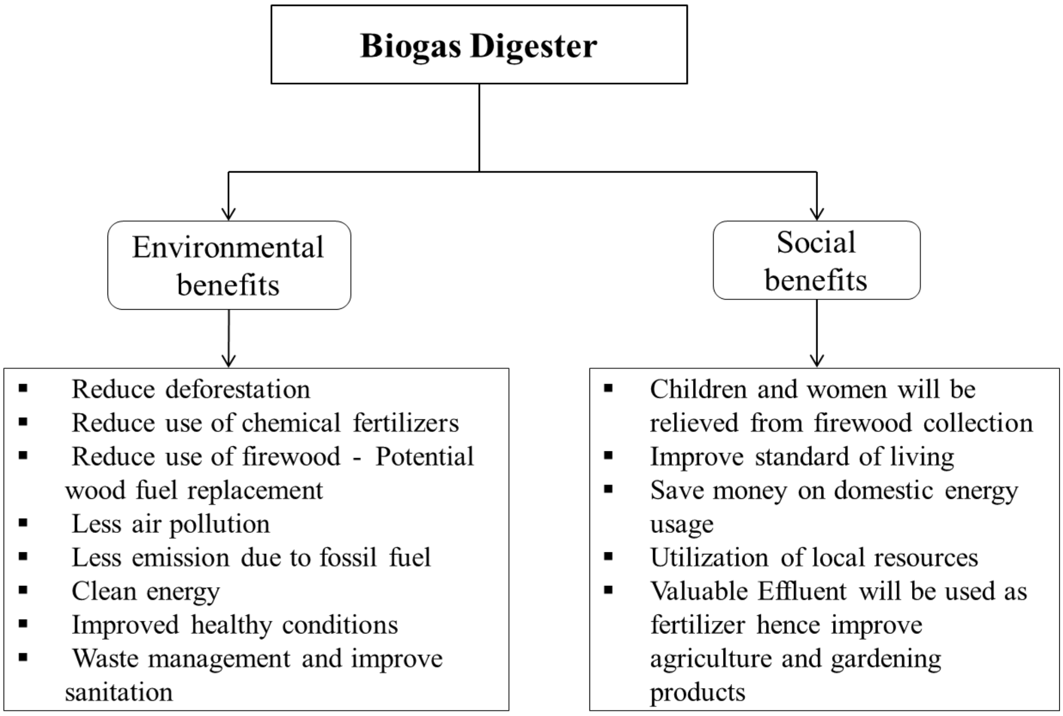

Figure 4: Environmental and social benefits in using biogas for cooking

There will be need for MATLAB/Simulink with homer Pro simulation to design the systems components and to analyse the financial feasibility studies of the developed system respectively based on the system configurations, conversion and model combinations. HOMER software unlike other software's is widely used for economical, optimal design, rural pricing and power management consideration (Marte, et al., 2014). With current willingness to pay for the installed solar systems, the biomass – solar PV micro hybrid system will help to have reliable and affordable energy in communities.

7. Conclusion

From the study it is seen that biomass-solar micro hybrid power plants will be the needed solution to reduce the energy crisis the country is currently facing. Especially the rural community will benefit a lot because this solution is easily implemented using the community existing resources and the only cost will be for solar system which will be affordable with elimination of storage batteries as the power will be supplemented by Biomass. With the availability of biomass and sunshine both in rural and urban areas, Zambia can greatly benefit from biomass-solar PV micro hybrid power plants energy solution.

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Junior mining and regulated artisanal mining and small scale processing of locally found commodities as entrepreneurial business ventures

Nirdesh Singh[1], Antoine Floribert Mulaba-Bafubiandi[2]

Abstract

Newly established exploration companies searching for mineral deposits and opportunities are often referred to as Junior mining. In Southern Africa semi-precious stones, silver, uranium, coal, gold and other precious minerals have attracted entrepreneurs' attention. Artisanal mining and small-scale processing on the other hand is a means of survival in rural areas where job opportunities are scarce and in some cases an enrichment path for many. In Africa, these operations focus on diamonds, gold, coal, semi-precious gemstones, and industrial minerals. Both junior mining and regulated artisanal mining and small-scale mineral processors contribute significantly to growing small to medium enterprises (SME) or even the large business sector which will result in an increase in the competitiveness of the economy and will create much needed employment. Some identified entry barriers to the realisation of the above mentioned mineral related business include access to appropriate technology, finance, regulation and skills. One has to inherently be a "mining entrepreneur" in order to overcome some of these challenges. This paper will present an overview of the current junior and artisanal mining and small-scale processing landscape in South Africa. It will look at the challenges faced by the sector, opportunities for business ventures based on mineral commodity types available and also the need for entrepreneurship and innovation to overcome barriers and succeed in what can be deemed a very risky and competitive environment.

Keywords: Artisanal mining and small-scale processing, entrepreneur, junior, mining, small-scale

[1] University of Johannesburg; P.O. Box 17011, Doornfontein; nirdeshs@gmail.com.
[2] University of Johannesburg; P.O. Box 17011, Doornfontein; amulaba@uj.ac.za.

1. Introduction

The economy of South Africa has been heavily dependent on the minerals and mining sector for over a century. South Africa is well endowed with mineral deposits and is has been a leading producer of gold, platinum group metals (PGMs), chromium and vanadium. It also produces aluminium, diamonds, iron ore, manganese, coal, titanium, and zirconium. The mineral wealth of the country is estimated in the region of US$2.5 trillion (Citi Bank, 2011). The sector however still faces a number of challenges even though it still has mineral reserves to last another 30 years. These challenges have existed now since the early 2000's when mining companies have had to drastically reduce costs and closely monitor the utilization of the labour. This had to be done in order to remain competitive and ensure that mines run profitably to avoid shutting down (Neingo & Tholana, 2016)

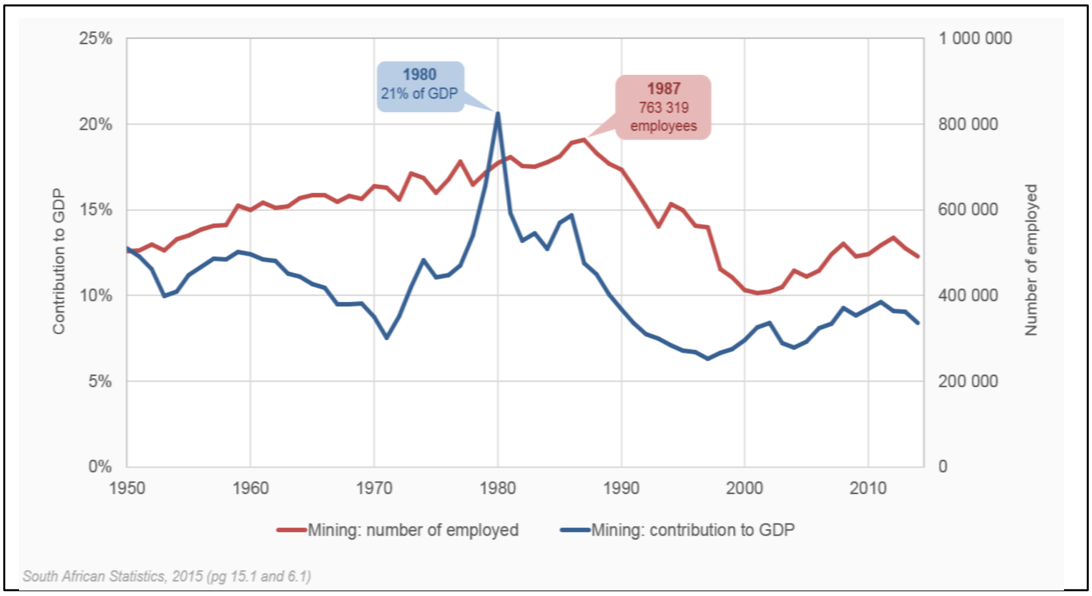

Fig. 1: Contribution of Mining to the South African GDP (StatsSA, 2015)

On the backdrop of a sector that is in recession, artisanal, small and junior mining have become very important players in the sector. The country has seen that this type of mining has a key role to play especially for the benefit of broad-based black empowerment (BEE) and communities that greatly need assistance and opportunities for job creation (McGill & Theart, 2006).

This paper will present an overview of the current junior and artisanal mining and small-scale processing landscape in South Africa. It will look at the challenges faced by the sector, opportunities for business ventures based on mineral commodity types available and the need for entrepreneurship and innovation to overcome barriers and succeed in what can be deemed a very risky and competitive environment.

2. Junior Mining

There are a few variations of exactly what a junior miner or junior mining is but the most appropriate definition is an exploration company that is constantly looking for potential unexploited or existing mineral deposits. Those deposits containing gold, silver, uranium and other types of precious minerals are usually targeted. The rationale behind this is that there is an opportunity to find large deposits of minerals that could result in the set-up of a large mining and processing operation.

Junior Mining has three categories. In South Africa it is estimated that there are currently about 200 junior and emerging mining companies registered as opposed to Canada that has about 1150 (Mining Review Africa Issue 5, 2019). These are companies that look at the areas of exploration, development and mining within the mineral value chain. The staff that start-up junior mining companies include prospectors, geologists, engineers and very importantly "mining entrepreneurs". Many of these people enter the venture with their own capital and funds and are also highly skilled individuals. The idea is to maintain lower overhead and operating costs so that one can earn a much higher return on investment (ROI). There is however huge amount of risk involved in junior mining and this risk varies depending on the type of project and the stage along the mineral value chain. Commodities currently investigated by junior miners include gold, nickel, titanium, tin, vanadium, cobalt, copper, bauxite, and coking coal (Mining Review Africa, 2018). The figure below shows the success rate of junior mining ventures where is certain instances only 1 in 1000 mineral deposits will lead to a successfully (0.1%) operating and producing mining operation.

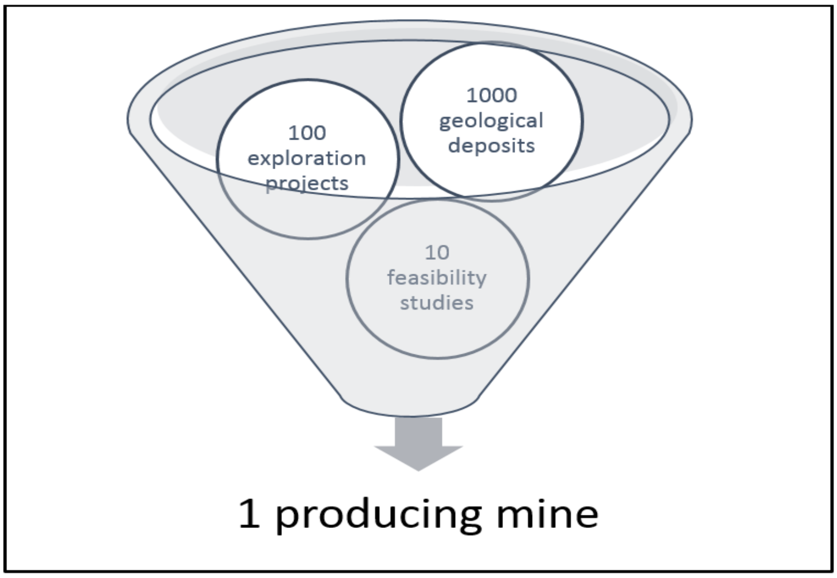

Fig. 2: Risk taken and success rate during Junior Mining Ventures. Data taken from (Mining Review Africa, 2018)

Junior mining companies face several threats and challenges. Competition from other junior mining companies is the first major threat. These companies focus on specific commodities and have employees that are very experienced in this field. Innovation and technology improvements have made it easier during exploration stages to determine if projects will have a better rate of success hence there is higher entrance of competitors. The barrier for entry into junior mining is low but access to finance and suitable investors is the second challenge (Forster, 2005).

In South Africa there are limited investment funds available for junior mining ventures (Mothomogolo, 2012). As South Africa is still a development state there are limitations in terms of GDP and hence the investment budgets available for new mining operations. Funders take a number of criteria into consideration when evaluating projects and these include: mineral commodity type, location, state within the mineral value chain and project team (Eksteen, 2006).

The third challenge faced is that of contract mining. The management and daily operations of a mine is outsourced to contractors due to the unavailability of this type of expertise within the project team. The threat posed by contract mining is the loss of intellectual property and also the possibility of costs escalating. Work is some instance must be redone and if one changes contractors then the previous knowledge is lost (Rupprecht, 2015).

3. Artisanal and Small-Scale Mining (ASM)

In South Africa ASM plays an important role especially in a country where job opportunities are few. For many this type of mining is a means of enrichment and livelihood. There are however a number of negative perceptions associated with ASM and these include health, safety hazards and damage to the environment. ASM is most of the time associated with informal and illegal mining especially in communities and rural areas of the country (CASM, 2004).

ASM operations can be described as either semi-industrial or fully industrial. For the later which is usually associated with regulated small-scale mining, the level of mechanization (technology or equipment used), operational structure and degree of compliance as compared to international standards is advanced. These types of operations are predominantly funded and managed by business owners and stakeholders from countries that are themselves industrialized. They produce products that are niche even though in small quantities but utilise high grade mineral deposits. These require complex extraction and concentration techniques. This scenario tends to be found in countries with a positive investment climate and due to this, these types of operations generate fewer problems (social, environmental and operational). The rest of the small-scale mining community then look to these as positive examples (Hentschel, Hruschka, & Priester, 2003).

South Africa has placed huge emphasis on growing the small business sector as this is a means to stimulate the economy and create much needed employment. The mining sector has indicated previously is in a decline which has resulted in the prices of certain minerals dropping which has resulted in the closure of large-scale mines. Cost containment is one of the key factors in large mining operations and the improved management of small-scale mines could prove to be far more economically viable that larger ones. Small-scale mines have the potential to contribute to both local and global mineral production. In South Africa the mining and processing gold, diamonds, coal and industrial minerals on a small-scale poses several opportunities (South African Government, 1998).

The establishment of the Minerals and Petroleum Resources Development Act (MPRDA) in 2002 was a major shift for the mining sector in the country and a mechanism to regulate, promote and support those that wished to venture into small-scale mining. The Department of Mineral Resources (DMR) set-up a dedicated directorate to assist the sector and to also deal with some of the challenges faced. The department has grouped both the artisanal and small-scale mining sector into a collective called "small-scale mining". The major challenge is ensuring that these operations are all legalised rather than informal and that they comply with all relevant legislation (Department of Mineral Resources, 2015).

The collective called "small-scale mining" contains the following:

- New entrants – artisanal mining;
- Formal mining - sub-optimal operations;
- Entrepreneurs – businesses that have upfront capital.

Small-scale mining operations are spread across the country and they occur in all nine provinces in South Africa. These activities are predominantly conducted in the rural parts of the country but mineral availability is a key determining factor (Mahlatsi, et al., 2011).

Table 1: Mineral commodities exploited by Small Scale Miners in South Africa (Mahlatsi, et al., 2011)

Category	Commodity Type	Location
Precious minerals	Gold	Gauteng, North West, Mpumalanga
	Diamonds	Northern Cape, North West, Free State
Semi-precious	Tiger's eye, rose quartz, amethyst, feldspar, jasper	Northern Cape
Energy minerals	Coal	Mpumalanga, KwaZulu Natal
Industrial Minerals	Granite, sandstone, slate, aggregate, clay, gypsum etc.	All nine provinces

The MPRDA regulates the acquisition of rights to conduct reconnaissance, prospecting and mining. Mine health and safety is governed by Act 29 of the 1996 Mine Health and Safety Act. This act ensures that the mine owner is fully responsible for health, safety, training and the identification of all hazards within the operation.

4. Opportunities for selected mineral commodities

4.1 Copper and Silver

Lerama Resources is a junior mining exploration company that has two projects in the exploration phase within the Bushveld Complex. They have a vision to become a leading producer of small polymetallic base-precious metals. They are currently running the Boschhoek Copper project that is situated in Marble Hall within the Limpopo Province. The drilling work done thus far indicates a estimated resource at a 0.35% Cu cut-off grade of 5000 tons of 0.52% Copper for 26000 tons of contained copper metal. This also includes 1300 tons of heap leachable material (on surface) of 6600 tons of copper metal. This occurrence has been known for several years but has never been mined (Joburg Indaba, 2019).

A second project called the Albert Silver Mine Project is being run near Bronkhorstspruit in Mpumalanga Province. The drilling programme has indicated grades of 2% Cu, 150g/t Ag and 500ppm U in certain portions of the small underground operation. Lerama will continue to evaluate other projects in the Bushveld Complex. The objective of the exploration work is to prove the existence of economically viable and environmentally safe small mines which will add to the resource inventory of the country. This will then in turn create employment opportunities (Joburg Indaba, 2019).

4.2 Coal

In South Africa the entry requirements to become a supplier of coal to Eskom is very stringent. The research done by (Mahumapelo, 2015) found that the samples analysed from a number of small-scale coal mines within the country did not meet the specification of Eskom. It was also found that it would not be economically feasible to upgrade the coal further using existing processes.

For small-scale operators the opportunity that does exist is the briquetting of the coal to produce lumps or briquettes that can be sold for steam generation in boilers, heating and drying processes. The coal briquettes essentially replace the need for wood or liquid fuel. The process for upgrading the low calorific value coal to briquettes has been in existence since the 1800s and there have been several refinements since then. The process involves the compacting the coal into strong, homogeneous lumps using readily available equipment and technology. There are further options to produce briquettes with or with-out binder depending on the end use, cost and economics of the process (Berkowitz, 1979).

4.3 Semi-precious minerals

The Northern Cape Province is amongst the provinces in South Africa that houses substantial amounts of mineral resources. The province is well endowed with an abundance of gem quality minerals. These include tiger’s eye, sugilite, rose quartz, jasper, amethyst, amazonite, tourmaline and topaz deposits. These deposits are exploited on an artisanal and small-scale mining level, and hence benefits are not yet fully realised. The majority of the tigers eye mined leaves South Africa in a raw form and is sent abroad for further beneficiation. From the quarry, the good stones are separated according to their quality. The miners use colour and hardness to group the stones. Once that is completed, the rocks are packaged in sacks for selling. Currently no value is added to the run-of-mine (Mintek, 2011).

With its abundant resources in semi-precious gemstones together with the world’s economic important tiger’s eye resources, the Northern Cape Province is poised to have a significant competitive advantage in the growth development of semi-precious gemstones mining, processing and the manufacturing industry. Up to this point, the semi-precious gemstone industry in the Northern Cape has been unable to develop an internationally competitive industry, either in the field of lapidary work or even in other forms of manufacturing. It is known that the main catalyst for growth in the semi-precious gemstone industry is considering all the value chain segments as part of a production system which requires improvement at each and every stage in order to achieve sustainable economic growth (Mintek, 2011).

5. Conclusion

The decline of the South African mining industry has continued for many decades. Mining has been the backbone of the economy and has contributed significantly to the GDP. Considering this and with about 30 years of mineral resources still available for exploitation; innovation and entrepreneurship (which involves risk) is required to resuscitate the mining sector. Artisanal, small-scale and junior mining hence has a major role to play going forward in order to steer the industry in a new direction. Cost containment is one of the key factors in large mining operations and the improved management of small-scale mines could prove to be far more economically viable that larger ones. The junior mining sector faces several challenges which include access to appropriate technology, finance, regulation and skills all of which can be overcome with increased government support. Opportunities have already been identified in commodities such as copper, silver, coal and semi-precious gemstones to have the potential to contribute significantly to both local and global mineral production.

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Performance Analysis of Radio Resource Allocation in MIMO LTE

Tozgani Fainess Mbale[1], Charles S Lubobya[2], James Nkweku Nkrumah Nyarko[3]

Abstract

This paper investigates the effect of spectral efficiency as the number of service antenna and number of users in Multiple-input Multiple-output (MIMO) long term evolution (LTE) network increases. The performance metrics are the three channel estimators namely: Zero Forcing (ZF), Minimum Mean Square Error (MMSE) and Maximal Ratio Combining (MRC).

LTE is an evolution upgrade of 3G systems which makes use of MIMO antennas. LTE network delivers large data rates, provides voice, data and video calls at high speeds. MIMO has attracted much attention both in industry and academia due to its high data rate, high-spectrum efficiency and has shown the ability to increase data rate and improve reliability. Working with a 2X2 MIMO antenna or more in LTE can increase wireless channel capacity without the need for additional power or spectrum but also doesn't always equal better performance of the system in scattering environments. This paper focuses on a persistent challenge in spectral and energy efficiency in LTE systems. A quantitative research approach using MATLAB simulation was used to generate results.

Results show that the increase in the number of antennas and users improves the spectral efficiency and that MMSE shows superior performance than ZF and MRC under similar conditions. MMSE is 9 bits/Hz/cell more than MR for 65 service antennas and 113 bits/Hz/cell for 37 users.

Keywords: Spectral efficiency, Energy efficiency, Minimum Mean Square Error (MMSE), Zero Forcing (ZF), Maximal Ratio Combining (MRC)

1. Introduction

Long term evolution (LTE) just like electricity has become a necessity and is at the centre of modern society which also is an evolutionary step beyond the 3G in mobile wireless communication(Archana, 2015).It is mainly influenced by high data rates, minimum delay and the capacity due to scalable bandwidth and its flexibility (Aliyu, Universiti and Maijama, 2013).

[1] University of Zambia; P.O Box 3237; +260-211-290979; tozganimbale@gmail.com.
[2] University of Zambia; P.O Box 3237; +260-211-290979; cslubobya@unza.zm.
[3]Northwesten Polytechnical University;127Youyi Xilu,Xian;+868509242212;jnyarko@mail.nwpu.edu.cn

LTE offers many features with flexibilities in terms of deployment options and potential service offerings (Aliyu, Universiti and Maijama, 2013) 4G LTE is a rapid remote correspondence standard which builds framework's ability and information rates and created by the third generation project partnership (3GPP). It satisfies the point of accomplishing worldwide broadband portable interchanges (Dewangan *et al.*, 2017). Fig. 1 shows the network architecture of LTE.

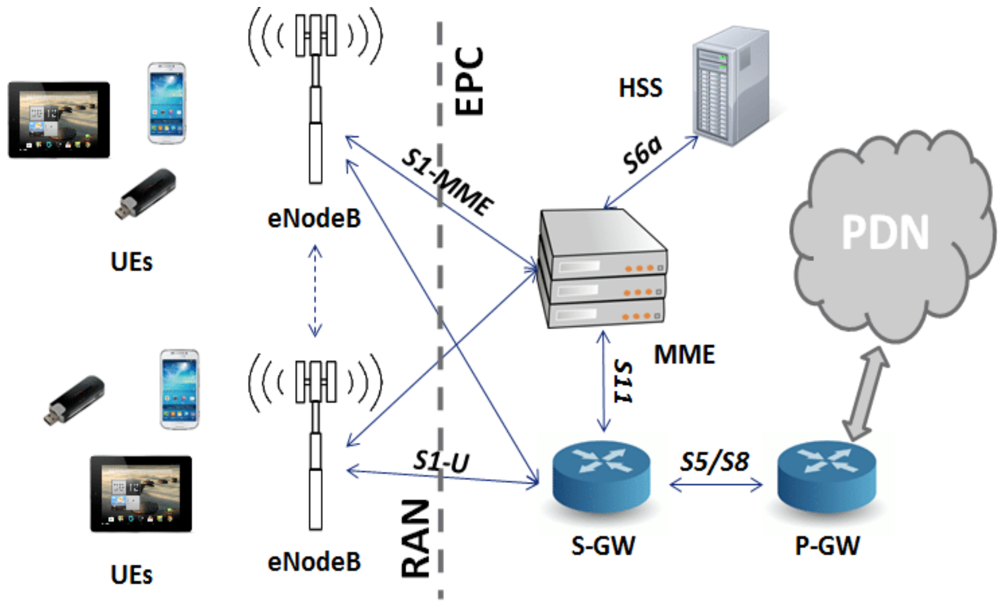

Fig. 1: LTE Network Architecture (Jermyn *et al.*, 2015)

The radio access network also known as the E-UTRAN (Evolved Universal Terrestrial Radio Access Network) is the interface between the subscribers and the core network, this access network grants the subscribers access to connect to the network via the antennas. The LTE access structure comprises of the mobile subscriber (MS) which is an LTE compatible phone which attaches itself to the antenna via a wireless signal connection between both entities. The antenna is physically attached to the eNodeB (evolved- NodeB), which serves as a base transceiver station. The major function of the eNodeB is to receive all signals (voice, data and control signals), modulate and transfer them to the core network.

The radio access network which is also known as Evolved-Universal Terrestrial Radio Access Network (E-UTRAN),which consists of User equipment (UE) and macrocells BSs. Using the S1 interface ,connection between PC and E-UTRAN is established between S-GW and macroBSs. X2 interface is introduced to permit interconnections among macroBSs for direct signaling. In EPC,S-GW functions as local mobility anchor point for inter macroBSs handover and inter 3GPP mobility and also for handling of IP packet transfer between the EPC and the associated UEs(Archana, 2015).

Generally 4G LTE deployments require two antennas on the mobile side thus LTE cellular handsets and devices inside other equipment provide dual antenna designs and operators assume this capability in their LTE service deployments. This paper focuses on spectral efficiency in comparison to the performance of three channel equalization techniques as number of service antennas and users increase.

2. Related Work

In (Tang *et al.*, 2014), it was proposed that the resource efficiency was used as a new system metric for EE-SE tradeoff in OFDMA based cellular network and the analyzed the properties of the proposed RE provide the optimal and solution. A major finding was that by using the proposed RE, significant amount of bandwidth can be saved with a slight increase in energy consumption. A similar conclusion can also be drawn on energy saving by bandwidth expansion. This shows that the proposed approach can improve the efficient use of available network resources. Three key performance metrics such as the spectral efficiency, the cell throughput and the energy efficiency were discussed in (Zhu *et al.*, 2014) of the proposed hybrid cellular structure which showed that it can significantly improve the spectral and energy performance. The results showed that the hybrid cellular structure can achieve higher spectral efficiency and cell throughput, proposed hybrid cellular structure and the energy efficiency is also increased slightly.

There are two familiar equalizers are verified by (Ibrahim and Jubara, 2016), the Zero forcing (ZF) and the Minimum Mean Square Error (MMSE),. In addition to the Soft Sphere Decoding (SSD) equalizer which is originally added for the LTE in MIMO transmission mode 3. From the simulation it was realized that the MMSE has better results than the ZF equalizer in case of single antennas configuration SISO and in MIMO, but the ZF equalization has the advantage in case of SIMO, in MIMO case the three equalizers are compared and the results shows that the SSD equalizer has the advantage over the ZF and the MMSE in LTE transmission mode three (3).

Furthermore, a low-complexity suboptimal algorithm based on uniform power allocation scheme was proposed in (Wu *et al.*, 2013) to reduce the complexity. Numerical results confirm the analytical findings and demonstrate the effectiveness of the proposed resource allocation schemes for efficient resource usage. Numerical results showed that significant power saving and energy efficiency increase can be achieved using the increases. The authors in (Fang *et al.*, 2015) Investigated and concluded that: Massive MIMO technology can effectively improve the spectrum efficiency and energy efficiency at the sacrifice of consume a lot of energy and deployment of antenna equipment. Since the spectral efficiency get the fastest growing this time, so select an appropriate number of the antenna can not only get high spectral efficiency, energy efficiency can also obtain good results. Channel sate information estimation has great potential in improving the system spectrum efficiency and energy efficiency. A number of combining techniques were compared on flat Rayleigh fading channels. It was found that joint detection (JD) performs well but at the expense of higher computational complexity; while the performance MMSE processing is sub-optimal but easier to implement than JD. The authors in (Shukla and Tharani, 2017) had a task of mitigating the effects of inter symbol interference (ISI) is accomplished by employing equalization techniques at the receiver side. When MMSE and ML techniques were used at the receiver, SNR values obtained for Rayleigh channel were much better than that obtained for Rician channel for the same value of BER.

3. Radio Resource Allocation in MIMO LTE

The purpose of radio resource management (RRM) is to ensure the efficient use of the available radio resources and to provide mechanisms that enable LTE to meet radio resource related requirements. In particular, RRM in LTE provides means to manage (e.g. assign, re- assign and release) radio resources taking into account single and multi-cell aspects (Jan and Ellenbeck, 2015) overcome long term evolution (LTE) challenges such as resource allocation, which is one of the most important research topics. In fact, an efficient design of resource allocation schemes is the key to higher performance. However,(Khasdev and Hirwe, 2016) It has a very flexible radio interface, and its core network is called System Architecture Evolution (SAE) or Evolved Packed Core (EPC) (Mousavi *et al.*, 2019). Mobile communication technologies are often divided into generations (Reyhanimasoleh, 2013) with 1G being the analog mobile radio systems of the 1980s, 2G the first digital mobile systems, and 3G the first mobile systems handling broadband data. The next generation, 4G or Long-Term Evolution (LTE), provides even better support for mobile broadband (Dahlman and Sko, no date).

MIMO technology is a wireless technology that uses multiple transmitters and receivers to transfer more data at the same time shown in Fig.2.

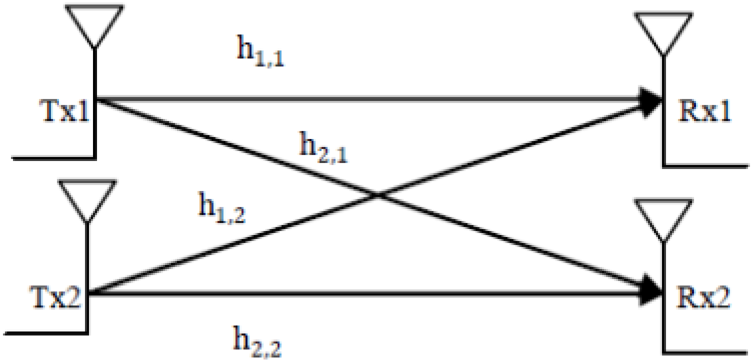

Fig.2: 2 transmit 2 receive (2 x 2) MIMO channel (Ahmed, Uddin and Rahaman, 2014)

MIMO technology takes advantage of a radio-wave phenomenon called multipath where transmitted information bounces off walls, ceilings, and other objects, reaching the receiving antenna multiple times via different angles and at slightly different times (Ahmed, Uddin and Rahaman, 2014). The base station and the users plays an important role in increasing the energy efficiency, namely, the energy efficiency is increasing with the distance decreasing and the spectral efficiency increasing (Ying *et al.*, 2012).
Energy efficiency is becoming increasingly important for the future radio access networks due to the climate change and the operator’s increasing operational cost (Xu, Qiu and Yu, no date). Unfortunately, the improvement in battery technology is much slow, leading to an exponentially increasing gap between the available and required battery capacity.Hence, design of advanced management schemes recently has focused on maximizing energy efficiency. It showed that although MIMO techniques have been shown to be effective in improving capacity and spectral efficiency (SE) of wireless systems spectral efficiency, i.e., the amount of error-free bits per second per Hertz (bps/Hz)(Casta, no date), energy consumption also increases thus the spectral and energy efficiency can be significantly improved (Yingchao *et al.*, 2015). It is also found that the distance between the base station and the users plays an important role in increasing the energy efficiency, namely, the energy efficiency is increasing with the distance decreasing. It is also found that we can change the number of antenna arrays at BS to achieve energy-efficient maximization, meanwhile, the distance between the base station and the users plays an important role in increasing the energy efficiency, namely, the energy efficiency is increasing with the distance decreasing (Ying *et al.*, 2012). Spectral efficiency (SE) and energy efficiency (EE) are the main metrics for designing wireless networks. Rather than focusing on either SE or EE

separately, recent works have focused on the relationship between EE and SE and provided good insights into the joint EE-SE tradeoff (Tang *et al.*, 2014). The channel estimator estimates the channel impulse response for each burst separately from the well-known transmitted bits and corresponding received samples (Venkateswarlu and Nagendra, 2014).

Zero Forcing Equalizer refers to a form of linear equalization algorithm used in communication systems which applies the inverse of the frequency response of the channel. The Zero-Forcing Equalizer applies the inverse of the channel frequency response to the received signal, to restore the signal after the channel. It has many useful applications. The zero-forcing equalizer removes all ISI, and is ideal when the channel is noiseless. However, when the channel is noisy, the zero-forcing equalizer will amplify the noise greatly at frequencies ***f*** where the channel response ($j2\pi f$) has a small magnitude (i.e. near zeroes of the channel) in the attempt to invert the channel completely (Ahmed, Uddin and Rahaman, 2014).

The MMSE is an equalization technique which maximizes the signal to distortion ratio at its output within the constraints of the equalizer filter length (Basak, 2015). Minimum Mean Square Equalizer (MMSE) is more robust equalizer where the minimization of the mean square error (MSE) between the desired equalizer output and the actual equalizer output is the key approach. The performance of MMSE equalizer is better because it is not able to eliminate the ISI totally but also able to minimize the total noise power (Kashyap and Bagga, 2014).

Maximal-Ratio Combining (MRC) is a method of diversity combining in which the signals from each channel are added together and the gain of each channel is made proportional to the RMS value of signal and inversely proportional to the mean square noise level in that channel. MRC algorithm greatly improves the performance of MIMO system over FS channels and has better performance than ZF and MMSE based receivers (Shukla and Tharani, 2017).

4. Methodology

The relationship between the spectral efficiency, the number of service antennas and number of users are considered using the three channel estimators; Zero Forcing (ZF), Minimum Mean Square Error (MMSE) and Maximal Ratio Combining (MRC).

The objective is to investigate the performance of the three equalisation techniques for application in MIMO system of wireless communication. The ZF equalizer thus neglects the effect of noise altogether, and is not often for wireless links. However, it performs well for static channels with high SNR. The more balanced linear equalizer is the Minimum Mean Square Error Equalizer, which is not eliminate ISI completely but instead minimizes the total power of the noise and ISI. Table 1, shows the simulation parameters used in the investigations.

Table 1: Simulation Parameters

Simulation Parameters	**Values**
Number of service antennas (M)	4-64
Number of users (N)	37
Number of subcarriers	1200
Number of antennas per user	2
Coherence block length	100
Power per user	-5dB

The simulation is carried out using MATLAB software to compute spectral efficiency against the number of users and service antennas.

5. Results and Analysis

Fig. 3 shows a steady exponential increase for the three estimators in spectral efficiency as the number of service antennas increases. Up to ten antennas, MMSE has the highest spectral efficiency of 12bits per Hertz per cell followed by MR and ZF which both had eight bits per hertz per cell spectral efficiency value. However, below ten service antennas, the performance of ZF was below 5bits/Hz/cell. Another interesting observation is that beyond twenty service antennas both MMSE and ZF performed better than MR averaging between 24bits/Hz/cell to 33bits/Hz/cell. The implications of these results are that below ten service antennas ZR performs quite poorly compared the MMSE and MR and that beyond ten service antennas MMSE and ZF performs better.

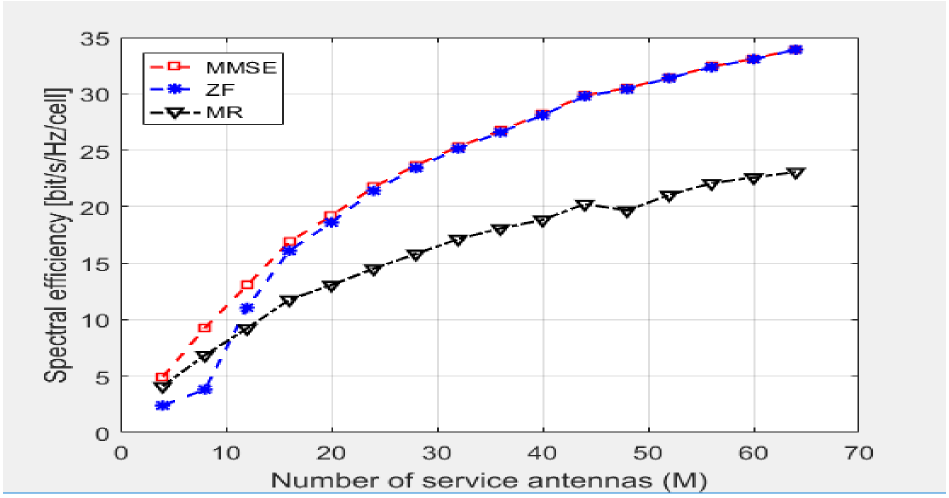

Fig. 3: Simulation results for spectral efficiency against number of service antennas of ZF, MMSE and MR

Fig.4 shows the effect of spectral efficiency as the number of users increase. Results show that irrespective of the number of users, MMSE and ZF increases gradually as compared to MR which had a moderate increase.

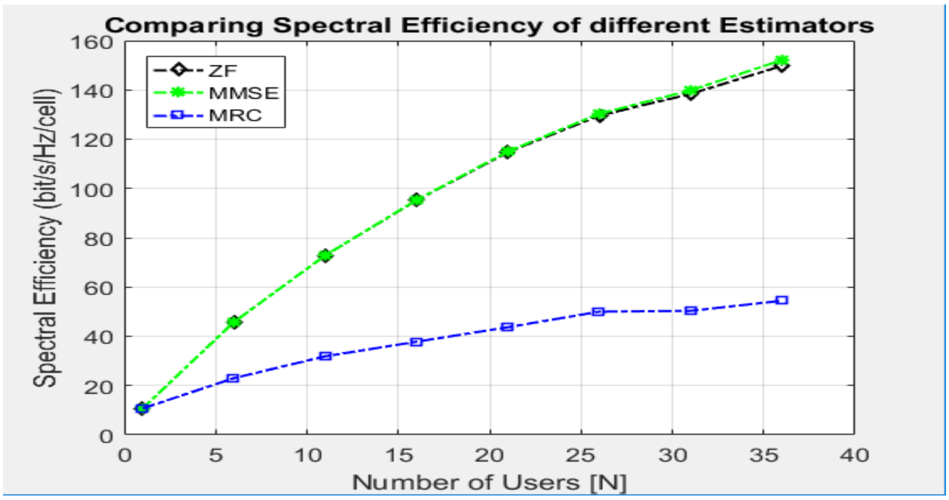

Fig. 4: Simulation results for spectral efficiency against number of users of ZF, MMSE and MR

Both MMSE and ZF achieved a maximum of close 150 bits/Hz/cell at 37 users. For the same number of users MR only achieved a pantry spectral efficiency of 57 bits/Hz/Cell. This means that MR performance has a marginal increases as number of users increase.

6. Conclusion

This paper investigated the effect of spectral efficiency as the number of service antennas and users increases in MIMO LTE specifically focusing on the three channel estimators performance ; ZF,MMSE and MRC. The simulation result shows that MMSE and MR performed better than ZF under similar conditions but MMSE exceed MR. From the results we can conclude that the multiple antennas increase data rates through multiplexing or diversity. Furthermore, it can be concluded that from the three considered equalising techniques, MMSE is the best for application in MIMO LTE systems.

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Codification: Engineering Practice in the Globalised Environment

Patrick J. Kawinga[1]

Abstract

There is significant need for us to operate in an environment with standards which every generation can live up to and improve on within the global setting of this world. Currently we have the GENERAL SPECIFICATION interim metric edition for the government of the Republic of Zambia which was updated in February 1973. Amendments and additional clauses have been minimal with the last one being officially done in June 1980.

We need to focus our attention on the defining organs which interpret our standards namely: -

A. Director of Buildings DB
B. British Standard BS
C. British Standard Code of Practice BSCP
D. Zambian Standard ZS

Should we retain the traditional trades arrangement of information with which both the Design and Construction sectors of the industry are familiar?

In anticipation, we should adopt methods that will generate improved environmental standards.

Do we have the right people with integrity to manage our standards? The quality of works is largely dependent on the right people. Continuous training will give the right people an understanding of the quality of works expected. This impact relates to the level of operation in which our environmental standards can be adhered to.

1. Standardization

There is significant need for us to operate in an environment with standards which every generation can live up to and improve on within the global setting of this world. Currently we have the GENERAL SPECIFICATION interim metric edition for the government of the Republic of Zambia which was updated in February 1973. Amendments and additional clauses have been minimal with the last one being officially done in June 1980.

We need to focus our attention on the defining organs which interpret our standards namely:

A. Director of Buildings DB, Director of Public infrastructure, Director of Preventive Maintenance

The custodian of all government infrastructure and heads the consulting entity aspect of the government republic of Zambia. The director of public infrastructure needs to set a standard for information security for engineers at an international standard to provide guidelines to support the implementation of engineering security information in engineering organizations. The

[1] Plot # 33011 Kafue Rd, P.O. Box 30289, Lusaka, Zambia. Telephone +260-211-235725; Cell +260-977-847410; Email: Patrick@jackkawinga.com; website: www.jackkawinga.com

director should also create a panel to award an engineering mark(ZmQ) to products that meet its quality standards. Engineering organizations may apply for the mark(ZmQ) to certify an engineering product meeting the standard including standards such as cables used for power supply in shielded form. Note the relations and administration of the **Engineering section** of the Director of Public infrastructure performing the following specific functions: -

1. Preparation of electrical, structural, water, drainage drawings and engineering designs to meet client requirements and ensure adherence to **standards,** specifications, statutory and design requirements.
2. Preparation of engineering drawings to facilitate tender documentation and construction.
3. Supervising the construction of Public infrastructure to ensure adherence to set quality and safety standards.
4. Manage construction contracts to ensure adherence to contractual obligations.

These specific functions need to be verified by the head who is the Director of Public infrastructure by confirming the documentation being done. It should never be a document of copy and paste. This has continued to be the practice of the sectional engineers. The Government of Zambia has put in place the necessary **standards** which the sectional engineers have continued to ignore, so how does the system function if the regulations are not being adhered to.

Case situation

The mechanical engineering bill of quantities for the current building housing the National Prosecution Authority did not have outdoor condensing units which was a significant amount of money needed to do the works and the team had to go back and seek authority from ZPPA to include the missing items and amount required to complete the works. This should never happen if the documentation is done according to the laid ***standard*** *of the government of Republic of Zambia. Who takes responsibility for the time and cost of this situation????*

B. British Standard BS

It has produced standards across a wide variety of industrial sectors. Its codes of practice and specifications cover management and technical subjects ranging from business continuity management to quality requirements. The BS certification is phased as 'CE' which means European Conformity and is a declaration by the manufacture that the product meets the requirements of the applicable European directive. It's a European directive and we should learn from it and create an equivalent applicable standard for CODIFICATION (ZmQ).

C. British Standard Code of Practice BSCP

The code of practice provides guidance in the design of new buildings to make them more accessible. Note the four levels of standardization: -

- compatibility
- interchangeability
- Commonality
- reference

These processes create: -

- compatibility
- similarity
- measurement

- symbol

The code of practice with the standardization emphasis can create a mutual level of operation in the engineering organizations to maintain the quality of products required for **CODIFICATION**

D. Zambian Standard ZS (ZMQ)

National Technical Regulation

An Act to provide for the principles of , and a framework for, technical regulation that are compliant with best practice and regional and international obligations to which Zambia is a party; establish the Department of Technical Regulation in the Ministry responsible for trade; provide for the development and implementation of technical regulation for public safety and health, consumer protection and environmental protection; provide technical guidance to regulatory agencies on the development, implementation, administration and review of technical regulations; domesticate the international and regional agreements on technical barriers to trade in order to ensure that regulations, standards, testing and certification procedures do not create unnecessary obstacles to trade but implement legitimate policy objectives and measures; and provide for matters connected with, or incidental, to the foregoing.

A technical regulation that is developed implemented or maintained by a regulatory agency shall comply with the requirements of this Act in its application. The provisions of this Act do not apply to a law, standard or technical regulation relating to national security the disclosure of which is prejudicial to the interest of the state.

The mandatory requirements for a commodity or service, and the method and scheme for assessing its conformity, which is contained in a technical regulation are exhaustive, have direct effect throughout the Republic and shall be amended by the introduction of an amendment or supplement to the technical regulation.

A technical regulation shall be developed, implemented, and maintained in accordance with the following principles

1. A technical regulation shall not be prepared, adopted, or applied to create an unnecessary obstacle to international trade, but to facilitate the trade;
2. A technical regulation shall be developed and implemented where it is necessary for the protection of human health or safety, animal or plant life or health, the prevention of deceptive practices and environmental protection;
3. Technical regulation shall comply with the requirements of international and regional agreements to which Zambia is a party;
4. Technical regulation shall comply with the national technical regulation framework, the functions of regulatory agencies and conformity assessment systems and sanctions;
5. Technical regulation shall consider the national economic interest, related processing technology or intended end-uses of products and the level of scientific and technical development;
6. The requirements of any technical regulations shall not create barriers to entrepreneurial activities to a greater degree than is minimally necessary for achieving its purposes;
7. Technical regulation shall be applied in a non-discriminatory and uniform manner to imported and locally produced commodities and services;

8. Conformity assessment systems and technical regulation shall not serve as disguised protection against imported commoditites and services;

9. Conformity assessment systems governing imported products and services shall not be less favorable than those accorded to domestic products and services;

10. International, regional, and national standards and norms, where available and applicable, shall be used as the basis for technical regulation;

11. The national quality infrastructure shall be used and suppliers shall choose their conformity assessment service providers who are technically competent and acceptable to, or so designated by, regulatory agencies;

12. Regulatory agencies shall not, as far as is practicable and consistent with international practice, provide or participate in providing conformity assessment for commodities or services that they are mandated to inspect and control;

13. Accreditation, certification, and inspection bodies shall be independent from suppliers; and

14. Technical regulations shall not be maintained if the circumstances or objectives giving rise to their adoption no longer exist or if the circumstances or objective can be addressed in a less trade-restrictive manner.

In this Act, unless the context otherwise requires-

"Zambian National Standard" means a standard approved by the Bureau under the Standards Act 2017.

"ISO" means the International Organization for Standardization.

Zambian standards organization is the **Zambia Bureau of Standards (ZABS)** specialized in the field of standardization, standard formulation, quality control assurance, import and export quality inspections, certification, and removal of technical barriers to trade. It was established under an ACT of Parliament, the Standards ACT, CAP 416 of 1994 of the laws of Zambia for the preparation promulgation of Zambian Standards.

It provides for standards certification to industry in Zambia.

Certification refers to confirmation or an attestation that products, processes, or systems of an organization meet the requirements of a standard or specification. It provides assurance that products, services, and processes meet national or international standards/specifications. This is done through a review, assessment, or audit. The bureau offers two types of certification schemes namely Product Certification and systems certification.

Product Certification

Product certification involves the issuance of a certificate or mark(ZmQ) to demonstrate that a specific product meets a defined set of requirements such as safety, fitness for use and/or interchangeability characteristics for that product, usually specified in a standard. It promises guaranteed quality to the consumer and acceptable manufacturing practices to the manufacturer. The product certification mark(ZmQ) is normally found on the product or its packaging and may also appear on a certificate issued by the product certification body. The mark (ZmQ) carries a reference to the number or name of the relevant product standard against which the product has been certified.

System Certification

A MANAGEMENT System is a company's structure for managing its processes and activities that transform inputs of resources into a product or service which meets the company's objectives while satisfying the customers' quality requirements, complying with regulations meeting environmental and public health objectives.

2. Ethics

Moral principles that govern a person's behavior or the conducting of an activity, I would recommend that we adapt to the world's largest technical professional organization for the advancement of technology code of ethics CODIFICATION

The following is from the IEEE polices, section 7- professional Activities (Part A-IEEE Policies)

7.8 IEEE Code of Ethics

We, the members of the IEEE, in recognition of the importance of our technologies in affecting the quality of life throughout the world, and in accepting a personal obligation to our profession, its members, and the communities we serve, do hereby commit ourselves to the highest ethical and professional conduct and agree:

i. To hold paramount the safety, health, and welfare of the public, to strive to comply with ethical design and sustainable development practices, and to disclose promptly factors that might endanger the public or the environment;

ii. To avoid real or perceived conflicts of interest whenever possible, and to disclose them to affected parties when they do exist;

iii. To be honest and realistic in stating claims or estimates based on available data;

iv. To reject bribery in all its forms;

v. To improve the understanding by individuals and society of the capabilities and societal implications of conventional and emerging technologies, including intelligent systems;

vi. To maintain and improve our technical competence and to undertake technological tasks for others only if qualified by training or experience, or after full disclosure of pertinent limitations;

vii. To seek, accept, and offer honest criticism of technical work, to acknowledge and correct errors, and to credit properly the contributions of others;

viii. To treat fairly all persons and to not engage in acts of discrimination based on race, religion, gender, disability, age, national origin, sexual orientation, gender identity, or gender expression;

ix. To avoid injuring others, their property, reputation, or employment by false or malicious action;

x. To assist colleagues and co-workers in their professional development and to support them in following this code of ethics.

IEEE (Institute of Electrical and Electronics Engineers) is the world's largest technical professional organization dedicated to advancing technology for the benefit of humanity.

3. Conclusion

Should we retain the traditional trades arrangement of information with which both the Design and Construction sectors of the industry are familiar?

In anticipation, we should adopt methods that will generate improved environmental **standards.**

Do we have the right people with integrity to manage our **standards**? The quality of works is largely dependent on the right people. Continuous training will give the right people an understanding of the quality of works expected. This impact relates to the level of operation in which our environmental standards can be adhered to.

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The Importance of Project Governance and Controls on Infrastructure Projects

Michael Oabona Kgengwenyane[1]

Abstract

The governance of public sector infrastructure projects has become an important topic of interest in the project, program, and portfolio management literature during the last decade. Moreover, the lack of effective delivery of infrastructure projects with associated problems such as cost overruns, corruption, and malpractice have served to emphasize the importance of effective project governance and controls. Due to the multiple underlying risks and complexities, the governance of infrastructure programs constitutes a critical element in strategic planning in developing countries.

Today, it is becoming a central focus for policymakers seeking to ensure success in selecting, designing, and implementing government-sponsored programs for these types of projects. This paper elaborates on a series of checklists, rules of thumb and best practices in project governance and control required to avoid the repeated missteps that cause capital projects to fail.

Major shortcomings in the areas of decision-making, stakeholder management, role ambiguity, owners team support, project sponsor involvement, capital cost estimates, and project definition are discussed and approach to remedying these shortcomings presented.

Keywords: governance, public sector, controls, best practices, infrastructure projects

1. Introduction

Infrastructure or capital projects are investments of substantial company or state resources intended to develop, improve, or refurbish an asset that is expected to generate cash flows or deliver a service. Only 60 % of finished projects actually meet all objectives the project is complete and the asset was put to service. Infrastructure projects are by their nature high-risk, high-reward activities and are one of the most important drivers of organisational or government success yet they are also the hardest to manage. The figure below gives some insights as to project failure rates.

[1] Innolead Consulting; 15 Lagos Road, Rhodespark Lusaka; (+260) 211 251 034 / (+267) 390 9102; okgengwenyane@innolead.co.bw.

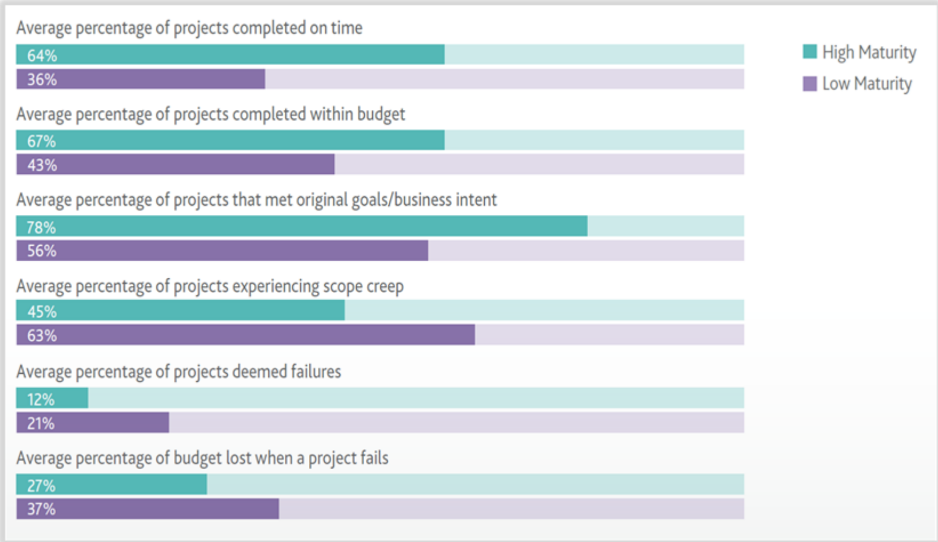

Fig. 1: Value Delivery Capability Maturity Leads to Greater Performance

Several reasons exist as to why effective delivery of these types of projects remains a challenge for governments worldwide. Firstly, accountability for capital projects typically ranks amongst the weakest areas for most nations. The relatively long period between decisions and benefits being realised compromises accountability. Secondly, the pressure for immediate results imposed by the voting electorate which in turn erodes capital efficiency. Lastly, the multi-functional nature of capital projects makes it easy for accountability to be shifted to other parties i.e. scapegoating.

The term 'governance' is derived from the Greek verb "Kubernao", which means "to steer". It is the "act of governing or directing the policies, management, and activities of an organization at the highest level, with the authority, credibility, and responsibility to do so" (Kanyane and Sausi 2015). In an international context, governance means the ways in which legitimate authority is used to cope with the country's social and economic resources for development (Meso et al. 2006). In contemporary project management literature, the project governance and controls have become an important topic for discussion, and organizations have used this approach to meet organizational goals and objectives.

Organizations initiate projects with the best of intentions to succeed, but due to governance and management issues, many projects fail. Traditionally, the outcomes of projects have been measured in terms of completing them within the constraints of scope, time, cost, and quality (PMI 2013). However, increasingly, assessments of projects are being expanded to governance, to include their ability to achieve strategic goals over considerable periods of time. An attribute of good governance is that it has the aptness to navigate the projects through different uncertainties and unexpected events. Effective governance is also imperative for public-private infrastructure development projects. Thus, failure of such large capital projects has highlighted the consequences of ineffective governance. Furthermore, in infrastructure projects, complexities and uncertainties are very common and the distinctiveness and individuality of infrastructure projects arise from their unique social and environmental requirements. Infrastructural needs are critical for the economic growth of developing countries. To achieve this, the effective governance of the infrastructure development projects has become a certain need and significant challenge, which defines the success of these projects.

Examples of challenges and complexities that have compromised the effective delivery of infrastructure projects have already been cited but this is by no means an exhaustive list. Major shortcomings in the areas of decision-making, lack of political will, owners team support, project sponsor involvement, capital cost estimates, and project definition also contribute to the low rate of project success.

This paper will elaborates on a series of rules of thumb and best practices in project governance and control required to avoid the repeated missteps that cause capital projects to fail.

2. Best Practices in Project Governance and Control

2.1 Effective Project Governance Structures

Project Governance encompasses the rules for project decision making and defines the roles and responsibilities of all Executives involved in a project. At the centre of project governance is the Project Sponsor. The Project Sponsor is the chief proponent or champion of the project and the single point of accountability for the value identified and delivered by the project. He is the force that advocates for a robust business case, clear barriers and fixes problems outside the control of the Project Manager.

The Project Steering Committee is also chaired by the Project Sponsor and staffed with Executives from the organisation that are major stakeholders in the project. The figure below is a basic example of a governance structure for a capital project.

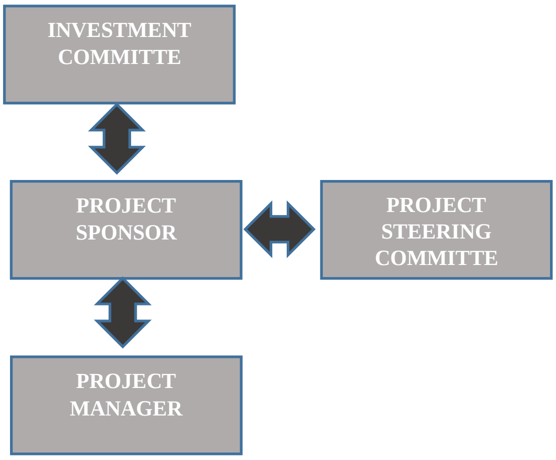

Fig. 2: Typical Project Governance Structure

The governance structure can be arranged in different ways and can be scaled up or down, depending on the size, nature and complexity of the project. Regardless of how it is configured, the governance structure has to provide a set of checks and balances that allows only business cases that are robust and effectively balance cost and benefit, risk and reward.

2.2 Implement Stage-Gates and Executive Control

The stage gates are the mechanisms for directing capital to the highest priority projects. With the stage-gate process, work on an opportunity or problem is not even allowed to start unless there is a consensus amongst executives that the identified business objective is something worth pursuing. Executives further control capital spending with the stage gates by only releasing the money needed to complete the next stage of the process. The purpose of funding only to the next gate is to ensure that gates are meaningful decision points for Executives.

Unfortunately weak gates are an endemic problem for the stage-gate process. The process will never work as well as it should if projects with weak or sub-optimal business cases are allowed to pass through the stage-gates.

Projects that adhere to the principles of a well-designed stage-gate process on average deliver the value expected at authorization. Those that do not, according to the Independent Project Assessors, lose about half the promised value.

“Using the stage-gate process effectively can shave off 25 % off the project lifecycle through better planning, reduced rework and superior risk management” (IPA)

2.3 Invest in Strong Owner Team

The role of the owner team is twofold. First, the owner team brings together the business expertise to fashion a project scope and strategy. Second, and most importantly, the owner team protects the best interests of the business by monitoring the activities of all 3rd party suppliers. Owner personnel take corrective action and give management early warning of deviations to the baseline project parameters.

Research by IPA has shown that robust owner teams produce capital assets that are higher quality and less expensive than owner teams that are understaffed or that have outsourced much of the owner team role to contractors. Further to this, they have established that capital projects with understaffed owner project teams relative to the benchmarks cost more than adequately projects by about 7 %. Well-staffed owner teams are also better at controlling project risks. IPA routinely reviews projects that have cost growth and schedule slip because the team is unable to manage the project. Projects in the developing world can overrun by as much as 30 – 60 % just because owner team was unable to effectively monitor contractor performance.

2.4 Employ Robust Project Controls

Project control includes the activities that track actual project performance against plan by collecting data, comparing to the plan, documenting the variance and ultimately using the data to recommend corrective action and develop forecast of the likely outcomes. Central to this process is the tracking of actual costs against estimated cost.

An effective controls system reduces project cost overruns and schedule slippage. The components of an effective Project Control framework are;

Planning and Scheduling, Cost Estimating, Scope Control, Cost Control
Schedule Control, Quality Control, Risk Management, Document Management,
Contract Management

A good project controls system is easy to understand and implement, easy to compare with applicable standards, and able to detect deviations early and feed progress reporting to facilitate timely intervention. Ultimately, a robust project controls framework gives an organisation the capability to improve project and programme success through improved performance management visibility and proactive response.

2.5 Political will

Public sector infrastructure projects are inherently political are heavily influenced by nuances of a countries political landscape. Project deadlines are often set on the basis of political debate rather than by well informed and realistic planning efforts. It is no coincidence that in an election year, the rate of spending on major, high profile capital projects tends to go up in most countries in an attempt to sway the electorate. In developing countries, political interference is a major hindrance for the smooth execution and delivery of infrastructure development projects.

The Pulse of the Profession, an authority in Project Management trends, indicates that 41% of under-performers stated that inadequate sponsor support was the primary cause for project failure. Within the public sector context, these Project Sponsors are typically Cabinet Ministers, Permanent Secretaries/Director Generals or Accounting Officers for the various state institutions. Given the complex, medium to long-term nature of large capital projects, success requires sustained political support from Government and partners (engineers and contractors).

2.6 Achieve a Strong Level of Project Definition

Historically, the costs and project risks from weak project definition are often underestimated. The quality of project definition at authorization is the best indicator of whether a project will come in on time and budget and be fit for purpose.

Projects with strong definition, on average, do not lose value from cost and schedule overruns or technical performance issues by the asset. In contrast, projects with weak project definition, on average, erode 25 % of the value expected at authorization and are much more vulnerable to being disaster projects with bad cost, schedule, and asset performance.

Executives ultimately determine what level of project definition a project achieves. They approve project strategies that will or will not allow a project team to complete the work needed to achieve strong definition. The trade-off being made is that the value gained by foregoing strong project definition in order to save time and/or money both exceeds the inefficiency and the risk associated with weak definition.

2.7 Develop Clear Objectives

Objectives describe what a business wants to accomplish with a project. They establish the criteria used to make all project decisions, and are used to measure the success of the project. Clear objectives are comprehensive, quantified, and prioritized. In addition, they also provide a coherent set of instructions to the project team on how to develop the project. Objectives will often start out as aspiration statements that are progressively refined into the quantitative targets i.e. Key performance Indicator (KPI's) used to measure performance.

3. Conclusion

The effective implementation of public sector development projects remains a challenge for the governing and implementing bodies for most countries in the developing world. Associated problems such as cost overruns, corruption, and malpractice have served to emphasize the importance of effective project governance and controls. The governance of infrastructure programs constitutes a critical element in strategic planning in developing countries and their successful delivery a vehicle for social upliftment and improvement of standards of living.

Major shortcomings in the areas of decision-making, stakeholder management, political will, owner team support, project sponsor involvement, unclear project objectives, and project definition have been elaborated on and best practice approaches to correcting them presented. What is abundantly clear, is that public sector infrastructure development projects need to invest in and adopt robust project governance and controls frameworks in order to be delivered successfully.

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Results from Independent Project Analysis (IPA) project database

Pulse of the Profession, 2018

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VoIP Calls over Bluetooth

Mwango Mukayi[1]

Abstract

Voice over Internet Protocol (VOIP) or IP Telephony is an umbrella term for a range of technologies that allow voice to be transmitted over Internet Protocol. With significant improvements in the bandwidth and end to end latency has mas made it possible to incorporate the voice and data possible resulting in a significant reduction of cost. In this paper we are proposing making VOIP available on a smartphone using Bluetooth. Essentially making VOIP calls over Bluetooth. All smartphone come equipped with a Bluetooth adapter, therefore if we make VOIP over Bluetooth available we won't need to use an IP phone in an office this will also add mobility session mobility to VOIP.

This paper focuses on how we can route VOIP over Bluetooth protocol. In this quest we will explore how the TCP/IP model relates to the Bluetooth protocol which makes it possible for the application like VOIP to be routed over Bluetooth. It also looks at how mobility can be achieved using Bluetooth as an access protocol. We are going to look at two different layers in the Open System Interconnect reference model (OSI) at which Hand off can be achieved.

Keywords – VOIP, Bluetooth, Internet Protocol (IP), Transmission Control Protocol (TCP)

1. Introduction

Voice over Internet Protocol or IP Telephony is a range of technologies that allow voice traffic to be transmitted over IP, Bluetooth is a low power cable replacement technology that is used to share information including voice. In this paper we are looking at how we can transmit VOIP over Bluetooth as an access protocol. We will look at the design of the TCP/IP protocol suite as a major technology over which VOIP operates and Ethernet that is the IEEE 802.3 and see why it is possible that VOIP can be routed over Bluetooth when we look at the relationship between Ethernet and Bluetooth. Since VOIP is an application program how does it relate to TCP/IP protocol suite? One of the most important things to take note of is that networking is done using what is called layering. That is to say various aspects of communications are handled by different layers of the protocol stack. If we appreciate this approach and how they lower layers relate to upper layers then we will see how one protocol can replace another to achieve the same end. VOIP

[1] Cell No.: +260-967-037-703; Email: mukayimwango@gmail.com

ca use either Session Initiation Protocol (SIP) or H.232 as a signalling protocol but in this case we will be looking at the use of SIP as a signalling protocol. We will focus on especially the Application Layer of the TCP/IP protocol suite, the Internet Layer and the finally the Network Interface layer. In this paper when we refer to Layers by numbers like layer 1 or 2 we mean layers of the OSI reference model.

2. TCP/IP Protocol suite

The TCP/IP protocol Suit is one of the most widely used protocol in the world today, it has become the standard of communication on the internet. This is often the protocol suite that carries VOIP traffic. An application like VOIP sits on top of the protocol suite as shown by fig 1.

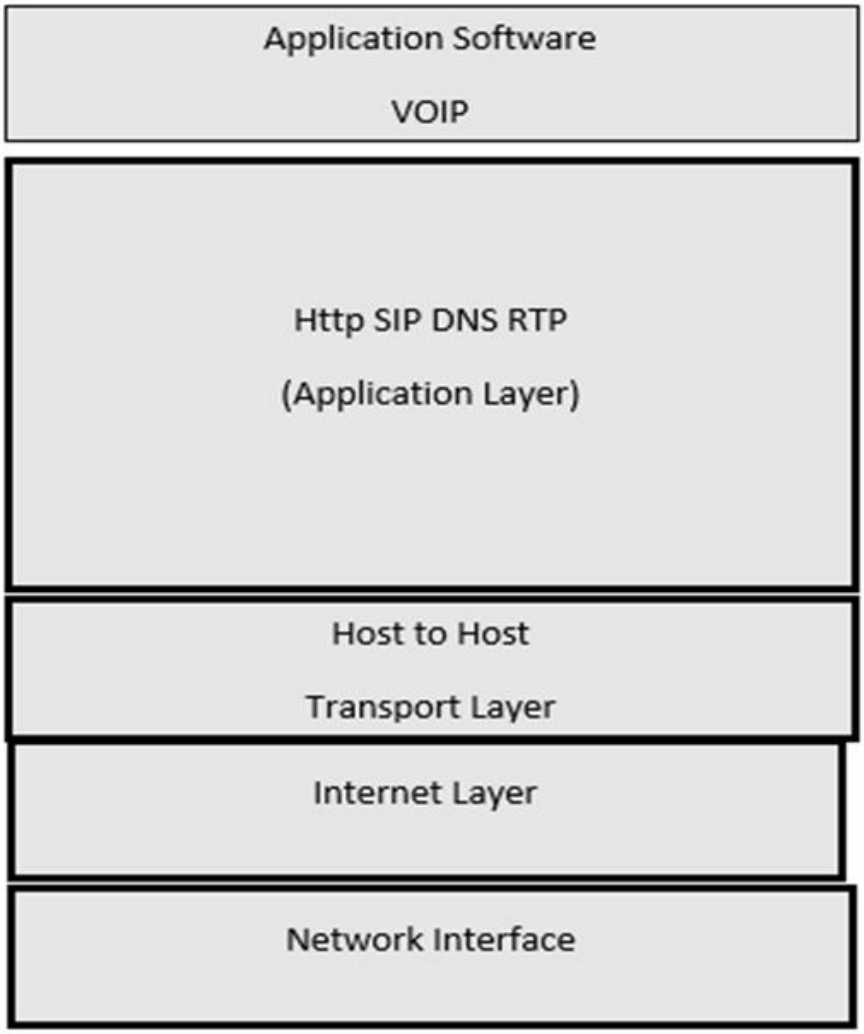

Figure 1: TCP/IP Protocol Suite

For any communication to happen using the TCP/IP we need two kinds of communication that is horizontal and vertical communication. Vertical communication is the communication up and down the TCP/IP model depending on whether we are receiving or sending data. Horizontal communication is when data is transmitted from one station to another using a medium either cable or wireless.

All these come into play when we use VOIP. When a VOIP request comes up the Application layer goes into action putting together a package that will be used to forward the request to its destination. VOIP uses Real Time Protocol (RTP) and SIP at the application Layer then this data package is handed down to the Transport or Host to Host Layer. At this Layer it uses the User Datagram Protocol (UDP) as a transport Protocol. For addressing UDP includes 8 bytes to the data which include the source and destination port numbers for the transport layer address. The protocols at this layer ensures that the services at the source and destination devices find each other. The addressing at this level makes sure that the peer layers has a logical connection. After this the data with the UDP header is passed on to the IP layer at this layer an IP Header which includes the IP address is added to the data. This information is used for routing purposes. It is this information that routers use to make decisions. The header includes both the source and destination addresses. This packet is now forwarded down to the network interface layer. It is worth noting that TCP/IP is a routable protocol suite. What we have looked at so far is an example of vertical communication from the application layer coming down to the network interface layer. It is important to note that TCP/IP has network independence. What this means is that since TCP/IP is from layer 3 going up it is not tied to any particular technology at layer 2 and layer 1.

It is little wonder that VOIP is transmitted over Ethernet or IEEE 802.3 and IEEE 802.11 which is wireless. What we are doing in each case is just change the layer 1 and 2 of the OSI reference model. In VOIP over Bluetooth we are instead using IEEE 802.15 which is Bluetooth. All these protocols are all networking technologies defined by the 802 committee of the Institute of Electrical and Electronic Engineers (IEEE). The core mandate of this committee is to define more of the Data link which was subdivided into two sublayers the Logical Link Control (LLC) and the Medium Access Control (MAC). Doing this made it easier for different technologies to interoperate, it also allowed for network protocols to be designed separate from the lower level Physical Layer and the MAC sublayer. If you take a look at the IEEE 802.11 commonly called Wi-Fi and IEEE 802.15 which is Bluetooth these two networking technologies use the same medium of transmission but the Medium Access Control mechanism is different. So the differ at the MAC sublayer. We will now take a closer look at the Bluetooth protocol that is the IEEE 802.15.

3. Bluetooth

The rationale behind Bluetooth is to provide a universal short range wireless capability. This is provided in the ISM 2.4GHZ band which is mostly free in many parts of the world and usually differs in the number of channels used from one country to another. Bluetooth was design to support an open ended list of applications ranging from data, audio, graphic and video.

3.1 Protocol Architecture

Bluetooth is defined as a layered protocol architecture. It consists of the core protocols, cable replacement and telephony control protocols with adopted protocols.

The core protocols form a five layer-stack starting at the bottom consisting of the following protocols. These are shown in black in figure 2.

It consists of the following protocols. Radio, Baseband, Link Management Protocol (LMP), Logical Link Control and Adaptation Protocol (L2CAP), Service Discovery Protocol (SDP) and also the RFCOMM.

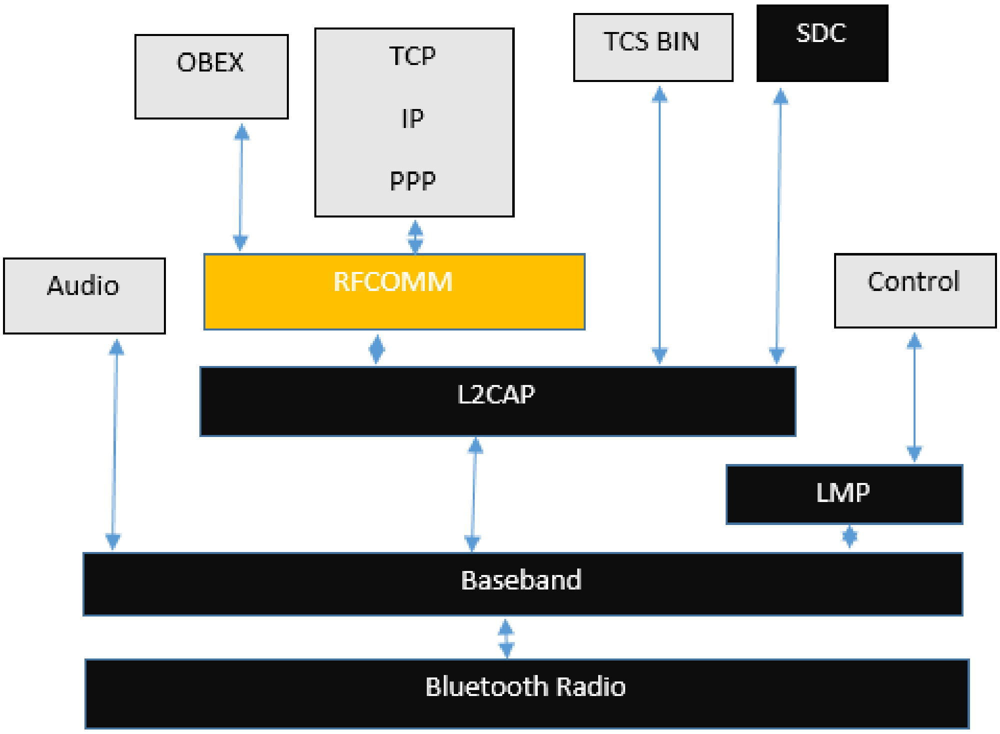

Figure 2: Bluetooth Protocol Stack

We will look at the overview of these protocols but we will spend much time on the L2CAP.

- **Bluetooth Radio:** Specifies details for the air interface things like Frequency, Power requirements, Modulation scheme.

- **Baseband:** It looks at connection establishing, Addressing, Packet formatting, Timing and Power management. It also defines Physical and Logical Channel and Link types and the Medium access control.

- **Link Manager Protocol (LMP):** It defines the procedure for link setup and link management when set up. The security aspect is also looked at this include Authentication and Encryption. It also negotiates the packet sizes for the baseband layer.

- **Logical Link and Control Protocol (L2CAP):** It is used for adaptation of higher layer protocols to the baseband layer.

- **Service Discovery Protocol:** This protocol allows one Bluetooth device to query another for services, device information and the nature of the services.

The **RFCOMM** is a cable replacement protocol. It presents a virtual serial port that makes cable replacement transparent.

3.2 L2CAP

The L2CAP Protocol is layered above the Link Management Protocol so resides in the Data Link Layer of the OSI reference model. Figure 3 illustrates this. It provides both connection oriented and connection-less data services to upper layer protocols. In effect it adapts the upper layers to the baseband layer as it sit in the middle. It can handle upper layer data packets of up to 64 kilobytes. It permits per channel flow control and retransmission using its flow control and retransmission modes. It has logical channels that are mapped to L2CAP logical links supported by an Asynchronous Connection-less Link (ACL) as a logical transport.

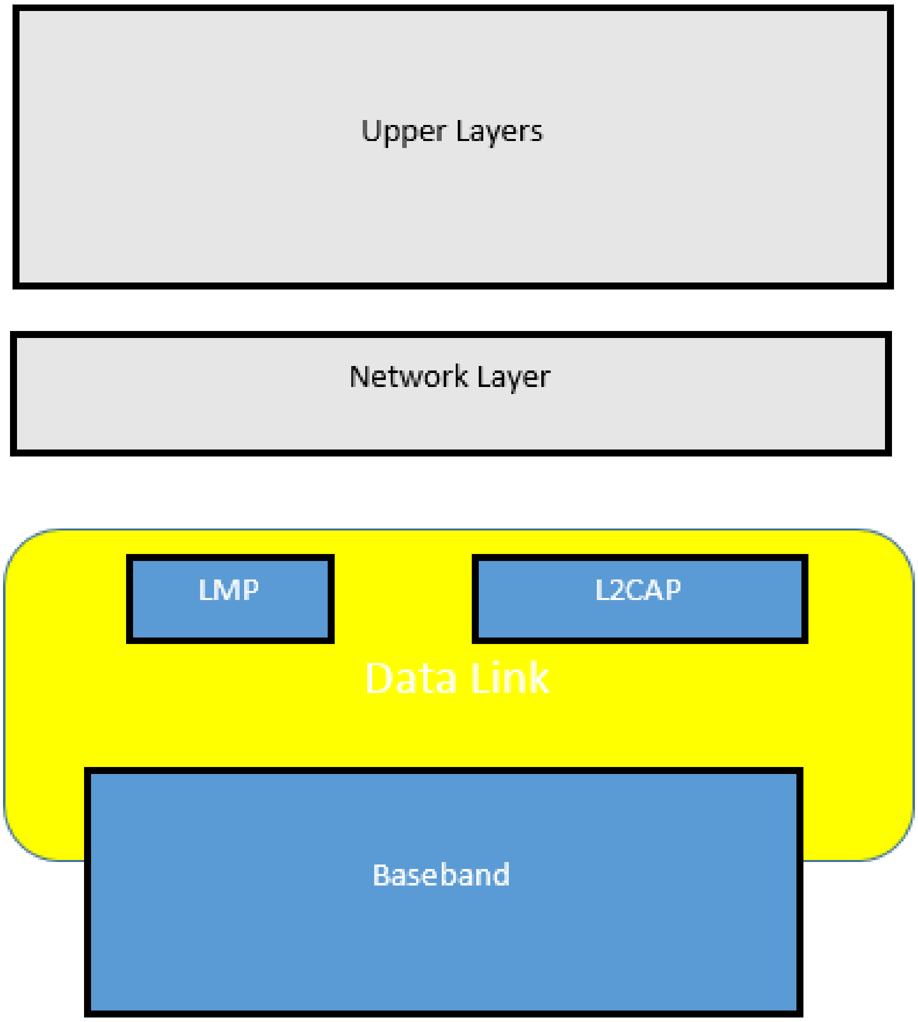

Fig. 3: L2CAP in OSI Layer

The functional requirements for L2CAP include protocol channel multiplexing, segmentation and retransmission (SAR) per channel flow control, error control, and group management.

The L2CAP is above the LMP and it interfaces the other communication protocols such as SDP, RFCOMM, TCS and BNEP. Figure 4 shows this.

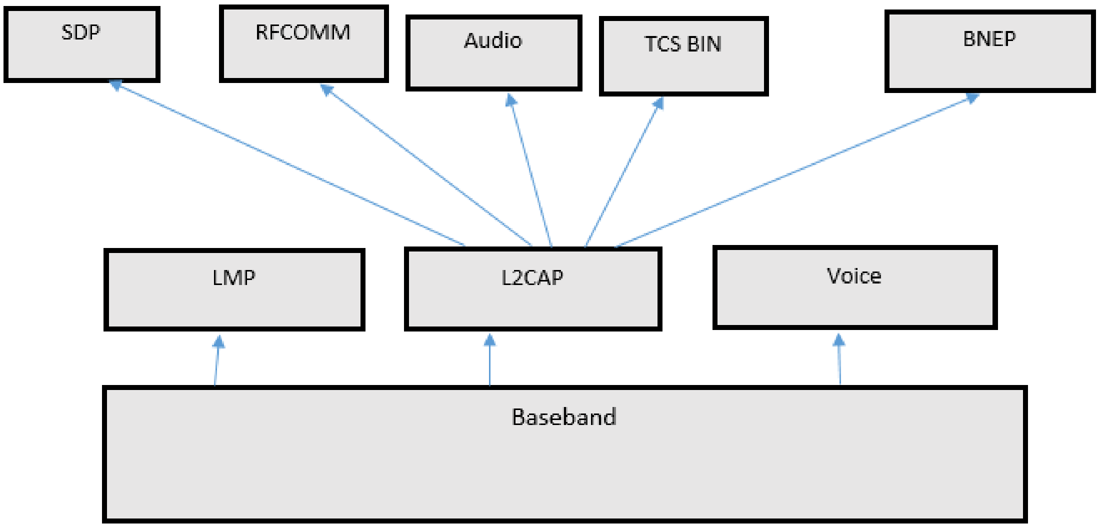

Fig.4:L2CAP Communication Interface

Voice quality channels for audio and telephony application and synchronous transparent connections are usually run on over synchronous logical transports. Packetized audio data like VOIP can be sent over protocols running over L2CAP.

Please take note of the fact that one communication protocols that interface with the L2CAP is the BNEP.

4. Bluetooth Ethernet Bridging

Considering the fact that VOIP can be transmitted over Bluetooth leads us to the next stage. Bluetooth is the over the air interface the backbone of the VOIP system is Ethernet. How do we bridge the two different protocols? We can achieve this using a Network Access Points. These are devices having one or more Bluetooth radio devices that acts as a bridge, proxy or router between a Bluetooth network and some other network technology like Ethernet. When a computing device is connected to the NAP the access point radio and host controller appears to be a direct bus connection to a network interface device with network access.

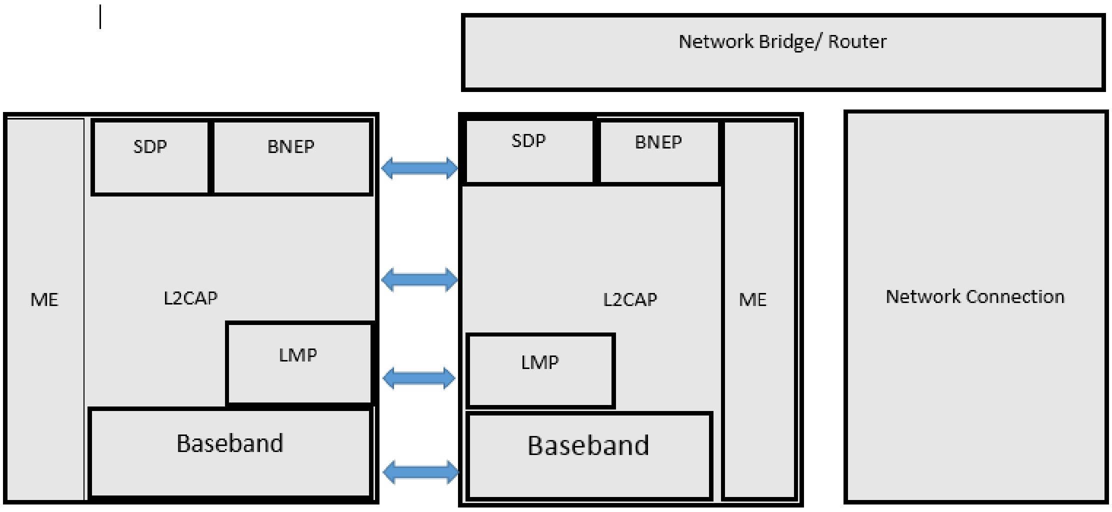

Figure 5: Network Access Point

All the data exchanged between these Bluetooth devices are encapsulated into BNEP frames and are sent as L2CAP messages. When an Ethernet packet is received it is encapsulated into a BNEP packet when this is done the Ethernet header is replaces with BNEP header which is further encapsulated into L2CAP and it is sent as such a message. This is how an Ethernet packet is routed over a Bluetooth medium. The opposite is true when a packet is to be routed from the Bluetooth to Ethernet. So it is by the use of the BNEP that this is made possible as this protocol sits right on top of the L2CAP.

5. Mobility Management

One thing about smartphones is that they are mobile. This presents a challenge in VOIP in that when you use IPv4 it was not design with mobility in mind. If a mobile node moves from one access point to another the effect is that it is assigned a new IP address, when this happens then data cannot reach the device since it's address has effectively changed. How do we handle this situation? It is by the use of Mobile IP. When you use Mobile IP a mobile node is assigned a permanent IP address in it' home network, when a node moves from one network to another it registers with the new network then a care-of –address is given which is more like a temporary address at which the node can be reached. The Home agent is also notified of this development. When a request for this particular node is raised using its permanent IP address then when it is directed to its Home network then the Home agent checks whether it in the home network or not. If it is not then the Home agent replaces the IP address with the Care-of Address and the data ia able to reach the mobile node.

In a situation where the mobile node is in session like an ongoing call, then since the user is moving its point of attachment changes then we have two situations. The first one if the user changes the point of attachment but does not change the network. In this particular case the session handoff is done using layer 2 handoff which is quicker and more efficient.

If the user changes the network as well then in such a case the Session Initiation Protocol (SIP) will perform an application layer handoff. In either case the session or phone call will not be interrupted.

6. Conclusion

VOIP over Bluetooth can be used either on an Intranet or in deed the Internet. This is made possible because the TCP/IP over which VOIP is done is technology independent. That is to say it is not attached to a particular networking technology. TCP/IP can be routed over Bluetooth while Ethernet as a backbone of the network can be bridged with Bluetooth.

The question of Mobility can be handled with the use of Mobile IP so that the mobile node will have a permanent IP address. Session mobility is handle either at Layer 2 or indeed Layer 7 of the OSI reference Layer as need maybe. This kind of application can help reduce to a great deal the cost of communication by incorporating data and voice. It will also make it convenient in that one can be reached for as long as he is in a company premises whether in the office or not.

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Benefits of Industry 4.0 in Foundry Engineering's Greensand Moulding Process

Farai Chrispen Banganayi[1], Hannelie Nel[2] , Kasongo Nyembwe[3]

Abstract

There is a need to introduce modern technologies to address inefficiencies in foundry engineering. The foundry industry is very old dating back as far as 1479. The early foundry engineers produced metal castings which were mainly cannons and bells. Foundries have been slow to adapt to disruptive technologies. However with the 4th industrial revolution foundries cannot afford to miss out. Foundry Engineering which is metal casting is under a lot of pressure from other competing manufacturing technologies like forging, fabrications and 3D metal printing as well as other materials like plastics and composites. The most common and cheapest way of producing castings is in greensand. This is due to the fact that it uses low cost raw materials. Though the process is cheaper than other casting processes. There is always a need for improving efficiencies in the means of production to compete with other manufacturing technologies. The 4th industrial revolution has become a pillar of improving competiveness in the metal casting process. This paper evaluated how the first cloud based green sand data analytic software Sandman plays a role in contributing towards the achievement of the sustainable development goals in African foundries. The greensand data analytic programme has been seen to be a key resource in driving for responsible consumption and production.

Keywords: Sustainable, Development, Foundry, Industry 4.0

1. Introduction

The metal casting manufacturing processes, involves making objects by pouring hot metal into a mould. Whilst a mould is an impression in the sand shaped to correspond to the required casting, produced by ramming sand on the pattern. The pattern is withdrawn from the sand to enable the mould to receive the molten metal (American Foundry Society, 2009). The global metal casting industry is facing several challenges and these include demand and constraints on our valuable resources, human, intellectual, financial and natural resources. It is therefore our responsibility to maximise and not waste the resources for the benefit of the future generations (Prucha, 2014).

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[1] University of Johannesburg; Metal Casting Technology Station Institution; Cnr Siemert and Beit Streets Doornfontein 2028 Johannesburg;+27115596390; fcbanganayi@uj.ac.za.
[2] University of Johannesburg; Department of Postgraduate Studies in Engineering Management; Cnr Siemert and Beit Streets Doornfontein 2028 Johannesburg ;+27115591711; Hannelien@uj.ac.za
[3] [3]University of Johannesburg; Department of Metallurgy; Cnr Siemert and Beit Streets Doornfontein 2028 Johannesburg;+27115596181; dnyembwe@uj.ac.za

The metal casting industry needs to look beyond production and invest in marketing, human capital development and management to have a strong future and enhanced sustainability (Spada, 2014).Currently, due to short product lead times, small-quantity batch production, diversified consumer needs, and inconsistent demand fluctuations, manufacturing companies are trying to achieve innovation, such as flexible and predictive production, in contrast to the mass production that is a typical manufacturing method. In terms of technologies that support manufacturing innovation, information and communication technologies (ICT) including enterprise resource (ERP) planning, manufacturing execution systems (MES), and programmable logic controller automated factories significantly improve productivity. However, they are unable to meet current production needs such as reducing manufacturing lead times and producing small and customized products (JuneHyuck, Sang Do, Hyun-Jung and Yong-Shin, 2018**).** Foundry operations need to be driven by sustainable development goals. Sustainability is the new approach to innovation and gaining competitive advantage. Sustainability drives innovation by driving new design constraints that determine how essential resources, energy, water, materials and waste are used in products and processes. Sustainability is the mother of technological and organisational innovations that gives both bottom line and top line returns. Companies need to modify their ways of doing business or introduce new ways of conducting business for them to survive. The benefits of sustainability are indisputable these include cost savings, compliance, quality improvements and enhancing reputation among others (Cooper, 2014).Casting defects are a major challenge in foundries and can be reduced by determining and controlling the relevant process parameters, through application of domain knowledge. This is however, a challenging task since the parameters vary within a wide range; and it is not easy to determine the specific range of values that should be avoided to prevent the defects (Sata, 2016).

Industry 4.0 is a strategic initiative introduced by the German government with the aim of transforming industrial manufacturing processes through digitisation. Industry 4.0 is key to handling big amounts of data. This data needs a lot of analytics to convert it to useful information. The data then supports solid actions, which is the backbone of an adaptive, continuously self-optimising process (Rojko, 2017). The fourth industrial revolution is growing and evolves around Internet of things (IoT), big data, and artificial intelligence (AI) (JuneHyuck, *etal*, 2018). In this modern society most industries have accepted the power of data analytics and adopted it in one way or another. Industries are striving to enable IOT integration in their production and anticipating to get profits out of the data analytics (Chowdary and Krishnan, 2018)

2. Building blocks of Industry 4.0 in the greensand moulding process.

Figure 1 shows the building block for industry 4.0. These are the areas in which interventions need to be taken in order to have smart green sand moulding processes. This paper will breakdown different areas within the greensand moulding process were information has been taken to supply to the various industry 4.0 building blocks in figure 1. This information will then be used in the integration which is what makes industry 4.0

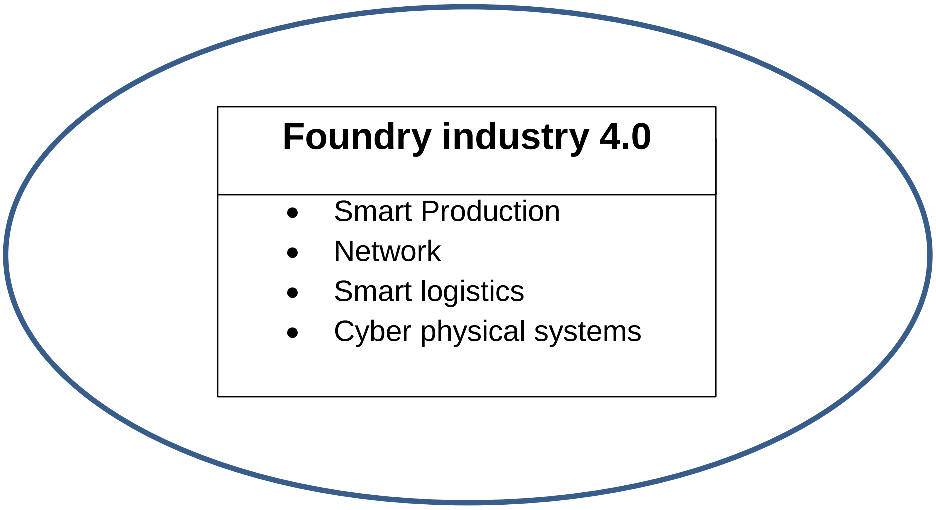

Figure 1: Building blocks of Industry 4.0 in greensand foundries

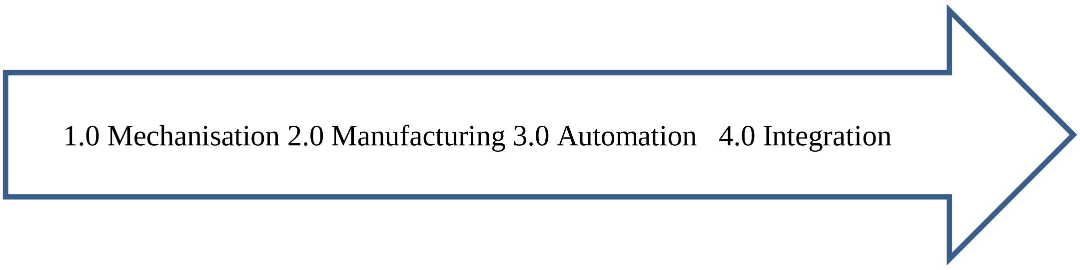

Figure 2: Evolution of industry 4.0

The greensand moulding processes has evolved from compaction moulding to pneumatic moulding machines then to high pressure moulding machines (Kothari, 2018). This could be sequence in which greensand moulding has been evolving towards industry 4.0 based on the industrial evolution process in figure 2.

3. Integration of greensand moulding industry 4.0 building blocks and automation

3.1 Digitalisation

The process in the foundry starts from digitisation which is converting manual information into the digital format. Digitisation is then followed by digitalisation whereby the results from the digitisation process are used to enhance business processes. Digitisation is very much possible to achieve in most areas of the foundry were data is collected. However based on the definitions there could be a number of foundries that are digitised but however have not attained digitalisation. This is because the information will be collected in a digital format but is not put to use in the business processes.

In most cases sand casting foundries collect moulding related data from the following sources

1. Production planning data
2. Sand preparation data
3. Sand testing data
4. Quality Control/Inspection

3.2 Smart Production

Cyber Physical Production systems (CPPS) is a promising technology of Industry 4.0 and an essential component of a smart factories. Specifically, CPPS are composed of collaborating computational entities that connect the cyber world with the surrounding physical environments or processes through data access in an internet environment. Smart factories allow the collection of massive amounts of in-plant data through real-time synchronization of the factory components and information systems, and they also improve quality and productivity through smart and flexible responses to abnormal situations that occur in a plan. Currently foundries have different components that can collect data but however this data faces a challenge of being synchronised because the other component with the data that needs to be synchronised is not capable or does not have sensors to collect the required data.

In a greensand foundry the equipment below are capable of collecting data;

1. Sand laboratory equipment.
2. Sand mixers
3. Moulding line
4. Humidity and temperature loggers

3.3 Smart Data

Smart data is data that can be collected and acted upon from collection before analytics can be done. Therefore smart data can be used in the decision making purpose for a specification action in real time.

Currently in the greensand moulding the most highly sources of smart data is

1. Humidity and temperature loggers

This source of data will be able to directly control the compactibility set points on the moulding line.

3.4 Industrial Networking

This is the collection of technologies at the internet protocol layer and below that enables transformation of industries. This forms the foundation of industrial internet of things (IIOT) were the industrial assets which are machines, environments and sites are connected to business professionals and processes. The network is an important infrastructure that supports various application needs and different deployment situations in the wide range of industry sectors. (Zhe Lou, 2018).

In greensand moulding connections are needed between the following professionals and processes.

1. Melting
2. Coremaking
3. Sand mixing/preparation
4. Moulding process
5. Sand reclamation/regeneration process
6. Fettling Process
7. Quality control Process
8. Technicians
9. Operators
10. Technical Professionals
11. Process Professionals
12. Production Professionals
13. Maintenance Professionals

Through the network we can get self-optimising processes.

3.5 Smart Logistics

Smart Logistics is related to planning and control by tools, means and intelligent methods, the degree of intelligence depends on the applications and methods used since the traceability of products and the identification of the elements of its environment until the detection of the problem, the choice and the automatic execution of the solution. Douaioui (, 2018).

The logistics in greensand moulding have to do with information from the following processes;

1. Melting
2. Coremaking
3. Sand preparation
4. Moulding
5. Sand reclamation/regeneration
6. Fettling
7. Quality control

4. Sandman benefits of industry 4.0 in greensand moulding from implementation in African foundries.

4.1 Benefits realised during data collection

The implementation of sandman has immediate benefits before you can even start running the software programme. As you progress with collecting data and putting it in the format required by the programme you continue to accrue benefits. Collecting and arranging the data required by sandman is systematic. The final benefits are realised during use of the programme specifically that require networking and analytics.

4.1.1 Centralisation of data

Initially most of the data in the foundry was in different locations with different people. This system enabled all the production data required to produce a casting to be put in one central place. This makes it convenience especially when information pertaining a particular casting is required. There is a central place were information can be obtained in the foundry. In this case information from all the different foundry sub processes can be found in one place.

4.1.2 Disintegration of data

Part of the data was summarised data. Digitisation enabled the foundry to disintegrate their data. The data was summarised as monthly consumption, for new sand, bentonite and water. The digitisation enabled the consumption data to be broken down to component, shift, and day wise. Disintegration of data becomes key to smart logistics. This allows you to be better able to plan and not waste resources and financial resources on unnecessary inventory especially when it comes to materials used for production.

4.1.3 Collection of previously neglected data

Additional data was collected which was previously ignored. Amount of core sand used per part was compiled as part of the component master enabling core sand to be measured more accurately to the lowest level of production. There are a number of areas in the foundry where production takes place and a lot is missed out because the data is not recorded. Industry 4.0 big data concept plays a key role where data is collected whether smart or raw. The ultimate goal is it will eventually be taken through some analytics engine so that it helps the foundry engineers to make informed decisions.

4.2 Benefits realised when using the programme

The use of the programme mainly has to do with benefits derived from data analytics. The benefits are mainly to do with, cyber physical systems, smart production, smart logistics and network. This is the rea in which most of the value is significantly derived from algorithms.

4.2.1 Variable dose by need

There is now some degree of flexibility in the way different casting components are produced. The addition of water, bentonite, coal dust and new sand changed from being on a flat addition depending on sand test results and moved away from irregular based on sand laboratory tests and specification limits to a component wise or shift wise based on analysed data. Depending upon the planned production additions can be shift wise or component wise. This is the initial benefit that you get when you start using the software programme after uploading and cleaning the data.

4.2.2 Informed decision making

The foundry is now equipped with all its production data related to greensand moulding in one place. This allows the foundry to pull out the data it would like to use at a click of a button and make informed decisions. The data collected is mainly big data. The data is then refined by the use of algorithms and regressions in data analytics this point in time the data becomes smart. The programme is now able to tell something meaningful to the foundry engineer. Based upon the analysed data the foundry engineer was capable of making informed decisions.

4.2.3 Prescriptive analytics

The sandman software is capable of prescribing to the foundry what recipe to use in each shift. The tool is so specific to the extent that it gives you a dosage component wise and defect wise to reduce any particular defect with the ability of telling you your next sand test results after changes with a high confidence interval. The programme was capable of determining the condition of greensand in advance and prescribing the dosage of bentonite, coal dust and water in order to have optimal quality on that particular shift, day, or casting component.

4.2.4 Reduction in defects /improved Quality

The reduction in defects is the key to the software with cumulative benefits in other areas. Reduction in defects refers to the production of good quality castings. This provides customer satisfaction, reduces the lead times, fettling shop consumables savings, energy savings. The most important feature to this benefit is we now involve the product which is to be sold to the customer. On top of all the other process related raw material savings we now have metal. The biggest cost in the foundry is energy which has to do with melting metal. If there are defects chances are high that the components might need to be produced again depending on severity.

4.2.5 Increased raw material savings

The prescriptive analytics, dose by need and improved quality contribute to the savings in raw material and energy usage. Therefore the greensand moulding process becomes self-optimising production system within industry 4.0‘s cyber physical production systems. There is a significant amount of savings that you get from input materials at the initial stages of implementation. Ounce the system is stable it then maintains and continuously makes it better but in this case the savings are not as significant as at the start. The saving of energy is good for climate change since it reduces the emissions of greenhouse gases especially for African countries that rely mainly on fossil fuels for energy.

4.2.6 Internet of things

The internet of things that comes with this programme assists in monitoring of humidity and temperature which have a great influence on the preparation of greensand. The humidity and temperature controller allows for adequate moisture additions to the greensand and automatic adjustment of compactibility set points which are coherent to the environmental conditions at the given time. This is smart data at source. This innovation is a contributor towards industry innovation and infrastructure development.

4.2.7 Real time semi-automated tools.

The programme provides real time automated tools like histograms, run charts, trends, Pareto, analysis of variance (ANOVA). This significantly reduces the amount of time required by process engineers to come up with these tools and therefore being able to divert that time to other value adding activities.

4.2.8 Communication and institutional knowledge

The programme can improve communication within the foundry by communicating to relevant personnel on actions taken and process parameters in the greensand moulding plant via email and automated text messages. The programme has a feature for annotations which build up institutional knowledge with respect to any changes in the plant and how they affected the greensand moulding process.

4.2.9 Upskilling of Operators.

The operators can now load their information on tablets instead of writing manually on paper. The operators have now been upskilled by being provided and trained to use computers and tablets in their respective work areas.

5. Conclusion

Industry 4.0 brings phenomenal benefits in the operation of green sand moulding lines. The different elements of Industry 4.0 when combined have the potential of making very useful tools that eliminate waste and significantly increase efficiency whilst allowing for flexibility on products manufactured on greensand moulding lines. The benefits attained from industry 4.0 in green sand moulding contribute significantly to sustainable development goals under industry innovation and infrastructure SDG 9, responsible consumption and production SDG 12, and climate action SDG13. Based on these implementations it was observed that greensand foundries have a lot of potential to become smart factories. However the foundries need to first digitise their data.

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Least Cost Planning Technics in Electrical Infrastructure Projects: ZESCO Ltd, a Zambian Case Study

Matemba Roy Chilengi[1]

Abstract

In today's age, Planning and Design of Electrical Power Transmission and Distribution systems have become an important and a continuous activity. This is because of continued population growth resulting in increased power demand. As a result, older equipment and systems are being expanded and/or replaced by the new and more suitable ones based on size, capacity, technology etc. Meanwhile, decisions regarding choice of equipment to install have long term effects on the overall performance of a power system as most of these equipment have a life expectancy of 15 to 30 years, which is a long period in that, some equipment may become obsolete in less time (e.g. 2 to 10 years) due to rapid changes in technology. Adding to this complexity, electrical energy cannot be stored in large quantities economically, so transmission and distribution systems should be designed and constructed to operate with optimal efficiency as these systems have to deliver the energy as and when that power is demanded. Thus it is incumbent on the power system or network planners and designers to optimise these networks in terms of cost/usefulness/avoiding obsolescence/considering alternatives and so many of such factors so that the respective organisations/countries etc. optimise the designs and maximise benefits from these investments especially in Africa where we have limited resources for capital investments. With these varied considerations comes the quest for Least Cost Planning *(*Ann Davison, *Least Cost Planning*, 1991*)* in implementing such infrastructure projects. The questions being: what options do we invest in? How much of funds are available? How do we optimise our choices?

In this outlay, I labour to highlight some of the modern trends to consider in planning and design of transmission and distribution systems (or in general infrastructure projects) so that we come up with Least Cost Options in the light of limited resources. Applying Least Cost Planning Techniques, I highlight some of the projects ZESCO Ltd has undertaken and achieved desirable results from which all of us as Engineers from all walks of huge industry can apply and make useful gains.

Keywords: Least Cost, Planning, Design, Power Demand, Transmission, Distribution, Optimise

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[1] ZESCO Limited, Head Office, Stand No. 6949, Great East Road, P. O. Box 33304, Lusaka, Zambia. Mobile: +260977893910; Email: mchilengi@zesco.co.zm

1. Least Cost Planning

Least Cost Planning (LCP) is a strategic planning process that uses the principles of cost-benefit analysis as its underlying evaluative framework (*Least Cost Planning: Principles, Application and Issues*, July 1995). Deciding on which programs and projects to embark on gets harder every year resulting and doing this for some years now has resulted in a systematic method with evolved decision making process requiring technics such as LCP. In ZESCO, we are always involved with expanding and building our power systems or networks through various projects and programs to an extent where decisions have to be made regarding which projects or programs should go-on and this has to be balanced against limited resources. To properly optimise such investments, we have had to work with approaches such as Least Cost Planning and we have a lot of classical examples where we have applied LCP to the benefit of the whole organisation and the country at large. In haste, I highlight the following:

1.1 Power Rehabilitation Projects in Power Generation Stations

Power Rehabilitation Project (PRP) in generating stations where instead of thinking of building new power plants, various power generating machines in various ZESCO power stations across the country were upgraded in terms increasing their Mega Watt power output without having to carry out the expensive and costly construction of new facilities but rather, changing a few technicalities within the same old setup of the already constructed power stations in the end resulting in expansion of the requisite power output. Cases in point being, Kafue Gorge Hydro Power Station upper where old existing six generating machines were upgraded from 150MW each to an output of 180MW each by simply changing some technicalities such as the machine winding and control system etc. a similar method of increasing the power output has been done at Kariba North Bank Hydro power stations. Similar approaches have also been carried out in other smaller hydro power stations such as Lunzua power station upgraded from 750kW to 14.8MW by just taking the water intake point upstream from where it used to be, same generating machines, thus increasing the head, hence increasing the power output at that station; Similarly upgrading Musonda Falls Power Station from 5MW to 10MW through some related approach has been done; Lusiwasi Power Station from 12MW to 15MW etc. *(ZESCO Reference Documents and Reports)*. By such acts, LCP was applied with an eventual increase of so many MW thus increasing the output but rather in a least cost way. The alternative would have meant building completely new power stations which would be a very big cost and would take very long periods and have huge environmental impact. By this approach, huge capital investments are deferred for the future but in the meantime, we get the highly needed increase in the amount of power rather at lower cost than it would be, thus helping the situation. This is part of ZESCO's Least Cost Planning in expanding its infrastructure projects. .

1.2 Power Transfer Capacity Upgrades in Transmission Lines

1. Various transmission projects such as Leopards Hill – Coventry 132kV line, Kabwe – Kapiri 88kV line, Kafue – Mazabuka 88kV Line etc. had their power transfer capacity increased or uprated by simply applying new technologies involving a modern conductor type called High Tension Low Sag (HTLS) ('Engineering Transmission Lines with High Capacity Low Sag ACCC Conductors' CTC GLOBAL First Edition 2011) where instead of building new

transmission lines, the old power conductors and insulators were changed and replaced with the new HTLS conductor which has a high power transfer capacity of about 2.5 times higher than that of old conductors (e.g. increasing from 86MVA to 200MVA power transfer capacity on the Leopards Hill – Coventry 132kV line within Lusaka, enhancing power supply by increasing the amount of power flowing right into the Lusaka CBD) without having to construct new transmission lines really. In addition, installation of the same HTLS conductors comes with additions of various superior qualities in performance of conductors such as having 20% less sag under the same loading conditions (which is due to the conductor's light weight, high modulus of linear expansion capabilities etc.) Thus giving a lot of desirable improvements without carrying out transmission tower modifications. In new transmission and distribution lines, these desirable capabilities of HTLS conductors can allow lower transmission tower heights, thanks to superior sag performance of HTLS and this leads to reduction in the transmission tower construction cost as well as the lead time in carrying out such projects in that less materials, less tonnage in steel are utilised. Because of these desirable properties of HTLS conductors, much longer spans can be achieved in the new transmission and distribution lines again reducing construction costs by cutting number of towers installed, giving low sag- low loss-high capacity design, making this another classical example of LCP as applied in ZESCO. The same approach can be applied to lower voltage power distribution lines with the intent of reducing investment costs but attaining the required increases in power transfer capabilities.

1.3 Utilisation of Double Circuit Towers in Transmission Lines

In LCP considerations, installation of double circuit towers increases our optimisation of our limited resources in that two transmission circuits are constructed where only one circuit was to be originally constructed. This gives a many-fold advantage in that the cost of installing two transmission or distribution lines in terms of line supporting towers is reduced to one and half times or so thus reducing the cost, reducing the construction time it would take to construct two transmission or distribution lines and material of having to build two separate power circuits. In addition, this significantly reduces more requirement of right of way (ROW), or the servitude area or the way leave required for installing transmission or distribution lines not to mention the reduced visual impact by having one structures as opposed to having two structures for two transmission or distribution circuits. This innovation entails a classical application of LCP and ZESCO has applied this technic in a lot of places in construction of its various transmission and distribution lines across the country. A few examples applied are on the 330kV Lusaka West – Mumbwa; 330kV Mumbwa – Kalumbila; 330kV Maamba – Muzuma double circuit transmission lines as well as many double circuit distribution lines around the country. In fact, this least cost planning option envisions what transmission and distribution circuits if the future will look like in that it will be multi-circuit for a given way leave as more wayleave spaces for lines cannot be afforded now, due to continued development of the various areas in which electricity is required. As seen in figure 1, double circuit transmission line saves space or wayleave area and reduces increased visual impacts as opposed to single circuit transmission lines in figure 2 below.

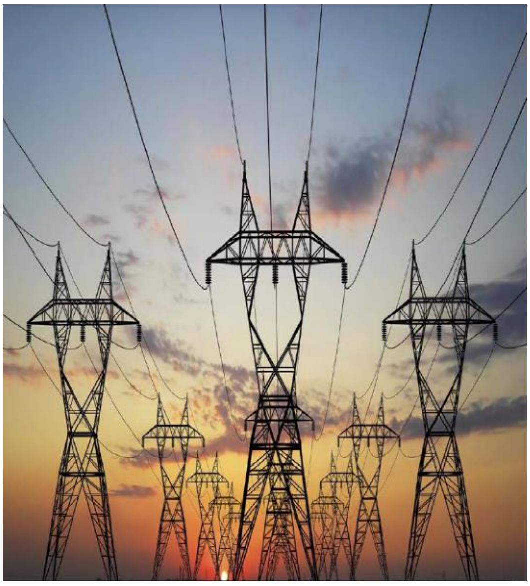

Figure 1: Double Circuit Transmission Line ***Figure 2:*** Single Circuit Transmission Line

1.4 A Focus on Energy Efficiency Strategies

The long standing tradition in electrical industry as it has always been, is that there are two sides to every electricity meter the utility side and the customers side as depicted below,

Figure 3: Two sides to every energy meter, Utility side and customer size.

Because there was lesser demand for electrical energy in the past, the historical approach to customer service was based on the electric utility's obligation to serve. The prevailing attitude was that an electric utility organisation like ZESCO had to serve the customer but that service ended at the meter connection point. Beyond that point, what customers did was their own business. However, in today's age, with the LCP way of looking at things, times have changed and customers need to be looked at as a resource much like we would consider a new "power plant" in literal sense. Customers or End user behaviour directly impacts how a utility like ZESCO must operate and that significantly affects what its costs of operation will be. The business of End Use is huge! i.e. for the utility, sellers of energy efficient appliances/devices as well as the customer. This is because it brings into picture the importance of "Energy Efficiency" in terms of creating virtual energy or virtual power stations in that the saved energy becomes available for other users, apart from the user who is saving energy. Businesses will thus figure out that working on the other side of the meter is not only good for customers, but it is good for the utility company as well as mother Earth (good energy stewardship!). In the end, this defers the utility's requirement for investing in new generation just in the interim case thus freeing uo some capital until later. This in itself entails LCP.

As the most basic of approaches, with LCP implied, ZESCO is now advising and giving reasonable guidance to customers on choices that can help conserve electricity usage. Use energy saving lights, use of low wattage appliances and the like comprise energy efficiency. Together with the already practiced slogan of "switch and save" applying more energy efficiency practices to households can help save a bit more energy as demonstrated in figure 4 below where we optimise factors bring in EE in households.

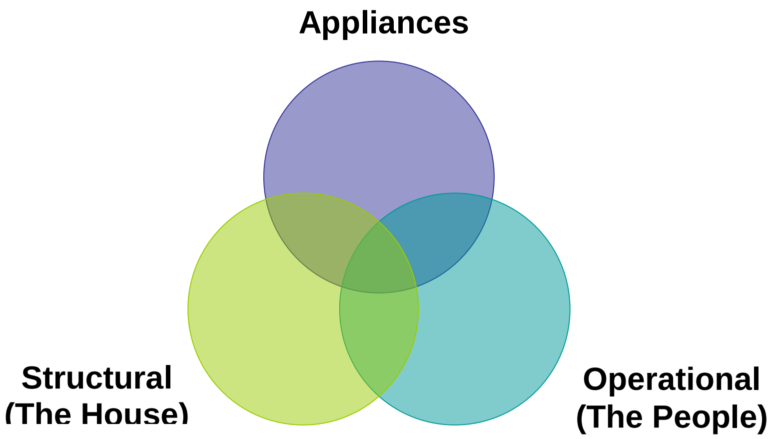

Figure 4: Optimisation of Energy Efficiency in houses resulting into an LCP outcome

Use of electrical energy in households basically, has a matrix of 3 contributing factors that influence each other but are related in such a way that their optimised intersection gives the pinnacle of Energy Efficiency. That intersection is where our efforts in LCP converge or focuses on to help push our countries overall use of energy to optimise on energy savings. Understanding Energy Use in households is easy if we look at 1.Appliances 2.Operation of these appliances by people (attitude and behavioural), 3.House or building itself as a structure and how it uses energy is a key in reducing energy use. These intertwine and form the diagram above Appliances: Type, Wattage (power rating), sizing of appliances, less or no standby power by disconnecting etc. are important considerations and as ZESCO, we now advise our customers to take an extra concern although sophisticated but simply advise on using lower power rating appliances for instance energy saving bulbs which have lower power ratings and consume less electricity than incandescent 60W, 100 W bulbs but produce reasonable luminous intensity for required purposes. Operational domain is where the behaviour and attitude of energy users (the people) should be well advised, informed through various communications like TV & radio adverts etc. Optimisation of each of these factors as described leads us to operate our household needs in the intersected areas and eventually right in the centre where there is Energy Efficiency thus helping with optimal use of electricity which we really need so much at the moment and this really, is LCP at its most basic. This creates the needed energy and helps defer capital investments

1.5 Implementation of Demand Side Management Strategies

In an effort to manage the power demand in the Zambian electricity industry and avoid or reduce load shedding or significantly optimise use of energy, in recent years efforts in demand side have intensified. Application of demand side management (DSM) programs creating virtual energy/power stations which could supply additional customers but with the same generation capacities as installed in the country. This is achieved through ZESCO's application of DSM activities aimed at increasing efficiency by the use of energy saving lights, high efficiency motors in industries, operating plants very close to unity power factor etc. all being classical examples of LCP in that less capital is used where we could have needed to use a lot of capital hence a higher cost had we built new electrical infrastructure just by reducing demand through the application of energy efficiency. Encourage use of natural lighting and natural wind flows in design of modern buildings making the buildings energy efficient as contributing to a cause as above. DSM may also involve helping energy consumers adjust the time of use and through distribution of energy saving bulbs. This is intended to shift consumption especially for time of use customers like manufacturers from consuming energy at peak time to other time periods like shoulder and off-peak periods. The effects of the consumer response so far to shift in time of use factor was analysed and it has showed that there is a possible shift consumption from peak to shoulder the off-peak time periods. So far ZESCO has considered, approved and distributed millions of energy saving light emitting diodes (LED) as a demand side strategy.

2. Conclusion

In a way, as laid above, applying LCP to many projects can help reduce the huge capital costs required to do completely new projects in ways that can achieve close to the result expected when completely new construction or projects are carried out but in LCP this is achieved with much lesser capital injection where possible. This capital can then be freed for other immediate needs while deferring the other capital intensive projects for the future when probably resources for such projects could have been sourced. LCP is an emerging concept that embodies both a planning process and specific analytical techniques for evaluating the costs and benefits of projects looking at how some expansion can be achieved but not with huge costs. In other words, LCP is also called Integrated Resource Planning, where you holistically look at everything in terms of costs and benefits and then you choose the option that somewhat maximises the benefits i.e. you analyse and look at all integrated resources at your disposal and come up with a plan that gives the most benefits. Thus it is incumbent on the power system network planners and designers to optimise the designs and options they choose such that the projects eventually implemented are optimised in terms of cost/usefulness/avoiding obsolescence/considering alternatives and so many of such factors so that the respective organisations/countries etc. optimise the designs and benefit from these investments especially in Africa where we have limited resources for capital investments hence LCP.

LCP embodies the use of both planning and analysis techniques in order to meet a set of objectives having a combination of improvements, policies and programs that are less expensive than any other combination. Principles of LCP include: (i) application of benefit-cost analysis to evaluate alternative systems and projects (ii) Consideration of policies and investments (iii) involvement of the public in development of alternatives etc.

For a country to have adequate and reliable electricity supply and power networks that match the demand, it calls for a deliberate effort to plan and develop both the electricity generation, transmission and distribution capacity of the country, based primarily on optimised investment plans. This is only achieved by applying least cost planning. The purpose of LCP is to derive the forward looking least cost electricity supply options that can satisfy the project demand over a given time. This plan ought to be continuously revised and updated every short period in order to reflect any changes since the least cost plan was developed. Focusing on LCP will help promote research and development in our sector, encourage international cooperation, technology transfer and adoption of newer technologies. It helps in using resources efficiently thus contributing to the management of the resource in a sustainable manner. This approach, fully and properly applies to other sectors involved with building various infrastructure needed by the country, hence the call to use Least Cost Planning techniques across all sectors of our countries economy.

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Technology acceptance of the rural aluminium melting furnace in Limpopo Province, South Africa

Kulani Mageza[1, 2], Antoine F. Mulaba-Bafubiandi[2] Jan-Harm Pretorius[3]

Abstract

A study was conducted to assess the technology acceptance level by the rural foundries on the aluminium smelting furnace transferred by the Metal Casting Technology Station (MCTS). In 2017 the MCTS developed aluminium smelting furnace for the rural foundries in Limpopo Province, South Africa with better heat conservation and lesser coal consumptions which is used as primary source of energy. The smelting furnaces were transferred to six rural foundries in the Limpopo Province, in pilot study to determine whether the new aluminium furnace is an appropriate technology for aluminium rural foundries. The study was conducted based on a qualitative approach with primary data collected through closed-end questionnaires and researcher's observations on each of the six rural foundries. The study revealed that 100% of the foundries under study fully adopted the newly designed furnace. In conclusion, this study successful assessed the technology acceptance of the new aluminium smelting furnace for the rural foundries in Limpopo Province, South Africa.

Keywords**: Technology Acceptance, Aluminium Melting furnace, Metal Casting Technology Station**. **Rural Foundries**

1. Introduction

Rural development is one of the key strategies on promoting inclusive growth with an attempt to fight against unemployment and poverty in rural communities. Universities are the key stakeholder towards driving the rural development project through the use of applied science and technology generated within the institutions. Metal Casting Technology Station (MCTS) is an entity within University of Johannesburg (UJ) funded by the Department of Science and Technology (DST) managed through the Technology Innovation Agency (TIA). The primary mandate of the MCTS is to enable industry, particularly small businesses, to benefit from the specialised knowledge and innovative technology of the universities in order to unlock the competitiveness of the metal industry through technology innovation to deliver socio-economic value.

Rural foundries are defined as small enterprises in villages known for the production of aluminium cooking pots using coal fired furnace. The aluminium cooking pots are mostly popular in rural areas as

[1] University of Johannesburg;P.O.Box 17111,Auckland Park,2008;+27 11 559 6952;kmageza@uj.ac.za
[2] University of Johannesburg;P.O.Box 17111,Auckland Park,2008;+27 11 559 6215;amulaba@uj.ac.za
[3] University of Johannesburg;P.O.Box 17111,Auckland Park,2008;+27 11 559 1730; jhcpretorius@uj.ac.za

compare to cast iron pots, as they are lighter in weight, offer better heat transfer, cheaper and are locally manufactured within the rural communities (Adair, 2016).

The most commonly used smelting practices in South Africa for casting aluminium pots employs coal fired furnace made out of superimposed two steel drums as the furnace body, without any lining, and a cast iron pots as crucibles with ambient air being used as air supply for combustion (Sanders, 2016). Masilela (2010) pointed out that this particular practice leads to challenges such as non- compliance with air quality management (due to emissions), waste management (due to slag, ash and waste sand), and health and safety issues. Sanders (2016) estimated the amount of carbon emission emitted by the rural foundries to be 19.1 kg per 80kg of coal used to melt aluminium scrap. The lack of lining in the furnace was the major source of heat deficiency as such a furnace has limited heat conservation mechanism to contain the heat inside the furnace and promote effective smelting of aluminium (Mabunda, 2014).

MCTS provided a support to six rural foundries by redesigning the furnace, developing and transferring the furnaces to the rural foundries in collaboration with the National Foundry Technology Network (NFTN). The new furnaces demonstrated 50 % improvement in reducing melting time, compared to the 6 hours the foundry usually took to fully smelt the same quantity of metal (Banganayi et al., 2017) and also indicted 75 % improvements in reduction of coal consumption (Banganayi et al., 2017). The improvements in the melting furnace were attributed to a better insulation due to the laying of a refractory lining, the lid cover and also continuously flow of air generated by the solar blower as shown in figure 1 (Banganayi et al., 2017). A research project was subsequently set to assess the level of technology acceptance of the new aluminium smelting furnace transferred to the selected six rural

foundries in Limpopo Province.

Figure 1: Shows the old aluminium melting furnace (left) and the improved aluminium furnace (Right)

2. Literature review

To understand technology acceptances, it is of great importance that first need to conceptualise what is technology. According to Wahab, (2012) technology is the incorporation of tools or technique, product or process, physical equipment or method by which the human being potential is increased and efficiently used. Then Kim and Hong (2016) defined technology as the use of scientific knowledge for practical purposes or application whether in industry or in our everyday lives. In other words, specialised knowledge generated from scientific findings is applied to develop services or product in order to satisfy human needs.

Technologies are classified into two group: Advanced technology (AD) and appropriate technology (AT). The advanced technology is defined as front end engineering equipment's or tools which promote high productivity and efficiency while appropriate technology (AT) is defined as process, object, or practice that improves community's satisfaction by meeting their required needs (Pamatang et al., 2013). The AT is mostly used to refer to a simple, small-scale technology that a community could adapt (Pamatang et al., 2013). Table 1 shows the summary of the two technologies. The meaningfully purpose of technologies is when is transferred and utilised by the communities to enhance their capabilities, in daily operations therefore the concept of technology transfer become usefully components in this study.

2.1 Technology Transfer

Technology transfer (TT) is viewed as the movement of artefacts and knowledge through specific media from one place, individual or firm to another (Mazurkiewicz and Poteralska, 2017). The TT is made up of two words, "Technology" and "Transfer", a general meaning of technology has been used as a body of knowledge, techniques, equipment, methods, and processes coming out of science, invention or practical experience to make human activities convenient (Mazurkiewicz and Poteralska, 2017). While the term "transfer" in this context means the movement or shifting of tangible and /or intangible items through a suitable media from one point to another (Walter, 2012). The movement of tangible objects such as machinery, equipment, tools, items and intangibles like information, technical know-how, from the developer to the users or vice versa is a process known as technology transfer (Mazurkiewicz and Poteralska, 2017).

Table 1: Shows the difference between two technologies

# Description	Appropriate Technology	Advanced Technology
Nature	Simple	Complex
Equipment	Tools	Machinery
Skills Level	Skilled	High specialised
Raw Material	Mostly local	Local and imported
Maintenance operation	Easy	Complicated
Productivity	Low	High
Factor Intensity	Labour intensive	Fairly capital intensive
Cost	Cheap	Expensive

TT an iterative process which is made up of many individual steps for sharing knowledge and generation of new products, processes, machinery, experience and skills (Taghva et al., 2014). In order to simplify the process of TT, four stages were proposed by (Kooli- Chaabane et al., 2014). The four stages are prospecting stage, developing stage, trial stage and adoption stage.

2.1.1 Technology Transfer Stages

Prospecting Stage: This focuses on identification of the user's needs; generation of concepts, and selection of the appropriated technology (Kooli-Chaabane et al., 2014). The needs for TT are mainly driven by operational deficiency, research findings, market competiveness, change in policies and regulations, technological opportunities and human curiosity (Beecroft, 2015). The prospecting stage is highly analytical, with the focus being on preliminary analysis, searching and screening (Kooli-Chaabane et al., 2014).

Developing Stage: This is a transition phase, where the selected concept needs to be developed into a physical technology (Kooli-Chaabane et al., 2014).This is the stage where the technology is introduced to its operational use with the development of the prototype and its testing with the customers as soon as possible (Beecroft, 2018). During this stage it is vital to seek customer feedback and input continuously, because this will help to maintain the technology development in the right direction, meeting all customer requirements (Blohmke, 2014).

Trial Stage: At the trial stage the developed technologies are field- tested with the purpose of completely validating the technology and preparing it for the final launch (Kooli-Chaabane et al., 2014) Testing may therefore dramatically decrease the chances of failure through revealing flaws that could occur during operations (Ting and Lewkowicz, 2015). Nothing helps a consumer make a decision about the product more than actually trialling the products and determining its added benefits and usefulness for possible complete acceptance and adoption (Beecroft, 2018).

Adoption Stage: Adoption is the acceptance and continued use of particular products, services or ideas (Awotide et al., 2016). According to Renaud and Van Biljon (2008), technology adoption is a process which begins with the users becoming aware of the technology and ends with the users fully embracing and using the technology. When the users embrace the technology they are more likely to replace the item if it breaks, find innovative uses for it and cannot contemplate life without it (Renaud and Van Biljon, 2008).

The acceptance or rejection of the technology starts when the users are aware of the technology (Hazen et al., 2015). The Technology Acceptance Model (TAM) has been used by various researchers to predict intentions of the users to either accept or reject the technology (Renaud and Van Biljon, 2008; Chen, 2013; Hazen et al., 2015).The TAM explains human behaviour in relation to the belief, attitude and action of purpose (Chitungo and Munongo, 2013). The TAM proposes factors that are important for determining user's attitudes toward embracing the new technology (Renaud and Van Biljon, 2008).

1. External variables (EV) such as demographic variables influence perceived usefulness (PU) and perceived ease of use (PEU). The Perceived Usefulness (PU) is refer to the degree to which users believe that a particular technology would enhance their performance. Perceived Ease of

Use (PEU) is the degree to which users believe that using a particular technology would be free of physical and mental efforts (Chen, 2013).

2. Attitudes towards use (A) is defined as 'the user's desirability using the technology. The (PU) and (PEU) are the sole determinants of attitude towards the technology system (Chitungo and Munongo, 2013).Behavioural intention (BI) is predicted by attitude towards use (A) combined with perceived usefulness (PU) (Chen, 2013).Actual use (AU) is predicted by behavioural intention (BI).
3. Perceived Risk (PR) is the uncertainty about the outcomes of the use of technology. Hazen et al. (2013) describe the use of certain technology as posing certain threats to users. Therefore careful assessment needs to be made to ensure that the technology promotes and protects the users and community.Relative Advantage (RA) is the identified benefits of using a new technology as compared to the current technology. Convenience benefits, such as less melting time (for the prototype furnace),high quality products and less coal usage present significant influencers in the adoption of the technology (Chitungo and Munongo, 2013)
4. Personal Innovativeness (PI) is describe as willingness of users to embrace the new technologies and their related services for accomplishing specific goals. Users with higher PI are more likely to develop positive attitudes towards adopting technology than users with less PI (Chitungo and Munongo,2013)
5. Perceived Cost (PC) is defined as the extent to which a user believes that using technology would cost extra money. Hazel et al. (2015) explained that the cost of technology and aftersales have a significant influence on user acceptance which in turn can have a negative effect on adoption.

The technology proposed through this study was particular focused on rural areas with a population having low disposable income. Therefore, keeping the cost of the technology as low as possible was critical to ensure positive acceptance, as rural foundries have low purchasing power and are price sensitive (Chitungo and Munongo, 2013).The TAM has been recognised as a powerful theory in its own right and has been modified and extended to assist in explaining the adoption of a various technologies in the society at large.

3. Methodology

This study used a descriptive approach which was necessitated by the intent to describe the acceptance of the aluminium melting furnace by rural foundries. According to Elsbach and Kramer (2016), this approach helps the researcher to gain insights from research participants or situations which will help greatly in understanding the intent of the rural foundries.

The most common descriptive research method entails the use of questionnaires, personal interviews, phone surveys and normative surveys (Conboy et al., 2012). Descriptive research generates both qualitative and quantitative data which define the state of the phenomenon being researched at a particular point in time (Conboy et al., 2012).

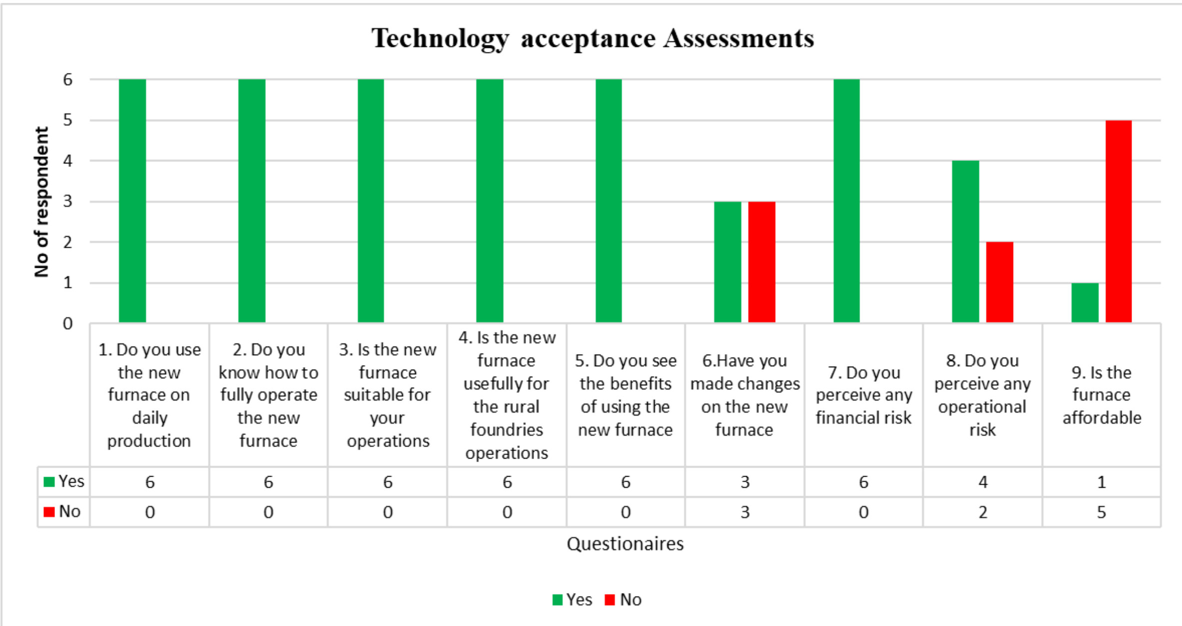
In this study a qualitative approach was used to assess the intent of the rural foundries on whether there had accepted or rejected the aluminium melting furnaces. Data were gathered through questionnaire which were prepared and formulated based on literature of TAM. TAM has been recognised as a powerful theory in its own right and which helps to explain human behaviour intentions towards accept technology (Chitungo and Munongo, 2013).

The questions in the questionnaires were structured as dichotomous, and they accorded the respondent the possibility of a ‘yes’ or ‘no’ answer (Bernard, 2013). These dichotomous items were used to determine whether the technology was accepted or rejected by the rural foundries based on the period that it has been implemented (Bernard, 2013).The questionnaires were administered through face-face interviews to the six rural foundries during which the researcher writing down the respondents’ answers. This approach was deemed to best suit the situation, mainly due to the fact that the majority of the rural foundries personnel have low levels of education and are not proficient in English. The closed ended questionnaires were translated back to them in their home language to ensure that they had a clear understanding of the questions. The questionnaire was designed in such a way that respondent’s at all six foundries were asked the same set of questions.

4. Results and Discussions

The results of the assessment for technology acceptance based on six foundries responses is shown in table 2 with the questionnaires’. The finding of this study showed that the usage of the furnace, indicates that all six foundries were using the new melting furnace in their daily operations. This was evident because of 100% yes responses to question 1 of the assessment and it was also observed during the time of sites visits.

Table 2: Technology acceptance assessment results.



The responses to question 2, showed that all the foundries know how to operate the furnace. This could be attributed to the effectiveness of training conducted to ensure that foundries knew how to operate the furnace. In addition the simple design of the furnace, using the original concept of their previous furnace, allowed ease of operation of the furnaces without requiring high skills levels.

The ability of the rural foundries to operate the furnace without high skills promoted the daily usage of the furnace. The literature in appropriate technology indicated that a transfer of complex technology to rural communities discourages the users to accept the technology. The ease of operations indicates that appropriate technology in the form of a smelting furnace was transferred to suit the education level of the foundries. The literature indicated that users will more likely accept technology when it is easy to use. Therefore, based on the results, the perceived ease of use of the melting furnace by the foundries means they are more likely to accept the technology. The compatibility is described as the perceived fit between the rural foundries and the new melting furnace. The more compatible the new melting furnace is, the more likely the rural foundries willing to accept it.

Questions 3 of the assessment addressed the issues around compatibility. In this case it meant the furnace was matched with prior experience. The assessment showed that all six foundries responded affirmatively, which meant that the foundries perceived that the new melting furnace fitted their previous experience. This was mainly derived by the use of the original concept to design and prototype the furnaces. In addition the integration of a solar power operated blower did not have much effect on the perception of the compatibility by rural foundries. Based on this result it indicated that the rural foundries might be more likely to accept the technology, since there were satisfied with the compatibility of the furnaces.

The results in question 4 and 5, implied that the all rural foundries perceived the new melting technology as useful and beneficial. All the six foundries respondent with yes on both questions 4 and 5.The rural foundries perceived that the new melting furnace was more useful compared to their previous technology. The furnace usefulness was indicated by the rural foundries that were able to produce more within less time, thus allowing them to complete production within reasonable working hours. The foundries indicated that the benefits that they observed by using the new melting furnace were shorter melting time, higher productivity, lower products rejection rate and less coal usage. The usefulness and these benefits attracted rural foundries to become more likely to accept the technology.

The question 6 is related to the personal innovativeness of the individual foundries. In general, the more innovative individuals are more likely to explore and accept the technology and are usually the trendsetters that play role to influence others. The results of personal innovativeness showed that three out of six foundries answered yes in response to this question. Ironically, three foundries which answered yes, all made similar change in the furnace by replacing the graphite crucible with their old cast iron pot.

The graphite crucible presented challenges related to taking off the aluminium melt in the crucible due to its convex shape which does not allow easy access for the scooping of molten metal, while the cast iron crucible pots is spherical and allows easy access to scoop the material. This is because it does not contain as much heat as the graphite crucible and has a short life span. In general these three foundries which have made changes to the new melting furnace are more likely to accept the technology.

Question 7 and 8 of the assessment dealt with perceived risks that the rural foundries might expected from the new melting furnace. Perceived risk is uncertainty regarding the possible negative consequences of using a product or service. In this case the risks were identified as possible financial risk and performance risk. All foundries have identified that the technology has no financial risk to them, as they have all answered in question 7, however the performance risk has been identified as the concern, since four foundries have answered yes, in question 8. This highlighted that the melting furnace was integrated with an air blower system, and therefore any breakdown of the air blower's solar system will greatly affect performance of the new melting furnace. The perceived risk by rural foundries is likely to have negative effects on the sustainability of the new melting furnace.

In response to Question 9 which was related to perceived cost, the total cost of a furnace was at ZAR 11 965.00, (~USD 767) however this technology was donated to the six rural foundries. The perceived cost was important to assess, as it provided the indication on whether the furnace was worth value for money in terms of affordability. The results showed that one foundry indicated that the furnace was affordable by indicating yes. The other five foundries showed that the furnace was not affordable by indicating no. The results indicated that due to low purchasing in rural communities, most of the foundries perceived that the total cost of the furnace was not going to be affordable for them. This was because, in the rural areas, the focus on spending is mainly on the basic needs such as food and household goods rather in technology. Therefore the total cost of the melting furnace needs to be reviewed to ensure affordability, and allow opportunity to purchase the technology to the other rural foundries which were not part of the project

5. Conclusions

The study concluded that the whole 100% of the respondent rural foundries used in this pilot study have fully accepted the new furnace with the refractory lining. As acceptance does not necessarily mean adoption which means a continuous and full use of the new technology, It would be premature to confirm its adoption. Further study on the adoption of the technology by the rural foundries in order to sustain their growth will clarify on the above.

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Effectiveness of the Pedestrian Fences to Curb Pedestrian Crossing the Freeways in Kwa-Zulu Natal, South Africa

Wasim Khan[1], Avi Menon[2]

Abstract

Traffic legislature across the world clearly indicate that freeways serve a high speed, mobility function and that pedestrians should be separated from vehicles on freeways. Despite this, pedestrian fatalities account for 47% of the total fatalities on the freeway management systems network in Kwa-Zulu Natal. Several interventions have been implemented in an attempt to reduce the number of pedestrian crashes on the freeways in Kwa-Zulu Natal. However, the effectiveness of these interventions have not been quantified. The effectiveness of the pedestrian fences was determined by analysing the advanced transport management systems data to determine whether the number of pedestrians crossing the freeway and the number pedestrian crashes had reduced after erecting the pedestrian fences.

The analysis showed that the number of pedestrians crossing the freeway and the number of pedestrian crashes did not reduce after the pedestrian fence was erected. The reason is that pedestrians preferred at-grade crossing because it was the shortest path and to escape crime that they would be exposed to if they used the pedestrian facilities. Also, occasionally, trucks crashed into the pedestrian fence which provided the pedestrians opportunities to cross at-grade. Pedestrian fences, in isolation, was found to be ineffective in reducing pedestrian crashes. Pedestrian facilities should be made safer to encourage the use of the facilities and damaged pedestrian fences should be fixed as soon as possible.

Keywords: Pedestrian fences, at-grade crossing, pedestrian fatalities

1. Introduction

Pedestrian and cyclist crash fatalities account for 26% of the total global fatalities (WHO, 2018). Pedestrian crash fatalities account for 40% of total fatalities in Africa (WHO, 2018). On the Kwa-Zulu Natal (KZN) Freeway Management System (FMS) network, 47% of the total fatalities were pedestrians. The South African National Pedestrian Action Plan had identified 356 hazardous locations for pedestrians across South Africa. More than half of the locations identified were on freeways (Ribbens, Everrit and Noah, 2008). This emphasises the relevance and the extent of the problem.

As a part of the FMS, South African National Roads Agency Limited (SANRAL) uses an Advanced Transport Management Systems (ATMS) to monitor the freeways. The purpose of the FMS is to provide

[1]Koleko Solutions; Building 16, Woodlands Office Park, Woodmead, Sandton, South Africa, 2196; +27 10 205 9294; wasimk@koleko.co.za.
[2]Koleko Solutions; Building 16, Woodlands Office Park, Woodmead, Sandton, South Africa, 2196; +27 10 205 9294; avim@koleko.co.za.

efficient and reliable transportation, that is safe, sustainable and of high quality. This is achieved through surveillance of the freeway, continuous data collection on the operations and the performance of the freeways, identifying incidents and congestion on the freeway and disseminating travel information to the road users. CCTV cameras, vehicle detection systems (VDS), loop detectors and variable message signs (VMS) are some of the devices used to achieve the above mentioned objectives. The FMS is centrally controlled and managed from the Traffic Management Centre (TMC).

The TMC is equipped to monitor the road network, disseminate traffic information and assist in incident response. The operators in the TMC receive a live video feed from the CCTV cameras. When an incident occurs, the details of the incident are logged in the ATMS system and the relevant traveller information, such as expected delays, is disseminated to the road users.

On average there were about six pedestrian crashes that occur on a monthly basis on the KZN FMS network. Freeways are designed for high speeds and mobility. Due to the high speed differential between a vehicle and a pedestrian, there is a high probability that a crash with a pedestrian could be fatal. Traffic legislation across the world clearly indicates that pedestrians should be physically separated from vehicles on high speed roads.

In the past few years, SANRAL has implemented several measures to prevent pedestrians from accessing the freeways. These measures include the construction of pedestrian bridges, fences and public transport stops on the freeway. The pedestrian fences erected at the Kwa-Mashu Interchange and in the Cliffdale area were selected as case studies. The effectiveness of the identified interventions was evaluated by analysing the ATMS data to determine whether the number of pedestrians crossing the freeway and the number of pedestrian crashes have reduced after the pedestrian fence was erected.

The details of the KZN FMS network and the background to the two sites are described in Section 2. Section 3 describes the methodology that was used in the study. The findings of the literature review are presented in Section 4. Section 5 presents the findings of the case study, followed by the conclusion in Section 6.

2. KZN FMS Network

KZN is located on the eastern shoreline of South Africa and it is bounded by Mozambique and Swaziland to the north, Free State Province and Lesotho to the west, and Eastern Cape Province to the south. The national routes in KZN consists of the N3 and the N2 freeways. Figure 1 shows the extent of the FMS network. The N3 links KZN to the north-western provinces of Gauteng and Free State and the N2 links KZN to the Eastern Cape and Western Cape provinces to the south.

According to the ATMS data, in the past year, 90 pedestrian crashes occurred, of which 49 resulted in fatalities. Even though only five percent of the total crashes were pedestrian crashes, this is still a major concern since more than 50% of the pedestrian crashes resulted in a fatality.

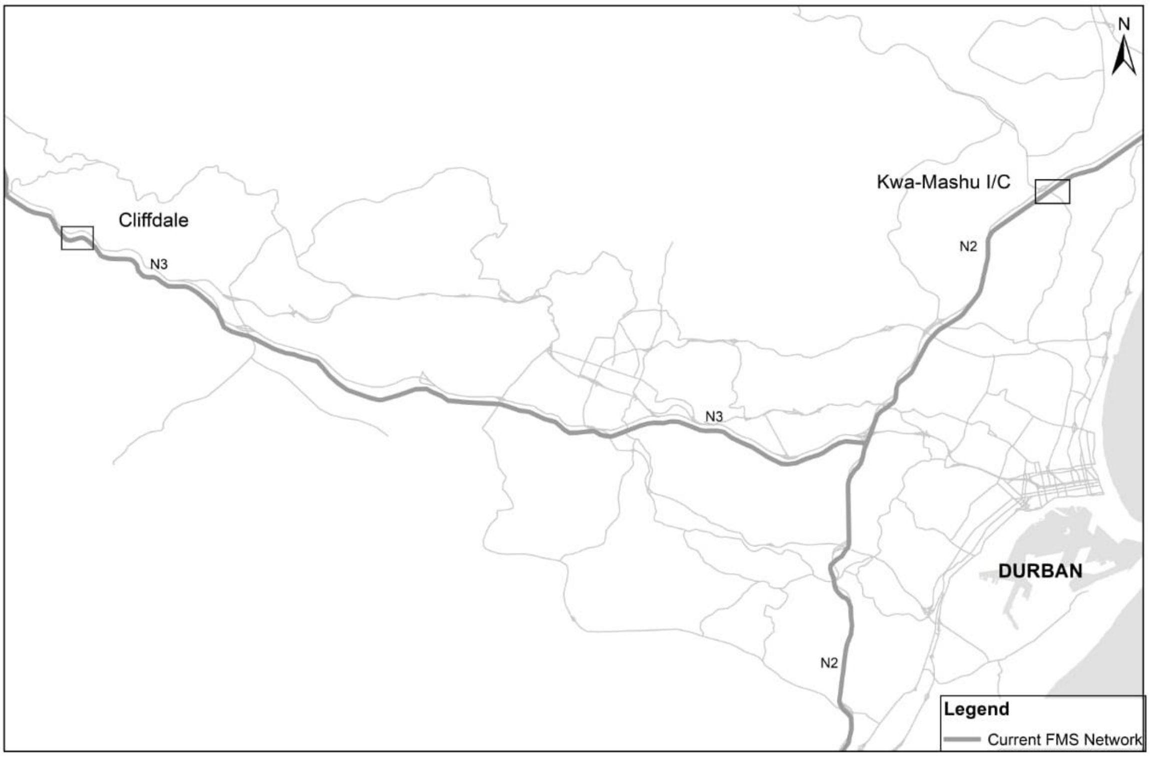

Figure 1: Extent of FMS network

SANRAL erected pedestrian fences, along the freeway, at the Kwa-Mashu Interchange and in Cliffdale in an attempt to reduce the number of pedestrian crashes in those areas. Figure 2 shows the location and the extent of the Kwa-Mashu Interchange pedestrian fence and study area. Figure 3 shows the location and the extent of the Cliffdale pedestrian fence and study area.

Figure 2: Extent of the Kwa-Mashu Interchange pedestrian fence and study area

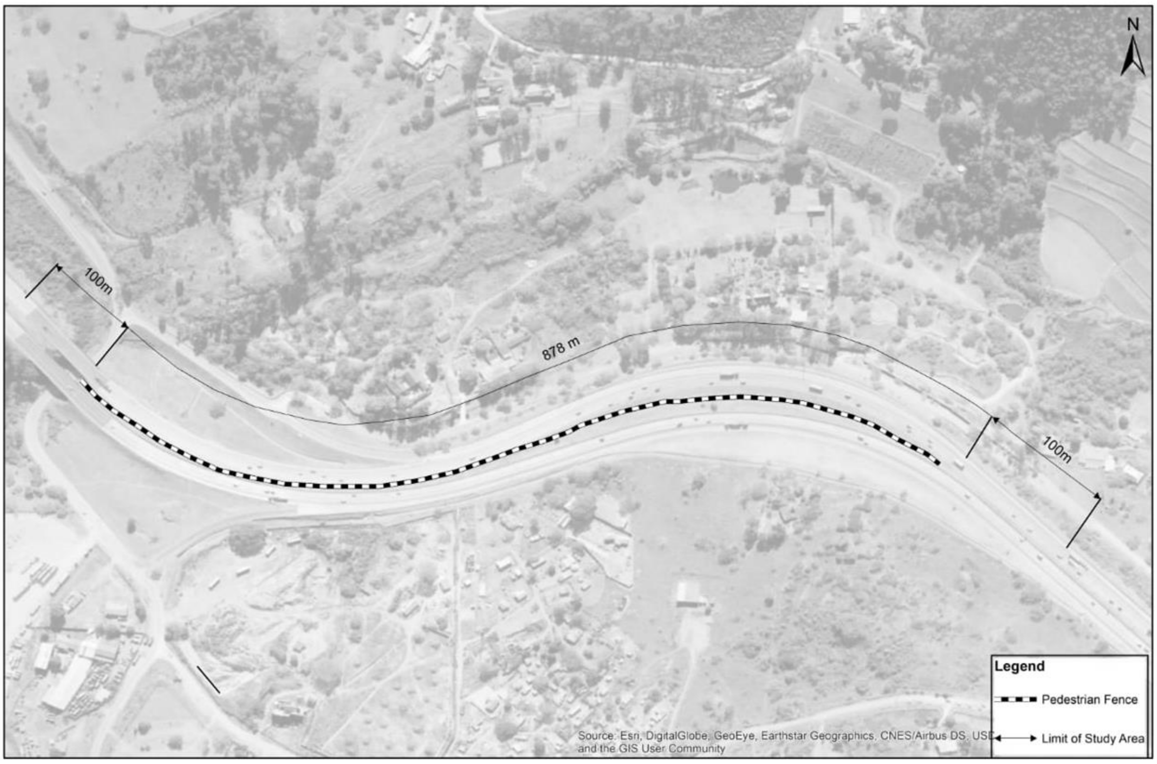

Figure 3: Extent of the Cliffdale pedestrian fence and study area

Kwa-Mashu interchange is situated, along the N2, in the Kwa-Mashu area and it is 18km north of the city of Durban. A public transport stop was constructed at this interchange to accommodate drop-offs. A staircase from the stop provides access to the pedestrian sidewalks on Curnick Ndlovu Highway. Curnick Ndlovu Highway is an arterial which intersects with the N2. These two roads are grade separated with Curnick Ndlovu Highway passing below the N2 highway.

The N2 separates the residential areas west of the N2 from the industrial area immediately to the east of the N2. Pedestrian crashes often occur when pedestrians cross the N2 while making their way between the residential areas and their place of employment in the industrial areas.

A pedestrian fence was erected, in April 2018, to prevent pedestrians from crossing the freeway. The fence was erected along the median of the N2. The fence was approximately 900m long as shown in Figure 4a.

Cliffdale is an agricultural area situated along the N3, 29km west of the city of Durban. The N3 separates the predominantly commercial area south of the N3 from the agricultural land use to the north of the N3. Pedestrian crashes often occur when pedestrians cross the N3 while making their way between the agricultural areas and the commercial areas.

A pedestrian fence was erected, in September 2018, to prevent pedestrians from crossing the freeway at-grade. The fence was erected in the median of the N3 and was 1500m long as shown in Figure 4b.

Figure 4a: Kwa-Mashu pedestrian fence

Figure 4b: Cliffdale pedestrian fence

3. Methodology

The methodology used in the study is discussed below. Local and international literature were reviewed. The review aimed at identifying reasons why pedestrians choose to cross at-grade and the effectiveness of interventions to reduce the number of pedestrians crossing at-grade.

Pedestrian fences were erected at the Kwa-Mashu Interchange and in the Cliffdale area in April 2018 and September 2018, respectively. The number of pedestrian crashes per month, which occurred within 100m of either sides of the pedestrian fences were extracted from the ATMS data. The time period analysed for the Kwa-Mashu Interchange pedestrian fence was from April 2017 to March 2018 and from April 2018 to March 2019. The time period analysed for the Cliffdale pedestrian fence was from November 2017 to August 2018 and from September 2018 to July 2019.

The effectiveness of the pedestrian fences were determined by comparing the number of pedestrians crossing the freeway and the number of pedestrian crashes that occurred within a time period before the pedestrian fence was erected to the number of pedestrians crossing and the number of pedestrian crashes that occurred after the pedestrian fence was erected. The TMC managers were interviewed to better understand pedestrian behaviour and land-use in the area.

4. Literature Review

A literature review was conducted to understand the effectiveness of pedestrian interventions and the reason why pedestrians choose to cross at-grade. Alticafarbay *et. al*, (2007), observed the use of five pedestrian bridges in the CBD of Ankara and surveyed the pedestrians using the bridges as well the pedestrians that crossed at-grade to understand the reasons why pedestrians chose to cross at-grade or use the pedestrian bridge to cross. The study found that travel time and the perceived ease to use the bridge were major factors when pedestrians selected their route. The preferred ease to climb the bridge was emphasized as an influencing factor when the study found that the bridge with escalators was the most utilised. This paper provided valuable insights into route selection, however, this paper only considered pedestrians crossing within a CBD.

Traffic legislation across the world clearly indicate that freeways should be solely for the use of motor vehicles and that non-motorised transport users should be separated from the vehicles. In spite of there being fences along the freeway and barriers in the median, pedestrian often choose to cross the freeway at-grade. There is a lack of sufficient research into why pedestrians choose to cross the freeway at-grade (Sinclair and Zuidgeest, 2015).

Studies (Ribbens, 1996; Behrens, 2010; Sinclair and Zuidgeest, 2015) also found travel distance and travel time were the two critical factors that influenced a pedestrian's choice to cross a freeway at-grade, rather than using the pedestrian bridge. The safety and security from crime that occurs on the pedestrian bridge was also found to be a critical factor.

Behrens (2010) studied the distance of the footpaths from the nearest facility and found that the mean distance was 123m on the freeway. Moore (1953) found that approximately 80% of pedestrians would use the pedestrian facility if it took the same time to cross the facility as it would to cross at-grade. Moore and Older (1965) showed that pedestrians would not use the facility if the travel time was 1.5 times longer than the travel time to cross at-grade. This was found to be true for the South African context (Ribbens, 1996). Surveys also showed that pedestrians were afraid of being robbed by criminals waiting for them on the pedestrian bridge. The surveys also found that in some instances the pedestrians would use the pedestrian bridge only when in groups.

All of the above mentioned studies were based on the usage of pedestrian bridges. However, at the time of writing this research paper, there were no literature available on the effectiveness of pedestrian fences in preventing pedestrians from crossing the freeway. This indicates the need to evaluate the effectiveness of pedestrian fences which is discussed in the next section.

5. Effectiveness of Pedestrian Fences

Several interventions were implemented in an effort to prevent pedestrians from crossing the freeway at-grade. This paper evaluated the effectiveness of the pedestrian fences as a treatment to prevent pedestrians from crossing at grade. The pedestrian fences erected at the Kwa-Mashu Interchange and at the Cliffdale were investigated. The findings of the study are discussed below. It should be noted that landuse surrounding the locations of these pedestrian fences did not change significantly during the analysis periods.

5.1 Kwa-Mashu Interchange

The analysis showed that pedestrian crashes did not occur on a monthly basis, as shown in Figure 5. In the period being analysed, 13 pedestrian crashes occurred in 24 months. There were also an additional 4 pedestrian crashes which occurred within 1km of the pedestrian fence.

Figure 5 shows that there were seven pedestrian crashes during the 'before intervention period'. It was found that there were six pedestrian crashes during the 'after intervention period'. Further analysis showed that majority of the pedestrian crashes occurred during the weekend (Friday evening – Sunday) and after sunset. Based on video surveillance and interviews with the TMC manager, it was found that the number of pedestrians crossing the freeway at-grade remained unchanged. The pedestrians either jumped over the fence or walked around the fence. Thus it was concluded that the pedestrian fence did not deter pedestrians from crossing the freeway at-grade, nor did the number of pedestrian crashes or fatalities reduce.

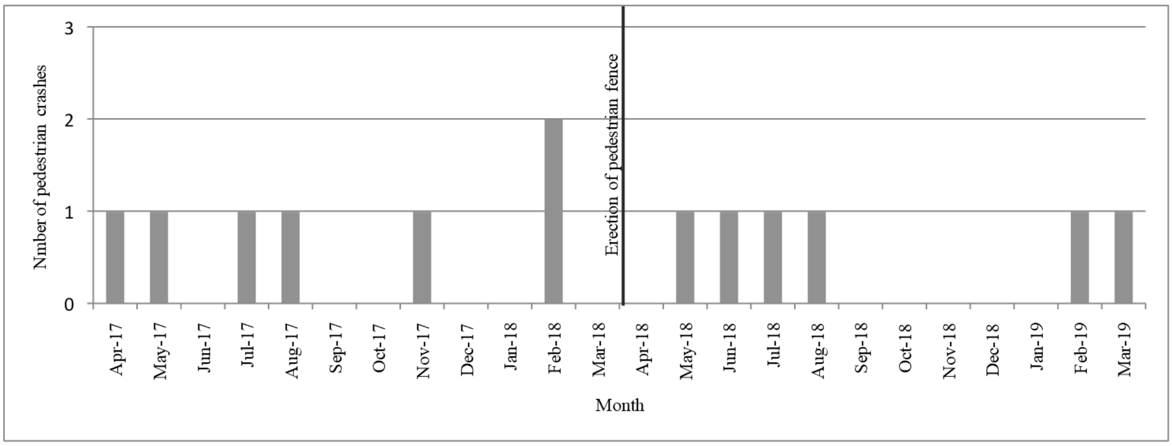

Figure 5: Number of pedestrian crashes that occurred in the Kwa-Mashu study area

5.2 Cliffdale Pedestrian Fence

The analysis showed that pedestrian crashes did not occur on a monthly basis, as shown in Figure 6. In the period being analysed five pedestrian crashes occurred in 20 months.

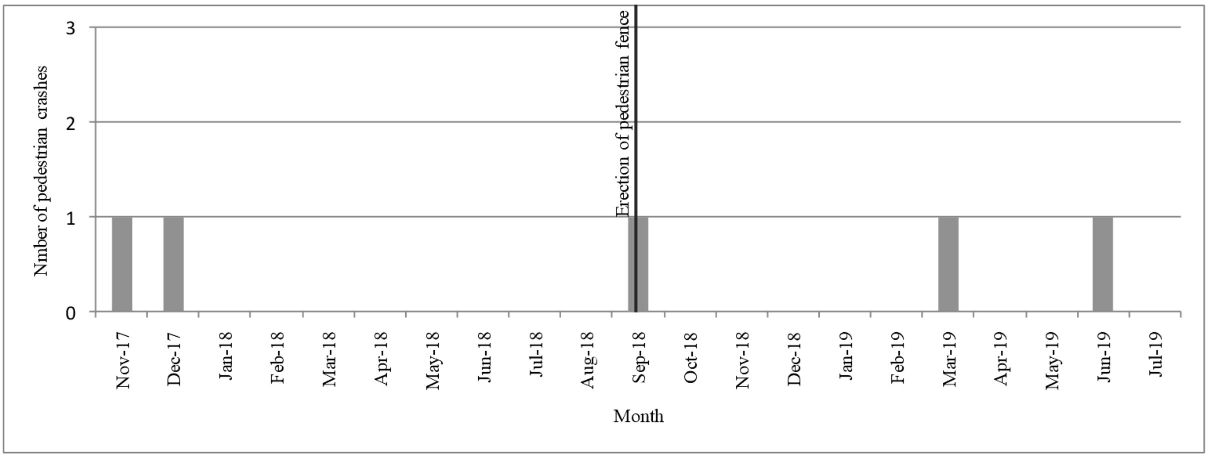

Figure 6: Number of pedestrian crashes that occurred in the Cliffdale study area

The pedestrian crash that occurred in September 2018 was excluded from the analysis since it occurred in the month that the pedestrian fence was erected. Figure 6 shows that there were two pedestrian crashes during the ‘before intervention period’. It was found that there were two pedestrian crashes during the ‘after intervention period’. Further analysis showed that all of the pedestrian crashes occurred during the weekend (Friday evening – Sunday) and half the crashes occurred after sunset. Based on the video surveillance and an interview with the TMC manager, it was found that the number of pedestrians crossing the freeway reduced, however there was no reduction in the number of crashes. Given the limited scope and budget, extensive surveys could not be conducted to determine the number of pedestrians who crossed before and after the pedestrian fence was erected.

The TMC managers were interviewed to understand why pedestrian crashes continued to occur after the pedestrian fence was erected. They indicated that trucks often crash into the pedestrian fence, resulting in damages to the fence. This created opportunities for pedestrians to cross the N3 at-grade until the fence was fixed.

5.3 Discussion

The analysis found that the pedestrian fences at the Kwa-Mashu Interchange and in Cliffdale were not effective in reducing the number of pedestrian crashes. However, the number pedestrians crossing the freeway at-grade did reduce in Cliffdale. It was found that the trucks often crashed into the pedestrian fence and damaged it. This created opportunities for the pedestrians to cross at-grade.

The number of pedestrians crossing the freeway at-grade at Kwa-Mashu interchange did not reduce because pedestrians continued to cross the freeway by jumping over the fence or by walking around the fence. The distance that the pedestrians would have to walk to use the bridge and the safety aspects were some of the factors identified. These findings are consistent with the findings of the studies completed by Ribbens (1996); Behrens (2010); Sinclair and Zuidgeest (2015).

Alticafarbay et al. (2007) proposed that utilisation of the pedestrian bridge could be increased by motivating the use of stair climbing with banners stating ”keep fit”, “daily exercise”, “work your legs”, “free exercise” and “stay healthy”. These banners have proven to increase the use of the staircase (Kerr et al., 2001). Sinclair and Zuidgeest (2015) suggested that more pedestrian bridges should be constructed and the safety of these bridges should be improved. Behrens (2010), went on further to suggest that construction of more pedestrian bridges alone would not solve the problem. These bridges should follow the desire line as much as possible and should be designed for universal accessibility. These recommendations should be further studied to identify solutions to reduce the number of pedestrian crashes on freeways.

6. Conclusion

This study aimed to determine the effectiveness of the pedestrian fences erected at the Kwa-Mashu Interchange and the Cliffdale area. The analysis found that the number of pedestrian crashes did not reduce after the pedestrian fences were erected. Further analysis also showed that majority of the pedestrian crashes occurred on the weekend and after sunset.

The number of pedestrians crossing the freeway at-grade at Cliffdale was found to be lower after the fence was erected. However, the fence was not effective in deterring pedestrians at Kwa-Mashu Interchange. The distance to the pedestrian bridge, desire line and safety were some of the factors identified. This is consistent the findings in the literature review. However, why the Cliffdale fence was more effective as compared to the Kwa-Mashu Interchange is not fully understood. The socio-economics of the area, availability of public transport or alternative modes, land-use and terrain are some of the factors that need to be further explored.

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Recycling Greywater from domestic households for reuse

Geofrey Kaliro[1]

Abstract

The African continent is facing challenges related to climate change which have worsened the problem of water scarcity. This had greatly affected agriculture production hence calling for methods which can avail water for irrigation and other domestic activities such as flashing toilets. The enormous effects of climate change are severe and endangering food security leaving so many rural and urban populations without source of livelihood and hence endangering human survival.

Several measures have been invented to bring calm to the increasing drought and untimely rains such as weather forecast, irrigation methods, solar wells and manual pumps plus relatively cheaper cost water pumps. But this has not addressed the challenge of unreliable rainfall and adaptability of the irrigation methods. This paper introduces a simple method of using simple tanks to collect water and using floating plants in plant bed to clean the odours and remove pollutants. Different tests were carried out to determine the BOD5, COD, phosphorous, potassium, nitrates, E. Coli and TSS and were found to be reduced. The study therefore recommended that is grey water is to be reused in irrigation purposes, nitrates should be added as fertilisers depending on the crops.

Keywords: Waste water, Climate Change, Food security

1. Introduction

Africa has been hit with a new wave of climate change with severe consequences to agriculture endangering food security. The IPCC (2018) warned that the level of temperatures in African regions such as sub Saharan and west Africa are already over 1.5 ^{0}C exceeding the global mean temperature. As climate events worsen, people are also threatened by more gradual changes, such as climbing temperatures and declining rainfall. Droughts alone have affected more than 1 billion people in the last decade, and the damage hits the agriculture industry, the primary source of food and income for many people in developing countries of Africa. Between 2006 and 2016, more than 80 percent of drought damage was absorbed by agriculture, and 2017 data from the World Bank reported drought has wiped out enough produce to feed 81 million people every day for a year since 2001 across the world (world bank, 2017).

[1] Holds a Diploma in Architecture, Municipal Land Supervisor, Jinja Municipal, Uganda East Africa 4th Year student of Bachelors of Civil Engineering, Ndejje University, Uganda East Africa. +256754131853, kalirog@gmail.com

As a matter of fact, if there were to be no further change in Africa's climate, its current state already presents grave risks to the continent's people and economies. Global warming could trigger more frequent and severe weather disasters, shifts in rainfall patterns and climate zones, and rising sea levels. To combat this precarious situation, there is need to revise the practices of water usage so as to avail more water for agriculture practices. One of the ways to improve water availability more water for agriculture practices in all regions is reusing water from kitchens, bath and wash rooms termed as grey water.

1.1 Problem statement

Many households in African societies have been accustomed to the old model of fetching water from the wells but development has introduced new piped water systems where water comes at a cost. Making matters worse, the climate change has worsened the situation as the water wells are drying up living many households with limited water to do all the activities such as irrigation and construction activities. Much of the water used in households goes for bathing, washing utensils and clothes and cleaning the houses. If all this water is collected in a system and directed to a single tank. There is much hope that water for the rest of activities can be availed and this can help aid agriculture activities through irrigation hence improving food security.

1.2 Literature review

Grey water is a wastewater derived from kitchens, bathrooms (i.e., discharges from shower, hand basin, bath), and laundry water. Grey water does not include the wastewater produced from toilet use, which is considered black water. The generated quantity of grey water can greatly vary between different households within one community and depends on different factors, such as availability of water and lifestyle of household. In general, the volume of grey water accounts between 50% and 80% of the domestic household water uses (Redwood, 2008). According to Faruqui and Al-Jayyousi, (2002), the domestic generated grey water volume in African communities is more than 3 litters per day per person in poor households and more than 10 litres per person in richer households.

1.2.1 Composition of grey water

The quality of grey water is highly variable due to the variability in household water use. Grey water contains the same contaminants (organic compounds, nutrients and pathogens) as raw sewage water. However, grey water contains low concentrations of contaminants compared to those in raw sewage water and black water (Otterpohl, 2002). Greywater has lower COD and BOD contents, because faecal matter and toilet paper are not present in greywater and because more water is used for the production of greywater than for combined wastewater (Ledin et al., 2001a).

Table 1: Average pollutants in grey water as compared to black water

Average pollutants loading		
Type	**Grey water**	**Waste water (Grey +black water)**
BOD5	34	71
SS	18	70
Tot. N	1.6	13.2
Tot. P	3.1	4.6
Tot. P*	0.5	1.9

1.2.2 Greywater Treatment Options

Greywater reuse methods can range from low cost methods such as the manual bucketing of greywater from the outlet of bathroom, to primary treatment methods that coarsely screen oils, greases and solids from the greywater before irrigation via small trench systems, to more expensive secondary treatment systems that treat and disinfect the greywater to a high standard before using for irrigation. The choice of system will depend on a number of factors including whether a new system is being installed or a disused wastewater system is being converted because the household has been connected to sewer.

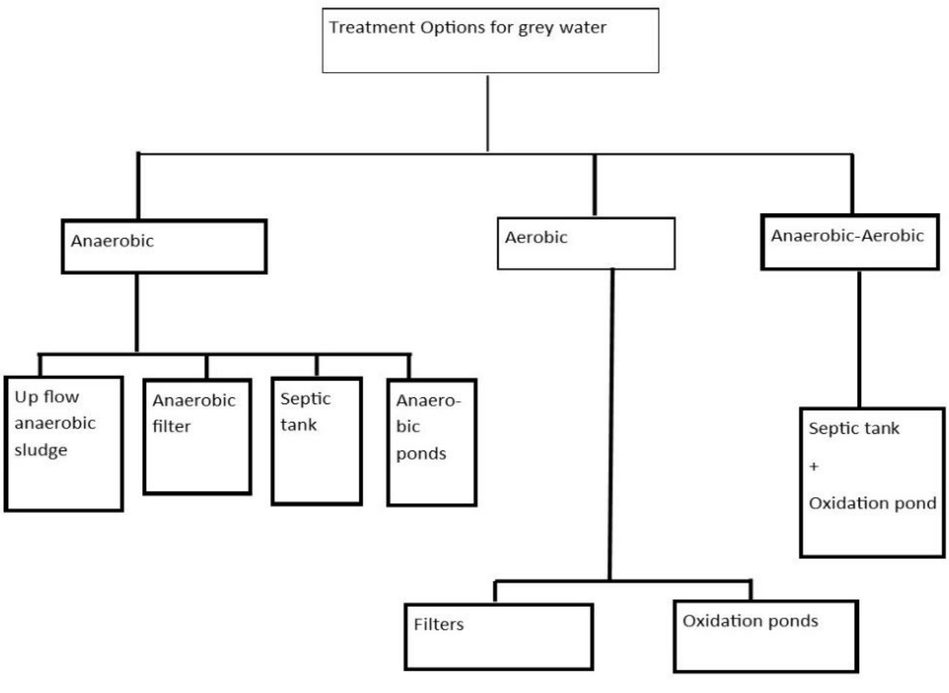

Figure 1: Treatment options for grey water

1.2.3 Components of Greywater Treatment Systems

A number of technologies have been applied for greywater treatment worldwide varying in both complexity and performance but commonly will comprise of primary treatment and secondary treatment. a) Primary treatment - pre-treatment to secondary treatment: - 1. Screening 2. Equalization

b) Secondary treatment: -1. Gravel filtration 2. Sand filtration 3. Chlorination.

2. Methodology

The set up for this experiment involved the use of an aerobic process of floating plants. Water collected from domestic purposes such as kitchen, wash and bathrooms is directed to the set up by the use of pipes as shown in the figure below. The data was collected using observation and interview guides with households in the researcher's home.

2.1 Grey water treatment system

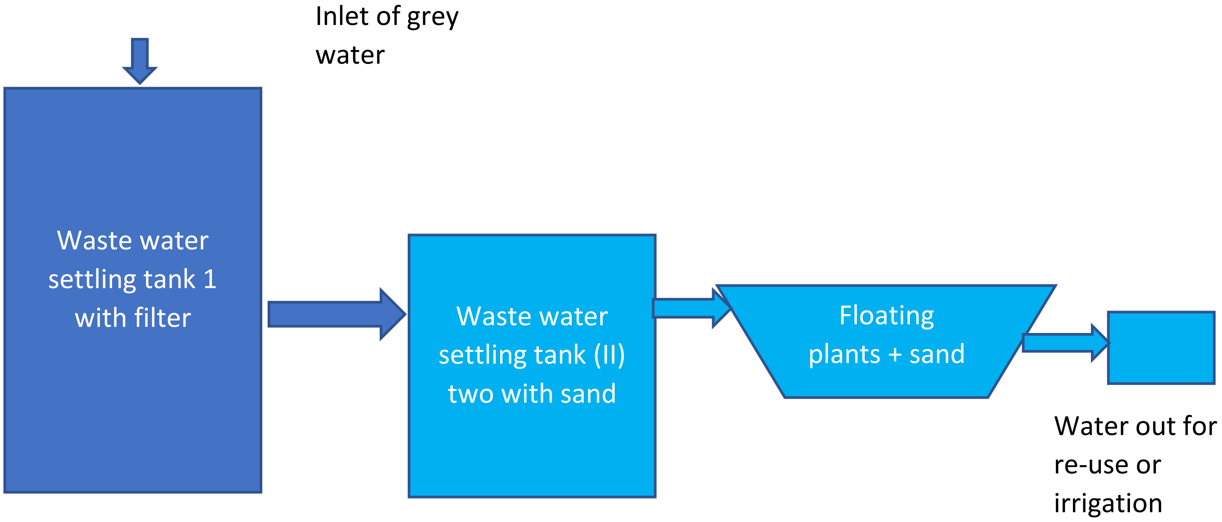

Figure 2: showing the block diagram showing a grey water treatment system

2.1.1 Description of the system

Screen/filter: This is used to remove floating and suspended materials such as Grease and oil from detergents used. Screen can be a mesh with less than 10 mm size to remove coarse particles. The screens can be placed at the inlet to the piping system of sources such as bathroom, sinks etc. to remove large particles and prevent an overload of particles at the outlet. The screens can be cleaned manually and solids disposed off along with solid waste.

Settling tank 1: This is the first tank which serves to receive the grey water after the filter and it is dependant on the number of people in the family/household. This serves to settle some solids while the rest of the water continues to the holding tank. Equalization or settling tank is required to collect grey water for continuous flow to the filters for treatment and facilitates in settling of course particles. It also allows for balance flow by taking into account maximum flow of greywater generated during morning hours due to bathroom use. Adequate aeration and mixing must be provided to prevent odours and solids deposition in equalization tank and this is achieved by providing baffles.

Removal efficiency of suspended solids in sedimentation tanks depends on surface area and depth of tank. Surface loading rate is the basic guidance parameter for determining size of tank.

Holding (Collection) tank 2: this is used to settle solids from the tank. A collection or storage tank is required to have the appropriate capacity to handle the average daily generation of treated greywater. In case the greywater generation is large with a capacity of more than 100 liters/day, collection tank may have capacity to handle half of the quantity of greywater generated per day.

Floating plants: the floating plants are for removing bad odour, BOD and suspended solids.

Slow sand filter: Colour, bacteria, suspended solids and some amount of BOD

2.1.2 Treatment tests for COD, BOD, E.Coli, TSS

Samples were picked from the grey water collected from the researcher's home and kept in properly marked plastic containers, and were well preserved by storing then at a temperature of 4^0C in an ice box.

BOD5: BOD was determined using the oxygen electrode method /Azide modification of Winkler method (APHA/AWWA/WEF, 2012).

Chemical Oxygen Demand (COD); Chemical oxygen demand was determined using the closed reflux colorimetric method (APHA/AWWA/WEF, 2012). The COD readings were obtained from a pre-calibrated spectrophotometer (Helios Aquamate NRTL/C England).

Total Suspended Solids (TSS); TSS were determined using the Photometric method (APHA-AWWWA-WEF., 2012). Measured volumes of well mixed samples were filtered through pre-weighed glass microfiber filters and dried in an oven (Model G90-C, Genlab, Widnes, England) at 103-105^0C for at least 1 hour after which the samples shall be cooled in a dessicator and then weighed.

Total Nitrogen (TN); Total nitrogen was determined using the Persulfate reduction method (APHA/AWWWA/WEF, 2012). The total nitrogen concentration was read from a spectrophotometer (Helios Aquamate NRTL/C England).

Total Phosphorous; Total phosphorus was determined using the Persulfate digestion with the Ascorbic method (APHA/AWWA/WEF, 2012). The total phosphorus concentrations of the samples was read from a spectrophotometer (Helios Aquamate NRTL/C England).

3. RESULTS AND ANALYSIS

Water produced in a home is calculated basing on the number of people in the house and the loading rate is determined basing on the number of times they carry out those activities. For example, washing, bashing, washing utensils.

Quantity of water produced in a 5-member household = number of litres used per person * number of people

Q = 20 *5

Q = 100 litres

Therefore, if a household produces 100 litres per day.

The tanks used in collecting the water should be at least half of the water used which is 50 litres.

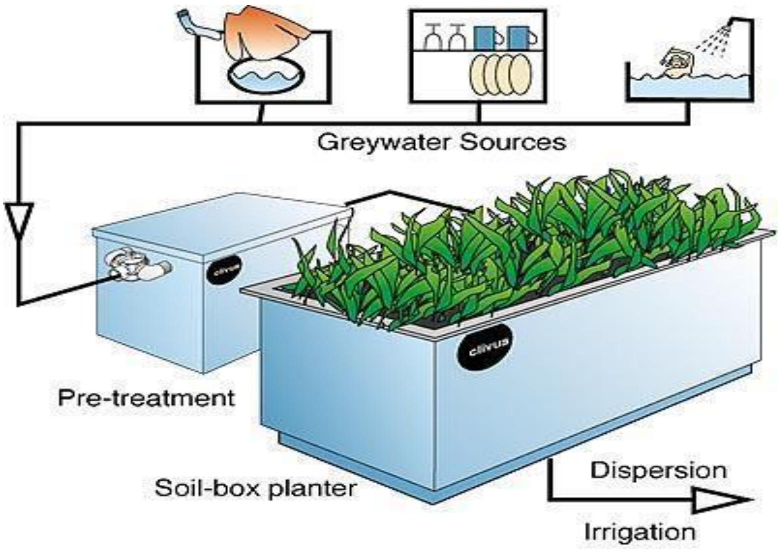

Figure 3: showing the anaerobic to aerobic treatment

Table 2: showing the results on the grey water collected from the researcher's home

Parameter	**Grey water**
BOD5	33
SS	17
Tot. N	1.7
Tot. P	3.2
Tot. P*	0.6

From the table of results, it can be understood that components like nitrogen which are needed by legumes are low in quantity ad therefore these can be added by application of fertilizers rich in nitrates.

The treatment unit significantly improved the quality of water with regards to BOD5, TSS, and a few other water quality parameters. Coliform and E. coli were completely eliminated. Treated water met the world health standards standards for reuse for irrigation.

A survey among the adult male population of the village overwhelmingly showed their eagerness to adopt this system for re-use in agriculture for different activities such as drip irrigation, flushing of toilets.

and use the treated reservoir water for uses other than agriculture. Such change in water use patterns will definitely have an impact on groundwater extraction, as household requirements for groundwater are likely to decrease.

4. Conclusion

The benefits of greywater recycling include: Reduced use of freshwater, Less strain on septic tanks or treatment plants, More effective purification, Feasibility for sites unsuitable for a septic tank, Reduced use of energy and chemicals, Groundwater recharge, Plant growth, Reclamation of nutrients, Increased awareness of natural systems of water treatment and sensitivity, to natural cycles. Saving water per day. Saving of drinking water by reuse of grey water. Grey water reuse for toilet flushing and gardening.

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Improving Incident Detection KPI on SANRAL'S Freeways in Gauteng, South Africa

Claire Birungi[1] and Avi Menon[2]

Abstract

The South African National Roads Agency Ltd (SANRAL) primarily relies on CCTV cameras to detect traffic incidents occurring on the Freeway Management System (FMS) network. On the Gauteng FMS network, over 90% of the incidents are detected using CCTV cameras. The operators have to manually pan, tilt and zoom each camera to detect incidents along the freeway. Traffic incidents are the major cause of severe or fatal injuries, congestion and delays on the freeway. They may also result in secondary incidents such as rear-end or multi-vehicle collision. It is therefore of utmost importance that the incidents are detected and cleared within the shortest time span. In the current contract, SANRAL has set the 'Incident Detection KPI' as 3 minutes. In other words, on average, incidents have to be detected within 3 minutes from the time of occurrence of the incident. Once the incident has been detected, the operator would rewind the video footage to determine the 'occurrence time' of the incident. However, in most cases (approximately 70%), the occurrence time of the incident is unknown. This is predominantly because the camera was facing away from the incident location (facing the opposite direction).

This study aimed at improving CCTV surveillance, given the current infrastructure and resources; thereby increasing the number of incidents with an occurrence time. The study assumed that there would be no changes to the current camera positions, type of camera being used and operational structure. It was also assumed that there would be no additional cameras or human resources. Several surveillance methods were evaluated. The proposed surveillance method was tested using a before and after study. Incident data from May 2017 was used as the "before" and incident data from May 2018 (three months after implementation of the proposed new method) was used as the "after" period. The results of the analysis showed that subsequent to the implementation of the automated pre-set surveillance method, the number of incidents with an occurrence time increased by approximately 15% – an increase of approximately 500 incidents. The paper eludes to some of the shortcomings that still exist in the new method and possible ways of overcoming it.

Key words: Incidents, Surveillance, CCTV Cameras, Freeways

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[1] Koleko Solutions Pty Ltd; Building 16, Woodlands Office Park Johannesburg; E-mail: claireb@koleko.co.za.

[2] Koleko Solutions Pty Ltd; Building 16, Woodlands Office Park Johannesburg; E-mail: avim@koleko.co.za.

1. Introduction

The South Africa National Roads Agency Limited (SANRAL) is mandated by the National Transport Policy to implement incident management (IM) programmes on the entire national road network of South Africa (Department of Transport, 2017). The IM programme was implemented and it is managed under the contract for the Design-Build Operation and Maintenance (DBOM) of the Gauteng Freeway Management Systems (Gauteng FMS). The objective of the IM programme is to mitigate any adverse effects of traffic incidents such as congestion, injuries and fatalities. To do so, one of the critical focus areas of the programme is early detection of traffic incidents (SANRAL, 2016).

The Gauteng FMS thus utilizes a network of Closed Circuit Television (CCTV) cameras, Variable Message Signs (VMS), Vehicle Detection Sensors (VDS) and incident response vehicles that are deployed along the freeway network to assist with IM. Each of the components has a specific purpose in the management of incidents on the freeway. The CCTV cameras have the primary role and are the primary source of detecting incidents that occur on the Gauteng FMS. On average, over 90% of incidents are detected by CCTV cameras. Figure 1-1 shows the deployment of cameras along some sections of the Gauteng FMS network and Figure 1-2 shows a typical view from a CCTV camera.

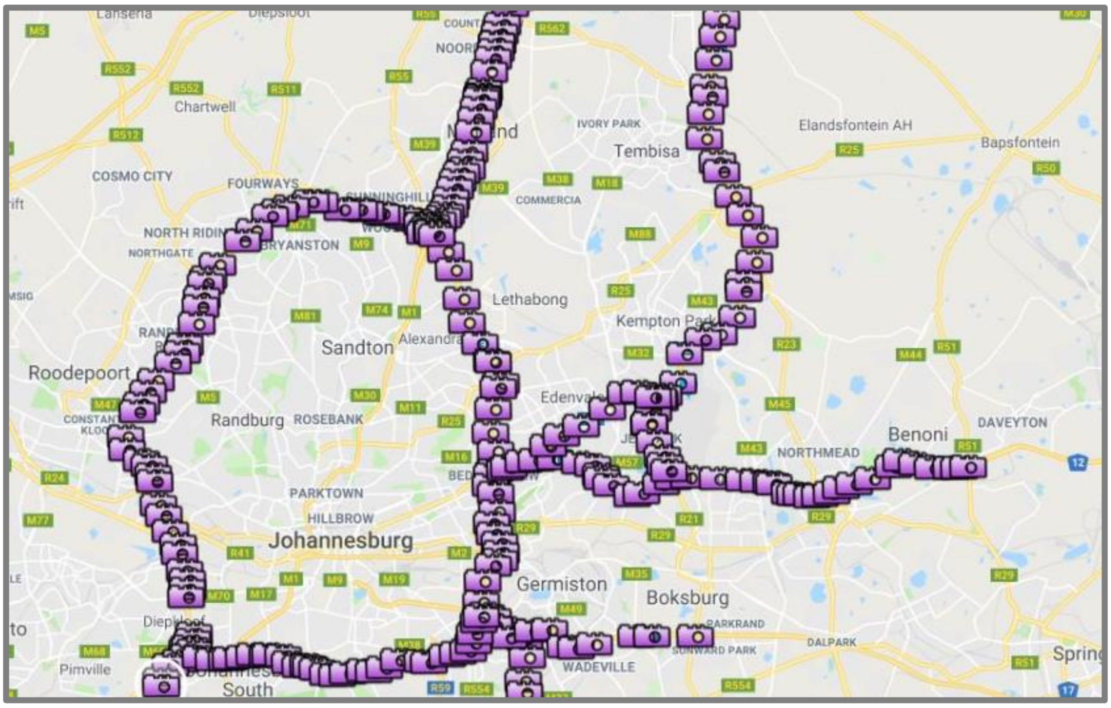

Figure 1-1: Deployment of CCTV cameras along the Gauteng FMS Network

Figure 1-2: Typical view from a CCTV camera

A team of operators based at the Traffic Management Centre (TMC) monitor the CCTV footages and identify any incidents that occur on the freeway. The number of cameras that each operator monitors depends on a variety of factors including the time of day, traffic volume on the section of road that is being monitored, known hotspot area and the number of operators available per shift. At any point in time, the operators can monitor between 16 and 32 cameras. The operator monitors the cameras on 3 computer screens – two computer screens that display up to 16 camera views on each screen. Any of the camera views can be manually maximised onto the third computer screen to view details of the incident which includes looking for the actual occurrence time of the incident. **Error! Reference source not found.**1-3 shows the current setup of an operator's workstation.

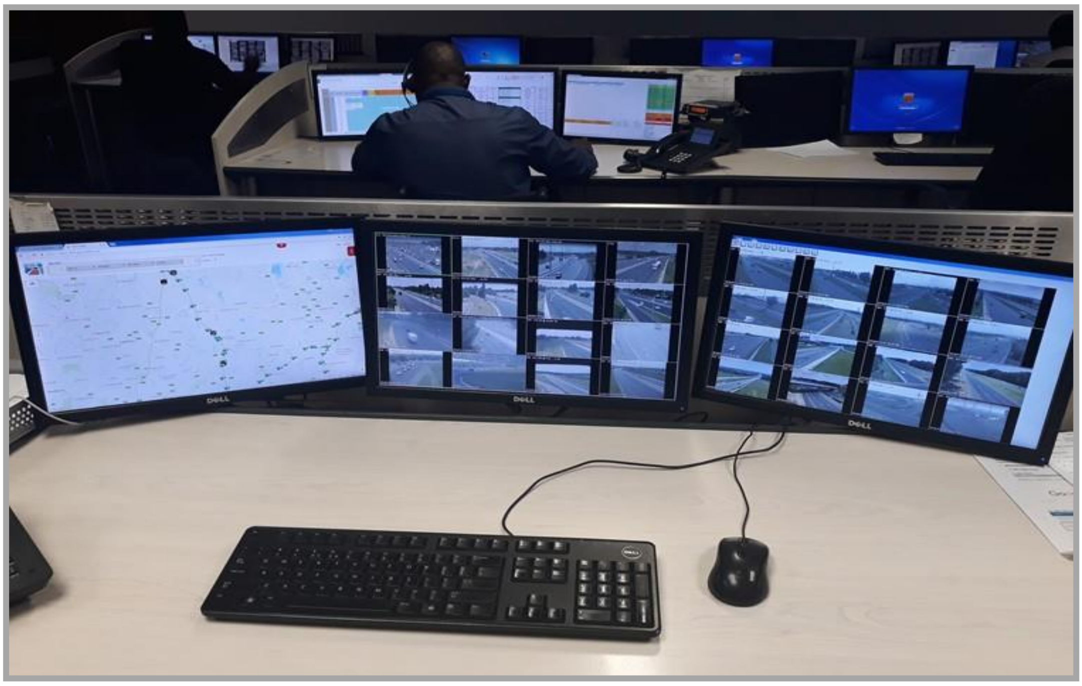

Figure 1-3: Typical Operator Workstation with Computer Monitors

When an incident occurs, the operator immediately captures the details of the incident in the Advanced Traffic Management Systems (ATMS). Based on past experience, the operators rarely see the incident occurring. Often, the operator observes traffic congestion on their section of the road and then they pan the camera to the front of the queue, only to realise that there has been an incident. The time when the operator detects the incident and registers it on the ATMS is recorded as the “Incident Detection Time”. Incident Occurrence Time and Incident Detection Time are two key inputs into the ATMS based on which one of the KPI is measured. In this contract, the detection KPI ensures that incidents are detected by the CCTV cameras within 3 minutes. In other words:

$$\text{Incident Detection Time} - \text{Incident Occurrence Time} < 3 \text{ minutes}$$

The “Incident Occurrence Time” is the actual time the incident occurred. If the operator did not see the incident occurring, then he/ she may rewind the video footage to determine the Incident Occurrence Time. In 2018, on average, there were 3200 traffic incidents detected per month on the Gauteng FMS. However, the incident occurrence time of approximately 70% of the incidents could not be determined, in spite of being able to rewind the camera footage. This is a cause of concern as it limits the ability to provide quick response, especially at severe crash sites. In addition, it decreases the efficiency of the whole network in terms of congestion and delays.

There are several reasons as to why operators may not be able to accurately detect the time of occurrence of incidents. These include:

- The camera could be facing in a direction away from the location where the incident occurred;
- The camera could be facing the correct direction, but it was zoomed in, well past the location of the incident;
- The operator missed the incident while he/she was manually panning through the cameras;
- The operator missed the incident while he/she was capturing details of the previous incident in the ATMS.

This paper highlights the new methodology that was developed to increase the number of incidents with an incident occurrence time – thus improving the KPI. It is important to note that the scope of the study was limited to improving the detection KPI using the existing infrastructure and resources available - the existing cameras positions, technical equipment (cameras, wireless communication devices, software) and human resource. Incident data collected from May 2017 (manual surveillance method) was used as the base or control scenario. The new method was piloted for a period of 3 months from March 2018 to May 2018. Incident data collected from May 2018 was compared with the base scenario. The findings of the study are summarised in this paper. The paper also eludes to some of the shortcomings that still exist with the new method and possible ways of overcoming it. The section below describes the manual surveillance method that was used.

2. Manual Surveillance Method

The spacing between the cameras on the network range between from 250m to more than 1km. The operator does not have a sequential continuous coverage of the freeway. The operator used a computer mouse to pan, tilt and zoom each camera. By doing so, the operator could view a stretch of the freeway that is within the radius of the camera's view to look for incidents. When an incident was detected, the operator would record the details of the incident in the ATMS. In order to detect an incident timeously, it is essential that an operator is able to view all the cameras and identify the incident as quickly as possible. The way in which the operator pans each camera, how quickly the operator cycles through the cameras and the operators' ability to not miss an incident while skimming through the various cameras determine the efficiency of the operator.

The disadvantage of this method was that the operator had to continuously pan one camera after another, up to 32 cameras, to view the sections of the freeway. This can be a cumbersome exercise, which may lead to fatigue and a drop in efficiency and responsiveness of the operator. Secondly, if the operator takes too long to cycle through the cameras, by the time he/she returns to the first camera, there may be an incident that occurred and was left undetected for a long time. Thirdly, the operator is expected to cycle through all cameras within a specified minimum time (3 minutes). The time constraint forces the operator to quickly skim through the cameras, which may lead the operator missing incidents. However, the advantage of manual surveillance is that when an operator pans the camera, he/she is able to have a comprehensive view of the freeway sections.

3. Alternative Surveillance Methods

Alternative methods of camera surveillance were then developed with the aim of improving CCTV surveillance to increase the detection of incidents. The following sections provide a description of the alternative methods that were explored.

3.1 Static-Continuous View Surveillance

Static-continuous view surveillance can be described as the positioning of the camera in a fixed position to view the entire freeway segment from end to end at specific times of the day. On the computer screen, the operator would be able to see the entire stretch of the freeway, without having to pan the cameras.

The direction of the camera view may be determined in such a way that the view is clear of any obstruction during its entire period, and preferably in the direction of the highest traffic volumes. In order to position the camera view clear of obstructions, the IT technician, traffic specialist, operator and supervisor should identify all possible sources of obstructions. Once the obstructions are known, the camera view should be set in the opposite direction of the obstruction. Some of the obstructions that are known include:

- The position of the sun (glare);
- Camera poles/ mast;
- Vegetation;
- Bridge deck, pillars, gantries and other infrastructure.

In this method, for example, each camera view (zoomed out) would be temporarily positioned in one direction during the AM Peak period and changed to the opposite direction during the PM Peak period. In other words, all the cameras would be ideally facing the same direction during the AM Peak period. During the PM Peak period, all the cameras would be rotated to face the opposite direction. Therefore, the camera view is changed only twice during the day. Figure 3-1 and Figure -2 show the ideal positions for static viewing for roads oriented in the east-west direction, for example, the N4 freeway. The dotted lines show the areas covered by the camera view. The distance between the cameras should not be more than 400m for the method to be feasible – based on the technical specification of the current cameras on the network (Teti Traffic, 2018). Otherwise, it would not be possible to achieve continuous coverage.

The advantage of this method is that it provides the operator with a continuous and holistic view of the freeway segment. In addition, it is less labour intensive for the operator, making it easier for him/ her to identify an incident. It can be said that this could be the ultimate alternative given that the cameras are optimally spaces to provide continuous coverage.

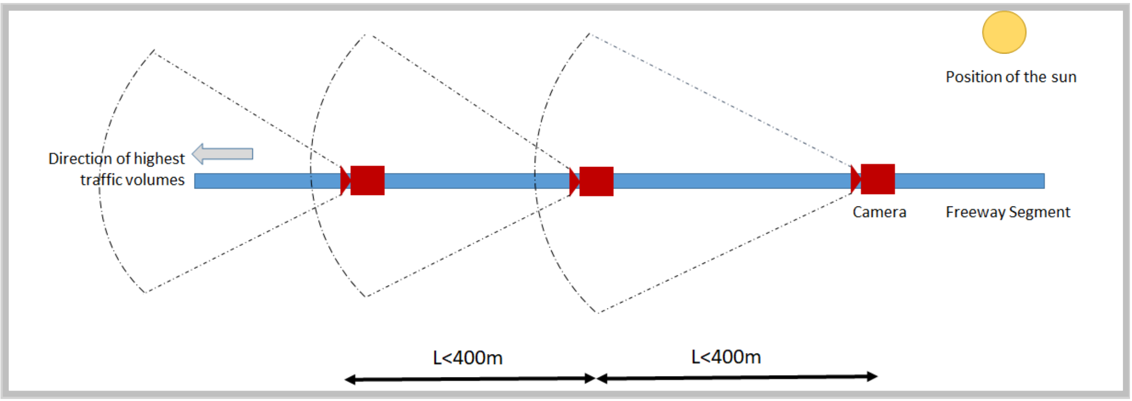

Figure 3-1: Static Viewing of the N4 freeway during the AM period

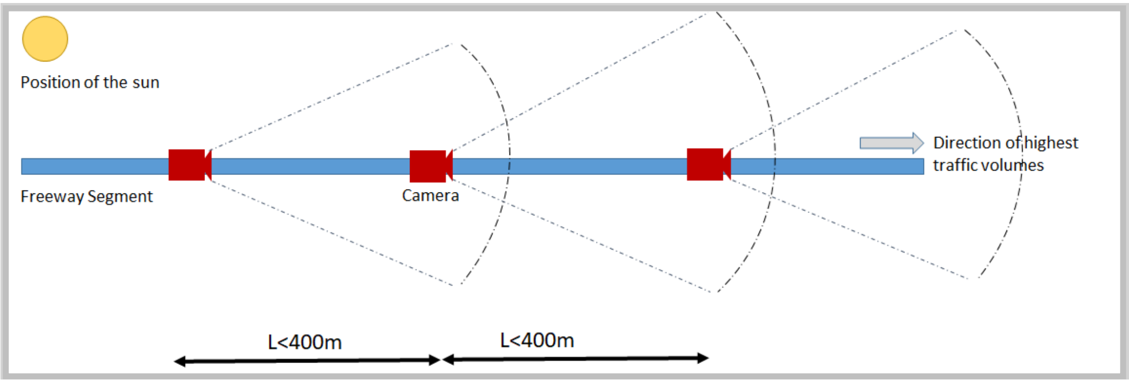

Figure 3-2: Static Viewing of the N4 freeway during the PM period.

3.2 Roaming View Surveillance

Roaming view surveillance can be defined as automatically positioning the camera to view various directions for a period of time so as to cover the road segments in its entirety. It is an alternative to the static-continuous view surveillance in cases where it is not possible to have a one-directional coverage. In this method, the cameras keep panning and tilting on either side of the camera pole along the freeway for short durations. For example, the camera will pan and tilt in the east direction for 30 seconds, pan and tilt in the west direction for 30 seconds and then pan and tilt back in the east for 30 seconds. This should happen continuously during all times of the day.

This method would only work effectively on freeway segments, especially if the distance between the cameras is short enough to provide an uninterrupted view of the freeway. This method is limited as the on-ramps, off-ramps and interchange terminals may fall outside the field of vision of the cameras. In urban areas such as Gauteng, the close proximity of interchanges and the presence of C-D roads pose a challenge to this method of surveillance. Figure 3-3 shows the ideal scenario for roaming view surveillance.

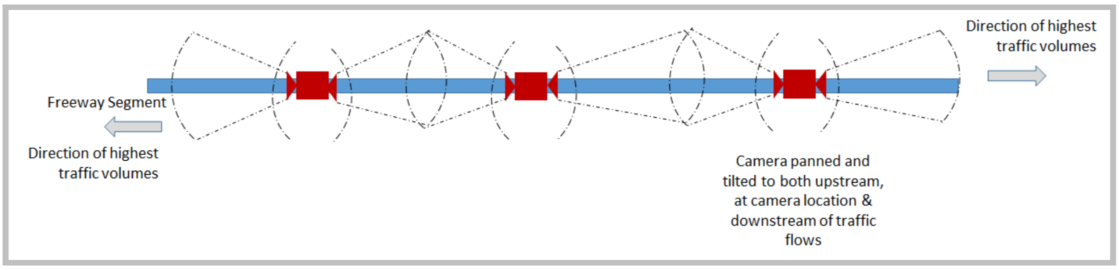

Figure 3-3: Roaming view camera surveillance

3.3 Automated Pre-sets Surveillance

Automated pre-set surveillance can be defined as programming the camera to automatically zoom, tilt and pan to different 'viewports'. The cameras would automatically cycle through these viewports allowing the operator to easily view the freeway segments including interchanges.

In order to determine where to view (viewport) and how long to view each viewport, the TMC manager and traffic engineer conducted an analysis to identify the critical factors. They include the following:

- Obstructions such as overhead sign boards, camera poles and bridge deck;
- Known hotspots on the sections of the road;
- Traffic parameters (speed, density, flow, peak period, direction);
- Geometry and length of the road;
- Environmental factors that may affect traffic patterns such as rainy weather conditions.

Based on this, the pre-sets (viewport, duration of each viewport) and the order of viewing the pre-sets for each camera were determined. It was a collaborative effort between the IT technician, the traffic engineer, TMC manager and operator to determine the pre-sets for each camera. Based on the initial assessment, it was found that the pre-sets for cameras monitoring freeway segments had to be different from those of cameras at interchanges. As discussed earlier, the cameras at interchanges are used to monitor the on and off-ramps and the interchange terminals; hence requiring more pre-sets. Figure 3-4 shows actual locations of CCTV cameras at an interchange and at a freeway segment.

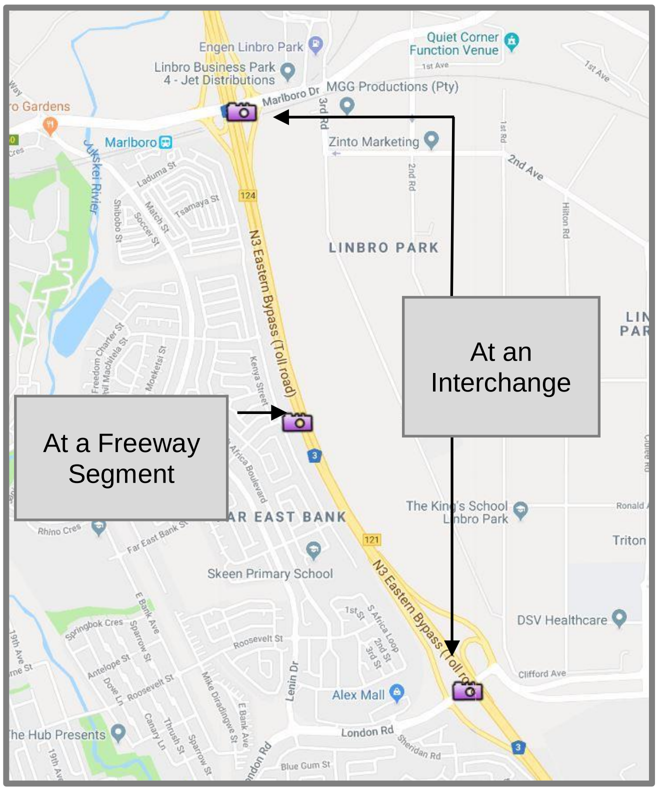

Figure 3-4: Actual locations of CCTV cameras at an interchange and at a freeway segment

3.3.1 At a freeway Segment

The time allocated to each pre-set was determined based on the five factors mentioned above. Figure 3-5 shows an example of the 3 locations where the camera would focus during a pre-set tour. At each of the 3 locations, the number of incident occurrences may vary. To determine the time allocated to each viewport (locations 1 to 3), the following steps were followed:

- Obtain traffic data collected using any of the various devices;
- Conduct an incident analysis on the different sections of the freeway segment to identify hotspot areas;
- Map/show incident variation/hotspots. This map would indicate the priority areas to focus on;
- Quantify total incidents in the Eastbound - Westbound direction or Northbound - Southbound direction;
- Depending on the incident distribution, allocate pre-set time per direction. The location with fewer incidents will be allocated less time as compared to one with more incidents;
- The total time allocated will further be divided into positions 1, 2 and 3 depending on the distribution of incidents in that directions;
- The total time allocated to complete all pre-set tours for all the directions and sections of the road (1, 2, 3, 2 and 1) should not exceed 180 seconds (3 minutes).

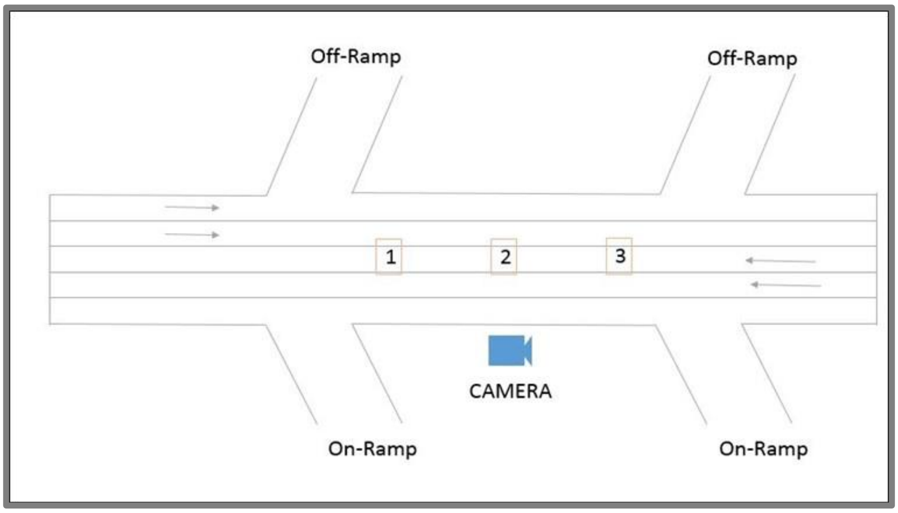

Figure 3-5: Setting up of pre-sets on freeway segments

3.3.2 At an Interchange

Figure 3-6 shows an example of pre-set locations of a camera located at an interchange. The steps (i to v) followed for a freeway segment would apply for cameras positioned at an interchange. The total time allocated to complete all pre-set tours would follow the cycle of 1, 4, 3, 5, 2 and 1. The time allocated and the number of cycles per pre-set tour would depend on the type of interchange. For example, a full clover would have more segments to view than a partial clover interchange. A full clover would, therefore, require more pre-set cycle tours compared to a partial clover interchange.

These cycle lengths would be optimized by setting smaller pre-set cycle lengths to increase the opportunity to capture the occurrence of an incident. By so doing, the operator would be able to monitor all the cameras within the required 3 minutes.

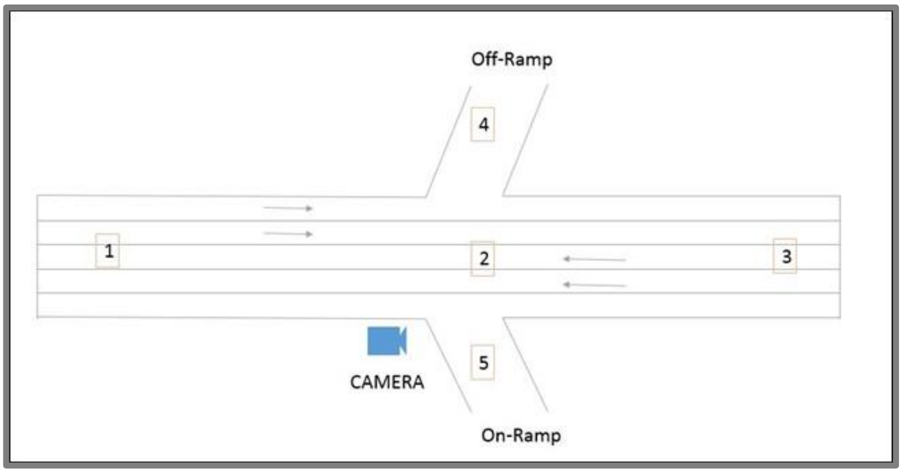

Figure 3-6: Setting up Pre-sets at an Interchange.

4. Selected Surveillance Method

The three alternative methods were evaluated by looking at the pros and cons of each method. The pros and cons are presented in Table 4-1.

From the comparison of the pros and cons of the 3 methods, it was determined that the automated pre-set surveillance method would be the only feasible method given the current scope. Regardless, it was found to be the most feasible option.

The setup and implementation of the automated pre-sets were conducted in March 2018. The pre-set times were set for each camera. With this method of surveillance, the operator may get to view a segment more than once within the KPI time and this increases the opportunity to capture more incidents at their time of occurrence.

As mentioned earlier, the methodology was implemented in March 2018. In the first two months, operators were familiarizing themselves with the new method. A before and after analysis was then conducted to determine the increase in the number of incidents as well as its efficiency.

5. Before And After Analysis

The analysis was tested over the entire freeway network by analysing the change in the number of incidents with occurrence time for each camera series for the month of May 2017 and May 2018. The camera series refers to the implementation phase of the project.

Figure 5-1 shows the comparison of the two months. It shows that for all the camera series (except for the pilot series), the number of incidents with occurrence time had increased. The total number of incidents with occurrence time increased from 706 in May 2017 to 1122 in May 2018 – an increase of approximately 500 incidents. The increase in the number of incidents with occurrence time was normalized with the overall number of incidents for each month. After normalising the data, it was found that there was a 15% increase in the number of incidents with occurrence time.

Even though there was a significant increase, there are some shortcomings that exist, which include:

- System unavailability due to power outages.
- In some locations, the distance between cameras was higher than the ideal 400m for continuous coverage. Infill cameras would be required for continuous coverage.
- An operator views camera footages on the 2 computer monitors and also logs in data in the ATMS on the third computer monitor. When an incident is detected, the operator does not attend to the camera views on the 2 computer monitors and only attends to the computer monitor where the incident details are logged in the ATMS. During the period, all incidents that occur may not be identified. The setup of the operators needs to be restructured such that there is a separate team viewing camera footages and another team capturing the data in the ATMS.

- There are several blind spots on the network that cannot be viewed. These include segments of the freeway under the bridge deck or blocked by camera pole or existing vegetation.
- Bad weather conditions affect the visibility of the camera. Severe weather also affects the wireless communication between the devices and the TMC.
- Some of the older cameras have lesser pixels and lesser clarity as compared to the newer ones. Therefore, during the night, visibility may be limited for incident detection.

Table 4-1: Pros and cons of the alternative methods

Method	Pros	Cons
Static-continuous view surveillance	▪ A continuous and holistic view of the freeway segment; ▪ Less labour intensive.	▪ If the distance between cameras is more than 400 meters, the method may not be feasible and this was the case along some of the road sections. Infill cameras may, therefore, be required, which falls outside the scope of this study.
Roaming view surveillance	▪ A continuous and quick view of the freeway; ▪ Provides the operator with a holistic view of the roadway segment; ▪ Less labour intensive for the operator to survey the freeway.	▪ Incidents that may occur on the ramps and on the cross streets may not be detected (may not have a continuous view of the full network). Infill cameras may, therefore, be required, which falls outside the scope of this study.
Automated pre-set surveillance	▪ The camera is able to view the segment or interchange within 3 minutes; ▪ More than one pre-set cycle may be possible within 3 minutes. This allows the operator to see the segment multiple times with 3 minutes; ▪ Continuous and quick view of the freeway; ▪ Provides the operator with a holistic view of the roadway segment; ▪ Less labour intensive for the operator to survey the freeway.	▪ Setting up of pre-sets for each camera is time-consuming and cumbersome; although it is once off.

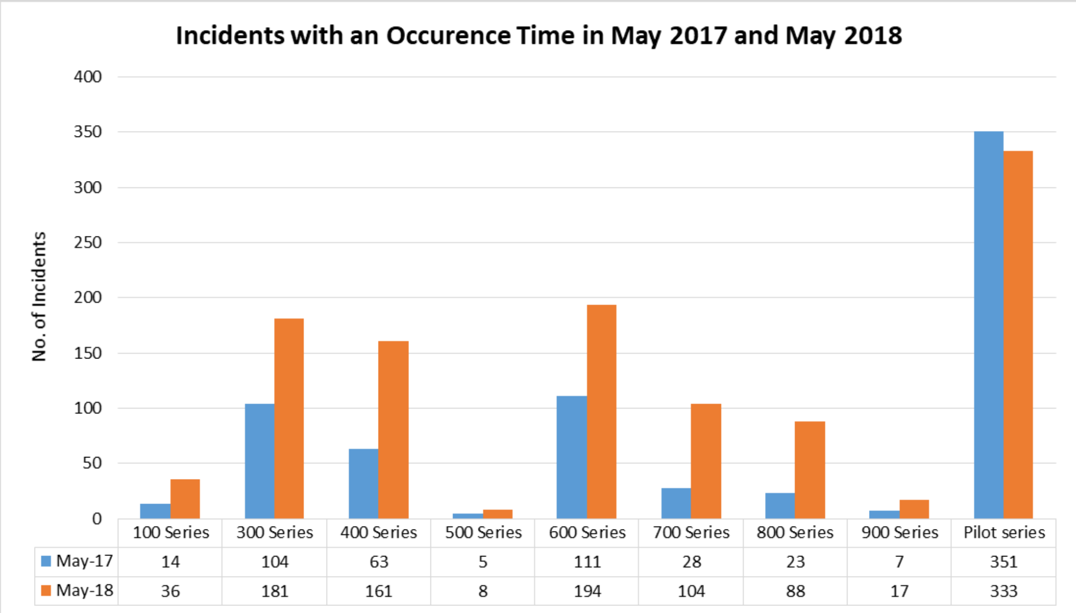

Figure 5-1: Incidents with occurrence time – a comparison of May 2017 and May 2018

6. Conclusion

SANRAL relies on manual surveillance of the CCTV cameras to detect incidents along the freeways. Only 30% of the total incidents had an occurrence time. Three alternative methodologies were then developed to increase the number of incidents with an occurrence time; thereby improving the KPI. The automated pre-set surveillance was determined to be the most efficient method, given the current infrastructure and resource constraints. The new method was tested by comparing the data from May 2017 which was used as the "before" and May 2018, three months after implementation of the new method, which was used as the "after" period. The results of the analysis showed that subsequent to the implementation of the automated pre-set surveillance method, the number of incidents with occurrence time increased by approximately 15% - an increase of approximately 500 incidents.

The study also revealed that there are some shortcomings that make it difficult or impossible to attain a 100% record of incidents with occurrence time. This presented an opportunity to mitigate some of the shortcomings. On freeway segments where the distances between cameras were more than the ideal 400m for continuous coverage, installation of new infill cameras was proposed. Proposals were also made to install cameras that have better visibility at night or low-light conditions. It was also recommended that the operator setup at the TMC be restructured such that there is a team viewing the camera footage, while another team captures the data in the ATMS.

In conclusion, the combined effort of the team members (Teti Traffic and Koleko) and the support of the client (SANRAL) assisted in improving incident detection and deploying emergency response on the freeways.

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The use of technology to improve road safety in the Kingdom of Lesotho

Hlulani J. Mathebula [1] and Avi Menon [2]

Abstract

Africa has both the least vehicle ownership per capita and the least amount of road network per square kilometre worldwide. In spite of this, Africa has a staggering high rate of road crash fatalities per hundred thousand people. Africa has a serious road safety problem. One of the main factors leading to the failure is the lack of reliable crash data. Engineers rely on crash data to guide them on where and how to intervene to reduce crashes. In the Kingdom of Lesotho there are on average two hundred crash fatalities per annum; almost one – every other day.

The crash data is captured manually on a paper based form. At the end of each month, a crash summary is sent to the Department of Road Safety. This study found that the data captured is inconsistent between the various police stations and often, during the collection process, important fields are left blank. The location of the crash, which is one of the most important pieces of information, is often vague.

This study investigated the use of technology to collect, store and analyse data. A system was proposed to improve data collection, storage and dissemination. The same system could also be integrated with the vehicle registration and driver's license system to identify vehicles that are not road worthy and repeat offenders.

Keywords: Crash, Fatalities, Technology, Data.

1. Introduction

The Kingdom of Lesotho (hereafter referred to "Lesotho") faces a number of fatalities which are a result of road crashes. There are on average about two hundred crash fatalities annually. The World Health Organisation (World Health Organization, 2015) has ascertained that globally, majority of the fatalities are as a result of road crashes. According to the statistics reported by (World Health Organization, 2015), it is the middle income countries which have high road fatalities than high income countries. Africa has by far been the number one continent which records the highest road fatalities, as illustrated in Figure 1 (World Health Organization on Road Safety, 2013). Despite the emphasis on road safety by the UN Decade of action for 2011-2020

[1] Koleko Solutions; Building 16, Woodlands Office Park, Woodmead, South Africa, 2196; +27727383844; hlulani.mathebula@gmail.com
[2] Koleko Solutions; Building 16, Woodlands Office Park, Woodmead, South Africa, 2196; +27726474671; avim@koleko.co.za

(World Health Organization, 2011), in African countries, the number of road crashes continue to increase annually. Most of the road crash victims are vehicle occupants followed by pedestrians. It is evident that African countries seriously need to address the road carnage. Reliable and accurate crash data is the first step towards improving road safety. Road crash data in some African countries including Lesotho, has remained underreported as illustrated in Figure 2 (Southern African Development Community, 2011).

Various studies (Jaehoon and Lyoong), (TRL Limited, 2014) and (Tamil Nadu Road Sector Project, 2011) have shown that technology can be used and relied on to manage crash data. Consequently, this can enable the implementation of interventions to improve road safety. A study done by (Jaehoon and Lyoong) through the Korea Transport Institute has shown the ability to create a technological system that allows for road crash data to be integrated, managed and shared. A technological system was launched in India in 2015 (TRL Limited, 2014) to streamline and centralise the management of road traffic crash data. The system was designed to simplify the identification of road safety problems. Additionally the system allowed the authorities to introduce interventions to reduce casualties resulting from road crashes. Subsequently, a follow-up study proved that this system has by far helped to identify a high number of hot spot locations (Tamil Nadu Road Sector Project, 2011). This has led to the implementation of interventions that have reduced the road crash fatalities. Furthermore, the system has also contributed in achieving other aspects such as better traffic management, improved road safety awareness, and improved road conditions.

From the above-discussed, it is indisputable that reliable and accurate crash data is needed to reduce road crashes. The implementation of crash data management systems with the use of technology can make it easy to achieve improved road safety. This system is one which will simplify the identification of crash hot spots and subsequently implementing measures to reduce crashes. The manual collection of road crash data in Lesotho has proven to be unreliable thus making it impractical for authorities to intervene and apply measures to reduce road crashes. This study investigated the possible options which can be put in place to improve the collection and storage of road crash data in Lesotho. Thus enabling the authorities to implement interventions to reduce road crashes.

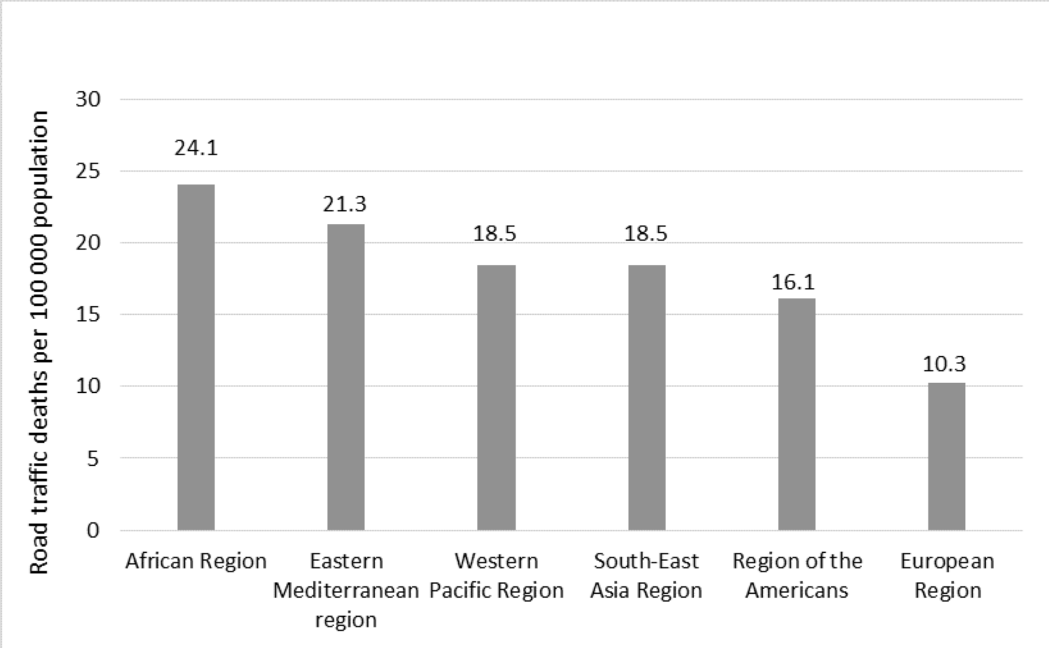

Figure 1: Road fatality rates per 100 000. Source: (World Health Organization on Road Safety, 2013)

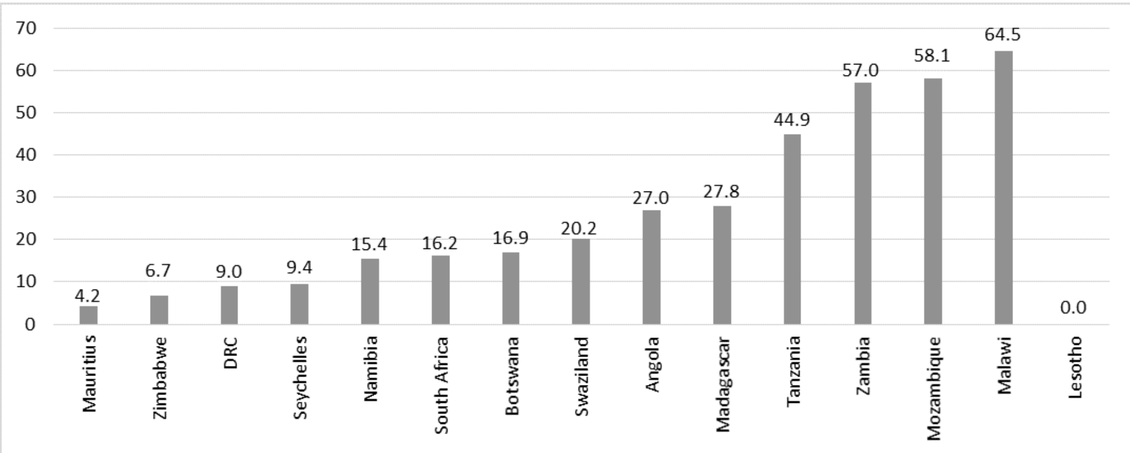

Figure 2: Number of fatalities per 10000 vehicles in the SADC region. Source: (Southern African Development Community, 2011)

2. Study Area

Lesotho is an enclave located in the Southern African Development Community (SADC) region and landlocked by South Africa as shown in Figure 3. Its terrain is characterised by its highlands, mostly with mountains and hills. According to the statistics reported by the (World Health Organization, 2015), the population of Lesotho was approximately 2 million with a vehicle population of approximately 123,000. The national road network is over 7,500 km with high vehicle population in the districts of Maseru and Leribe (Lesotho Road Safety Department, 2018). Based on a visual conditions survey conducted in 2014, 38% of the paved roads were found to be in good condition, 12% in fair to poor condition and 50% in very bad condition (Lesotho Ministry of Public Works and Transport, 2018).

When a crash occurs, the Lesotho Mounted Police Service (LMPS) officers would arrive on the scene and collect crash data on notebooks. The data is later transferred to a police register and an accident form. At the end of each month, the police station would send all the crash data for the month to its respective headquarters. There are eleven district police headquarters in Lesotho, each responsible for several police stations. On an annual basis, each police headquarter summarises the crash data for their region and sends it to the Road Safety Department (RSD), a department within the Ministry of Public Works and Transport. The RSD then analyses the crash data and compiles it into an annual report indicating the annual trends of road crashes, injuries and fatalities thereof. One of the major challenges in compiling the annual report has been the inconsistency of the data and the format of the data. Each police station collects and summarises the crash statistics differently. This makes it a cumbersome task for the RSD to collate the statistics and interpret it.

The crash data is made available in a summarised report format to the Department of Traffic and Transport (DTT) on an annual basis. Subsequently, the DTT is unable to proactively improve the road infrastructure to reduce crashes. It is clear that there is a need for a system that will be well-coordinated and integrated to improve the collection, storage and reporting of crash data in order to improve road safety.

Figure 3: Lesotho on the Southern African map

3. Methodology

The methodology entailed understanding the flow of events and processes undertaken in collecting, storing, managing, analysing and disseminating crash data. This encompasses all stages from when a crash occurs, to reporting the crash, arrival of police at the scene of the crash, collecting the necessary information, filling in the relevant forms and reports, and ultimately disseminating the findings of the analysis. The series of events is referred to as process flow in this paper.

Once the series of events (process flow) have been understood, the next step was to identify the responsible personnel or authority for each event. The available resources, organisational structure of the relevant department and applicable legislations and policies were investigated. This was done through a series of site visits and personal one-on-one interviews. In addition, a workshop was conducted with the relevant stakeholders to better understand the formal agreements and also the dynamics between the various departments. The workshop provided clarity on the current intergovernmental relationships, and helped identify the gaps pertaining to managing and sharing of crash data.

Based on these findings, possible solutions were developed for each event along the process flow. The pros and cons for each solution were then identified. Through a stakeholder engagement process the best suited alternative were identified. The section below summarises the findings of the site visits and interviews.

4. Findings

From the investigations carried out through the site visits, interviews and workshops, the gaps in the process flow were identified. The system of collecting, storing and sharing road crash data was found to be un-coordinated. There is no universal method of reporting crashes in Lesotho. The victim or a passer-by has to call the local police station to report the incident. If the individual reporting the incident is unaware of the telephone number of the local police station or if the number is busy, then this may cause significant delays in the emergency response process. The shortage of police vehicles and ambulances were also identified as a challenge faced in several police stations. In several instances when the police arrived on the scene, there were no trained personnel to provide medical care to the crash victim.

The manual-paper based method of reporting crashes posted its own challenges. The crash forms were either not fully populated (left incomplete) or the information was incorrectly filled. One of the biggest challenges with the paper based method was recording the location of the crash. In urban areas, the name of the nearest intersection or business was recorded as the location of the crash. In rural areas, the name of the nearest village or the approximate distance from the nearest village was recorded as the location of the crash. The use of kilometre markers or GPS coordinates would better help pin-point the location of the crash. This would equip the DTT to identify the hotspots.

5. Evaluation of an alternative / something along those lines.

Manual collection of road crash data has proven to be unreliable. Therefore, various possible alternatives were evaluated for each event of the process flow. Where applicable and feasible, the use of technology devices was proposed.

A national toll free number, a web-based reporting system and using social media were evaluated as alternatives for reporting crashes. Amongst other reasons, primarily due to the limited internet connectivity in the highlands, a national toll free number was opted as the most feasible option. Handheld devices (smart phone/tablet), digital pen and manual data collection using forms and a web-based system were evaluated as alternatives for collecting crash data at crash site. Due to their cost effectiveness and accuracy, handheld devices were the preferred option, as those shown in Figure 4 be used to collect crash data from crash scenes. The handheld device would automatically capture the GPS coordinates of the crash site, helping overcome of the biggest challenges with the manual system. The system also allows the officials to scan the driver's licenses and the license plates of the vehicles involved in the crash. When the driver's licences and the license plates are captured, the system would automatically retrieve information from a central vehicular database. The police officer would immediately be able to see the past violations and outstanding fines, if any.

The crash data is then sent to a central database wirelessly. The devices would connect to the internet via a sim card registered with one of the local cell phone service providers. In some areas, especially in the highlands, the internet speeds may be very slow or even unavailable. The devices would be programmed to store the crash data offline and when internet connectivity resumes, the data would be uploaded to the database. The RSD in collaboration with LMPS will be responsible to check crash data on a daily basis. If further information is required, then the LMPS officer who collected the data can be contacted.

A summary of the data can be viewed on a dashboard as exemplified in Figure 6, with an option of also viewing the details of the data. Thus the process of collecting, analysing and storing crash data would be integrated and manageable. Furthermore, crash data sharing amongst the departments would be simplified and valuable data would be safely stored.

Figure 4: Handheld device interface

For storing the crash data, Oracle, Microsoft SQL Server and Open Source (MySQL, PostgreSQL) were considered and evaluated. Due to its flexibility and cost effectiveness, the Open Source option was identified as the optimum solution.

In summary the primary benefits of implementing a crash database management system includes improving crash data collection, analysis, reporting and dissemination. The system would assist the authorities to identify crash hot spot locations. The system will further assist the public and insurance providers with more accurate data for insurance claims.

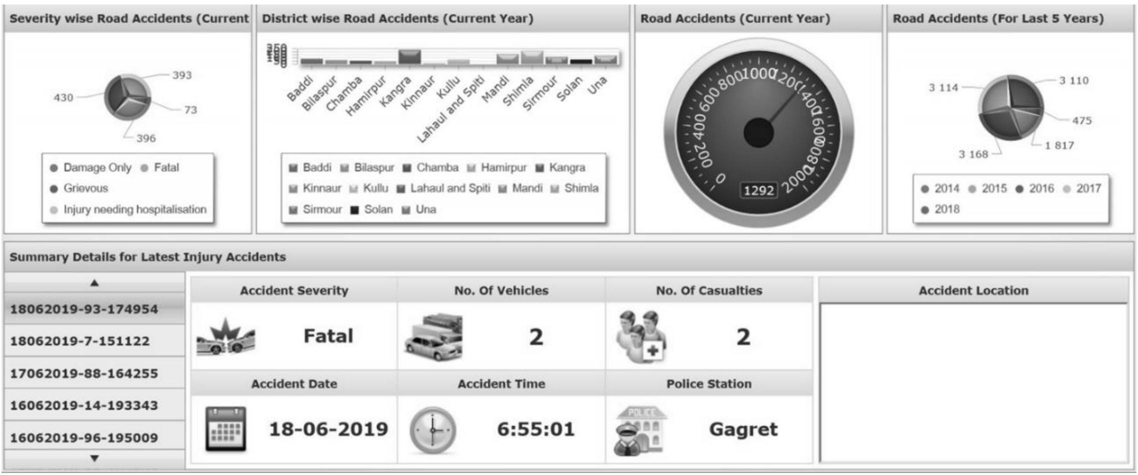

Figure 5: Example of the proposed dashboard

6. Challenges

A crash database management system will benefit Lesotho in various ways and push the country a step forward towards achieving the objectives of the UN Decade of action for road safety. However, there are issues which may not necessarily be solved by the proposed system. There is a shortage of transport for emergency responders, this includes police vehicles and ambulances. In addition to capturing crash data at the crash scenes, police officials have to attend to the crash victims. This is due to the lack of trained paramedics to attend to them. Not providing medical care to the crash victim timeously may have an impact on the victim's chances of survival.

Lack of technical personnel within the department to maintain the system and vandalism were also identified as risk in the sustainability and longevity of the system.

7. Conclusion

The Kingdom of Lesotho faces a number of fatalities resulting from road crashes. The current manual method of collecting crash data and analysis was found to be unreliable. It was established that reliable crash data is required in order to simplify the process of identifying crash hotspots. This enables the authorities to implement the necessary measures to improve road safety.

The literature review showed that the database management systems that have been implemented have, with the use of technology promote a well-coordinated and well-managed method of collecting, storing and sharing data. The proposed system would rely on the police officers to collect crash data using a handheld device. The device would upload the crash data whenever there is internet connectivity. Ultimately, the process of collecting, storing and sharing of data would be simplified and more reliable. As a result, the roads department would be able to use the crash data to improve road safety in Lesotho.

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Optimizing existing technologies through Innovative solutions for enhanced service delivery in ZESCO

Andrew Munde[1]

Abstract

ZESCO Limited is an Electrical Power Utility wholly owned by the Government Republic of Zambia whose mandate is to provide safe, reliable and affordable electrical energy to its clientele countrywide. The firm's mission is to make it easy for people to live a better life while its vision is to be the hub of electricity trading in the Region by 2025. This paper seeks to share findings of a study done in three key momentous projects that ZESCO undertook to significantly bolster its operations and efficiency namely; Optic Fiber Network via the Fibercom Division, introduction of the National Call Center and use of Business Information System or BIS. These were premised on the following Organizational turnaround descriptive pillars: the purpose of this study was to identify and discuss the key innovations derived by ZESCO in establishing its Optic Fiber Network, National Call Center and Development of its Business Information System. It went further to determine how the available infrastructure was optimized to lessen the development costs of these projects. It also dissected how these developments enhanced the reliability of the Network.

This study further delved into interdependence of these projects that has ultimately culminated into improved system operations and service delivery in ZESCO's provision of electricity to its valuable clientele. Various methods were used in undertaking this study including Questionnaires issued to ZESCO's clients whose signals ride on its Optic Fiber Network and those registering complaints through the National Call Center to determine customer satisfaction. Report generation in Microsoft package, Excel was utilized in analyzing data from BIS while Visio was used in mapping dependence systems. In the end, it was apparent that ZESCO's innovations have drastically reduce its project costs, improved its communication protocols and enhanced electricity service delivery to its customers.

Keywords: Innovation, **Optimization, Reliability, Enhanced** and **Service** delivery**.**

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[1] ZESCO Limited; Directorate of Distribution and Supply, P.O. Box 33304, Lusaka, Zambia, +260966531019, AMunde@zesco.co.zm

1 Introduction

Zambia has 2,897.21 MW of installed electricity generation capacity, of which 83% is hydro based. The rest of the generation mix is composed of coal (10%), HFO (4%), diesel (3%) and solar, less than 0.2 percent. National access to electricity averages at 45% with 67% of the urban and 4% of the rural population having access to power.

In 1996, the Government of Zambia set a goal for universal electricity access for all Zambians by 2030. Energy has been identified as an important driving force behind economic development in Zambia, and the government has declared its commitment to developing and maintaining energy infrastructure and services.

1.1 Zambia's Installed Generation Capacity

ZESCO Limited, a Government Republic of Zambia owned parastatal and the country's largest power utility has in the past two decades embarked into massive Power projects aimed at matching the nation's increasing energy demands with available power generating capacity. These projects involved Capacity upgrades of ZESCO's major Power Plants, Kafue Gorge and Kariba North Bank Power Stations, building of new Power Plants such as Itezhi tezhi Power Corporation, expansion of its Transmission Network like the Lusaka Transmission and Distribution Rehabilitation Project or LTDRP. Mini and Small hydro power plants have also been either upgraded or built altogether in selected Greenfield projects.

A summary of these Projects aimed at bolstering Zambia's Overall Generating Capacity are tabulated below;

Table 1: Development of Zambia's Power Generation Capacity, 2003-Date

Power Station Name	Initial Installed Capacity (MW)	Current Installed Capacity (MW)	Remarks
Kariba North Bank	600	1080	Power Station Upgraded with introduction of 2X 180MW new machines at KNBPS Extension
Kafue Gorge	900	990	Power Station upgraded
Itezhi tezhi Power Station ITPC	0	120	New Power Plant
Victoria Fall Power Station	108	108	Plant rehabilitated
Lunzua	0.75	14.8	Plant Upgraded
Musonda Falls	5	10	Plant Upgraded
Lusiwasi	12	12+(15)	Pre-commissioning Tests underway
Kafue Gorge Lower	-	-	750MW Power Plant still under Construction
Chishimba falls	6	6	Awaiting financing
Shiwang'andu	0	1	New mini-Hydro Power Plant
Maamba Collieries Company	0	300	New Independent Power Producer
Ndola Energy	0	105	New Independent Power Producer
Lunsemfwa	-	56	Existing Independent Power Producer

Similar expansions have been done on the 330, 220, 132, 88, 66kV and 33, 11kV Transmission and Distribution Systems respectively as they form a medium through which power flows from the Power Stations to the Load Centers.

2 Development of the Optic Fiber Network

The expansive and countrywide power network of ZESCO from Generation, to Transmission and Distribution required quick and uninterrupted transmission of signals for optimal operation of the Power System.

Signals are important for monitoring of:

- ✓ System measurands such as Generated Power
- ✓ Transmission and Distribution Voltage, Currents, Power factor
- ✓ Circuit Status of Circuit Breakers, Bus and Line Isolators
- ✓ Temperature measurements of Power and Distribution Transformers, Cables

ZESCO traditionally used point-to-point Micro wave links for signal transmission between its various stations. These required no cables, had multiple channels and wide frequency bandwidth.

However, this system suffered the following major disadvantages;

- ❖ Line-of-sight would be disrupted if any obstacle, such as new buildings got erected in the way
- ❖ Signal absorption by the atmosphere. Microwaves suffer from attenuation due to atmospheric conditions.
- ❖ Towers were expensive to build

An illustration of a Microwave link based Communication System is shown below;

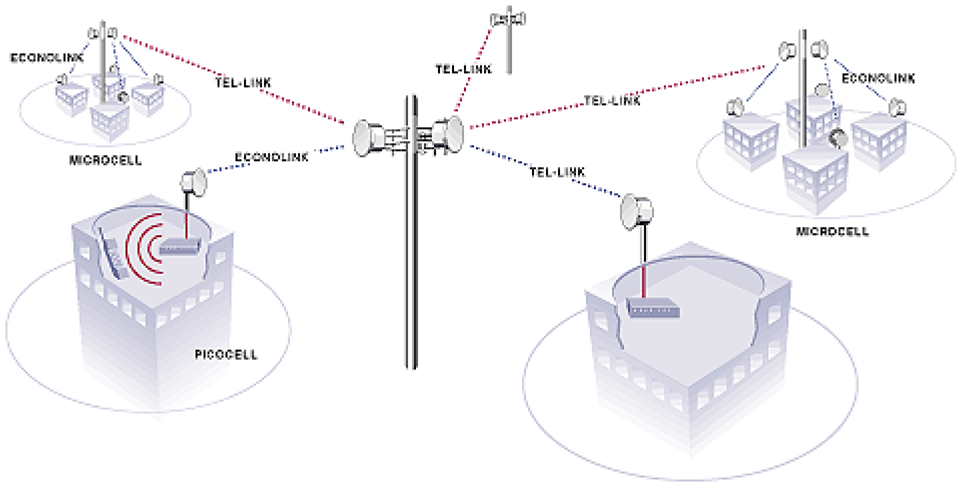

Fig. 1: General Architecture of Microwave Radio Signal links

The erection of many high structures through a booming construction sector in Zambia and the rapid expansion of the distribution network, made the use of Microwave link technology more demanding with ever decreasing reliability due to poor signal transmission.

ZESCO therefore had to devise ways of overcoming these technical hitches and improving its communication system.

This marked the genesis of Optic Fiber Network that was spearheaded by the Fibercom Division and now a subsidiary of ZESCO Limited.

The Optic Fiber lines could either be laid underground countrywide or strung overhead.

Even so, the scourge of vandalism made the laying of an underground system unfavorable.

ZESCO therefore had to innovate a plan of how this network could be strung overhead to enable the system national wide coverage and yet, at minimal project installation costs.

The utility already had existing steel towers and wood Poles on which were anchored Conductors for Transmission and Distribution lines respectively.

As a matter of innovation, a decision was made to implement this using Optical Ground Wire famously referred to as OPGW.

2.1 Usage of OPGW for Data and Voice Communication

An optical ground wire OPGW is primarily used by the electric utility industry, placed in the secure topmost position of the transmission line where it "shields" the all-important conductors from lightning while providing a telecommunications path for internal as well as third party communications. Optical Ground Wire is a dual functioning cable, meaning it serves two purposes; cable combines the functions of grounding and communications. An OPGW cable contains a tubular structure with one or more optical fibers in it, surrounded by layers of steel and aluminum wire. The OPGW cable is run between the tops of high-voltage electricity pylons. The conductive part of the cable serves to bond adjacent towers to earth ground, and shields the high-voltage conductors from lightning strikes. The optical fibers within the cable are used for high-speed transmission of data, ZESCO's purposes of protection and control of the transmission line, for the utility's own voice and data communication, and is also leased to third parties to serve as a high-speed fiber interconnection between their stations or clients.

2.2 Advantages of OPGW

OPGW as a communication medium offered significant advantages over buried optical fiber cable. Installation cost per kilometer was lower than a buried cable. Effectively, the optical circuits are protected from accidental contact by the high voltage cables below (and by the elevation of the OPGW from ground). A communications circuit carried by an overhead OPGW cable is unlikely to be damaged by excavation work, road repairs or installation of buried pipelines. Since the overall dimensions and weight of an OPGW is similar to the regular grounding wire, the towers supporting the line do not experience extra loading due to cable weight or wind.

The Optic Fiber Network has immensely offered the following advantages;

- Higher bandwidth support
- High carrying capacity.
- Immunity to electromagnetic interference and tapping.

- Optical fiber are so flexible.
- Optical fiber cables take up less space.
- Less signal attenuation and Resistance to corrosive materials.

The remarkable success of the project has largely being attained due to Optimization of the existing towers and structures to string the OPGW, thereby drastically cutting down what would otherwise have been huge project installation costs.

2.3 Coverage of Optic Fiber Network

ZESCO commands the largest optic fiber network in the country covering all the Ten provinces and interconnecting with Zambia's neighbors. The image below showcases ZESCO's Optic fiber coverage

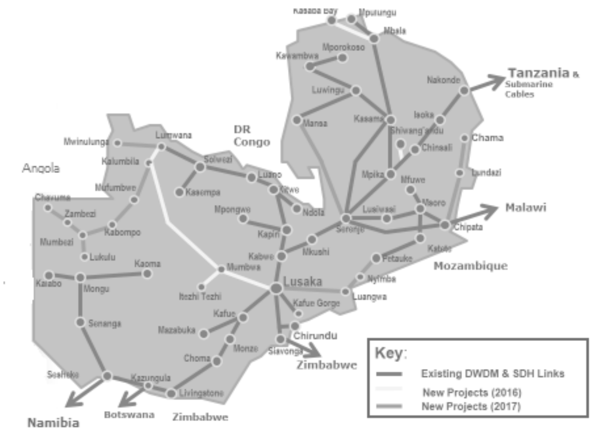

Fig. 2: Optic Fiber Network Map Coverage in Zambia

2.4 Communication Strides

The Optic Fiber network has facilitated for data and voice communication between ZESCO's National and Regional Control Centers, Offices and also for private telecommunication vendors.

The major outcomes of this project have been;

- Real time monitoring of Power System status
- Grid Automation leading to improved Network Reliability
- Remote operation of the System using Supervisory Control and Data Acquisition system or SCADA
- Increased internet use
- Telecommunication and data Transfer
- Integration with the National Call Center for improved customer complaints
- Implementation of smart metering technology

2.5 Research inquiry on Impact of Optic Fiber Network to Clients

As part of this study, a research was made to determine the impact and level of Customer Satisfaction in their access to services provided through this network by means of Questionnaires to both ZESCO's internal and external clients. The results of the survey were yet to be consolidated and analyzed as respondents were still making their submissions.

3 The National Call Center

With the installation of Optic Fiber Network, the performance of the National Call Center was enhanced.

The National Call Center is a centralized manned Computer System using Call Interactive Voice Response (CIVR) which is an automated telephony system that interacts with callers, gathers information and routes calls to the appropriate recipients. An IVR system (IVRS) accepts a combination of voice telephone input and touch-tone keypad selection and provides the appropriate responses in the form of voice, callback, and other contact methods.

Using this technology, ZESCO Clients can call and they will be routed to Call Center agents to lodge in their complaints regarding the status or quality of electricity service delivery affecting their premises.

3.1 Complaint Registration Process

Clients can lodge in their complaints by either dialing 0211363636, 322 into National Call Center or simply by sms to short code 3600 (on airtel only). Clients wishing to register a complaint on a supply service affecting their premise are normally required to avail the Service point or meter number which is a unique ID linked to each customer. The system also allows general members of the public to register complaints when they notice any defect on the ZESCO System such as slanted poles or vegetation overgrowth interfering with the Power Utility lines.

The complaints are registered in a Business Information System application called Outage Management System or OMS which stamps the time at which a complaint is logged and in which further updates on complaint resolution can be made.

The National Call Center works hand in hand with Regional Control Centers who are in control and dispatch field personnel to resolve these customer Complaints also known as faults on the network.

The type of complaints handled by the National Call Center include:

- No supply, Low or high supply voltage, Fluctuations of Supply (going on and off continuously)
- Cut or low-lying wires
- Fires, Arcing, shorting or sparking of lines
- Slant, Rotten or fallen Poles

- Faulty Meters, Burnt or stolen Service wires

A pictorial illustration of the Faults Management process is herein given;

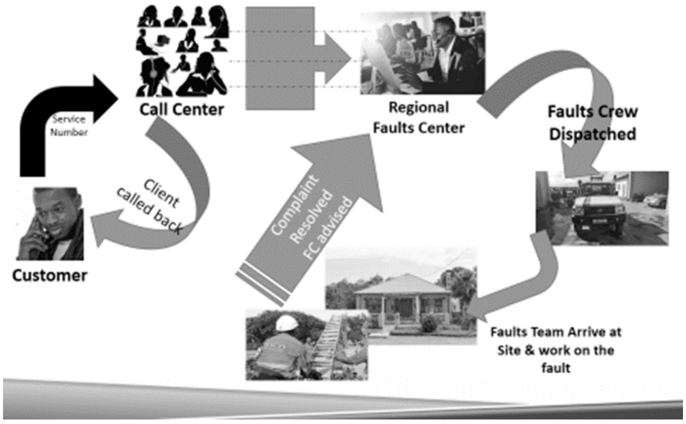

Fig. 3: Faults Management process

As part of the study, Questionnaires were issued to sample clients for the purpose of appreciating their perception of the effectiveness of the National Call Center and impression on the general faults management process. The submissions of these clients are still being awaited for analysis.

3.2 Faults handling in Outage Management System, OMS

Outage Management System was introduced as part of the Business Information System or BIS application for registration, tracking and resolution of customer faults and system incidences.

The Complaints are registered at National Call Center while incidences are created at Regional Control Centers. The Optic Fiber Network has remained the backbone of these systems as it's used for data and voice communication. A typical window of a Complaint registered in OMS is herein given;

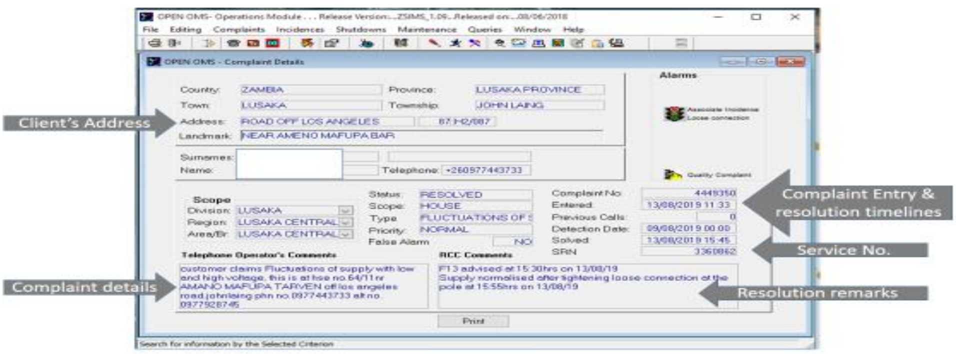

Fig 4: Typical OMS Complaints Window

The following key features are worthy noting

- Customer Service number or SRN in the Complaint window; signifies the Contract number existing between the Client and ZESCO
- Customer Stamping time; shown as Entered and Solved signifies the time stamped when the complaint was reported and then resolved respectively
- Operators Comments; gives the details of the complaint as seen by the Customer
- Address; is the physical address if the premises where the fault is reported from
- Scope: is the Region and Area where the fault is managed

The stamping of entry and resolution times are important as they assist in keeping track of how long it took the Utility to handle the complaint.

The study of this BIS application reviewed that the following have been the derived benefits;

- Management is able to accurately ascertain the efficiency of its service delivery,
- Other stakeholders like the Regulator use the information to deduce rating against agreed key performance indices
- The System also assists in keeping track of repeated failures of particular installations that could that could trigger the need for reinvestments or system upgrades.

4 Relationship; FibreCom, National Call Center and Regional Call Centers

A study was also done on the relationship and interdependence of the Optic Fiber System, National Call Central and Regional Control Centers in enhancing ZESCO's operations and impact on service delivery. The mapping below illustrates how these are interdependent and impact on quality of service delivery

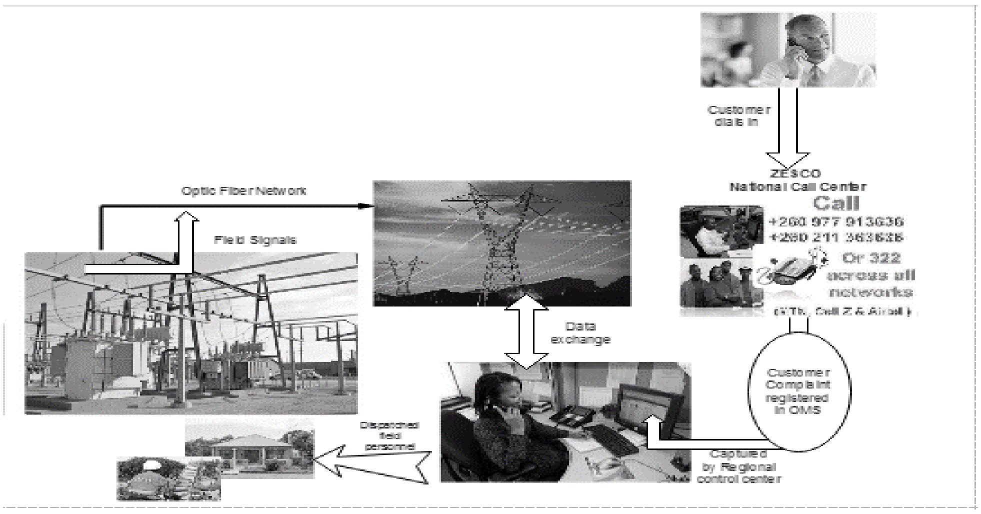

Fig. 5: Diagram showcasing System interdependence

The following were the deductions drawn from the study;

- ZESCO was now able to capture system status in real time based on a high speed and wide Optic Fiber System. This increased the response time to system outages,

- The National Call Center ensured Clients complaints were registered and reliably returned till the reported faults were cleared,
- Time stamping of Complaints in the Outage Management System ensured there was Management's oversight and expedited the duration of faults resolution. This significantly enhanced service delivery
- The return of complaint records helped in focusing priority areas for maintenance and system reinforcements thereby improving Network reliability.

5 Discussion

The study undertaken was aimed at analyzing ZESCO's innovation in development of the Optic Fiber Network System by optimizing the use of the existing infrastructure in establishing this network.

The development of this Network further enhanced the efficiency of Customer interface Systems like the National Call Center and Regional Control Centers where Customer Complaints are logged and managed respectively as the system could be monitored in real time.

The Outage Management System was further seen as an effective tool to monitor, track and resolve Customer complaints which offered good feedback to Management on the efficiency of field personnel and compliance to key performance indices. This input was also a useful trigger for initiation of system refurbishments and reinforcements.

The overall outcome of these innovative and interdependent systems have been improved System reliability and enhanced Service delivery.

To determine and have independent feedback on the effectiveness of these systems, Questionnaires were circulated to various clientele to offer them an opportunity to access the performance of the National Call Center and general ZESCO Faults management processes.

However, the survey was done within Lusaka only and was not extended to the other nine provinces of the country and therefore the feedback that shall be received may not be a full representation of the views of the Corporation's entire clientele. Even so, it will still suffice for the purposes of the study to appreciate the general perception on the performance of the Utility's systems in the eyes of a Customer.

6 Conclusion

It can be deduced that the Optic Fiber Network was a great innovation in enhancing ZESCO's data and voice communication System. The optimal use of existing structures such as Steel towers for stringing of the optic Fiber guard wire significantly reduced project installation costs and safeguarded such installation from social evils such as vandalism. The real time monitoring of the Power System availed the Utility an opportunity to see system status at any one time and respond to any breakdowns on the network promptly. The National Call Center further benefited from this innovation as customer complaints could easily be registered, tracked and resolved in good time due to enhanced management's oversight and comprehensive system data drawn from OMS.

The study thus concluded that such systems have led to improved system reliability, operational efficiency and overall service delivery.

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EIZ Headquarters:
Cl/7 Los Angeles Boulevard, Longacres,
P. O. Box 51084,
LUSAKA, Zambia.
Tel: +260 21 125 6214; +260 21 125 5161
Email: eiz@eiz.org.zm
Website: www.eiz.org.zm