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A Joint Journal of the Engineers Registration Board & The Uganda Institution of Professional Engineers

For Engineering Excellence

PREPARE FOR THE FUTURE

UGANDA INSTITUTION OF PROFESSIONAL ENGINEERS

NATIONAL PLANNING AUTHORITY

INTEGRATED TRANSPORT INFRASTRUCTURE AND SERVICES PROGRAMME OF THE THIRD NATIONAL DEVELOPMENT PLAN (NDPIII)

The third National Development Plan (NDPIII) which is being implemented from financial year 2020/2021 to 2024/2025 **seeks to increase household income and the quality of life of Ugandans**. The NDPIII is being implemented in line with the Uganda Vision 2040 which is geared towards transforming Uganda from a peasant to a modern and prosperous country within 30 years.

The NDPIII has 20 programmes under implementation by the Government of Uganda. One of the programmes is the **Integrated Transport Infrastructure programme.**

The goal of the programme is to develop a seamless, safe, inclusive and sustainable multi-modal transport system.

Objectives of the Programme

1. Optimize transport infrastructure and services investment across all modes.
2. Prioritize transport asset management.
3. Promote integrated land use and transport planning.
4. Reduce the cost of transport infrastructure and services.
5. Strengthen and harmonize policy, legal, regulatory and institutional frame work for infrastructure and services.
6. Increase transport interconnectivity to promote inter and intra-regional trade and reduce poverty.

Key Interventions of the Programme

The key implementation reforms required to fully implement this programme and realise expected goals in the five years:

1. Develop and implement service and service delivery standards against which performance is assessed.

2. Consolidate all railway projects under the Uganda Railways Corporation that is mandated with implementation of railway construction.

For Engineering Excellence

THE ENGINEER

A Joint Journal of the Engineers Registration Board (ERB) and the Uganda Institution of Professional Engineers (UIPE)

UGANDA INSTITUTION OF PROFESSIONAL ENGINEERS

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A message from the
Chairman, Joint Editorial Committee

Dear Esteemed Readers,

I am glad to present to you this second issue of the first volume of The Engineer, a joint international Journal of the Engineers Registration Board (ERB) and the Uganda Institution of Professional Engineers (UIPE).

Between the last edition and this one, this Journal of high professional standards has made the following strides:

- The Minister of Works and Transport, under whose docket the ERB and UIPE falls, launched the maiden issue of the Journal, Vol 01 Issue 01 which ran for the period January - June 2022, on 19th August 2022. This was on the occasion of inaugurating the 19th Board of the Engineers Registration Board;
- On the same occasion, the Minister launched the Journal's website, www.theengineer.co.ug which I now welcome you to visit and utilize to read and publish information with us;
- The top leadership at the ERB and UIPE has changed, but the Editorial Board has stayed to serve you;
- We have produced a bigger issue than the last one, and I hope you will find that it is with improved content;
- We plan to have a series of trainings in journal article writing and in the publication of engineering information for development.

As one of the tenets of the journal, this edition has endeavoured to cover all sectors of engineering and we have refrained from publishing under a designated theme in order to free writers to be innovative.

We still encourage writers to research and write about topics on how to harness locally available resources of land, materials and manpower to create products and services for the sustainable social, economic and technological development.

We also encourage institutions of higher learning, research centers and individuals researching on engineering related content to use this journal as their first-choice publication media. Being ISSN-registered, the journal is recognized internationally, and with content from the universities and other institutions, a lot of improvements are envisaged. We hope to reveal these in the next issues.

While we still maintain that the opinions and views in the articles are not necessarily those of the Joint Editorial Committee, we affirm that they have been selected in conformity with the professional understanding of engineering as "the application of scientific knowledge to provide solutions to problems that affect society and for the advancement of humanity".

I wish to take this opportunity to express my gratitude to the Joint Editorial Committee for a strenuous but thorough job. And I extend my appreciation to the employers of the members of the Joint Editorial Committee for permitting their staff to take time off their busy schedules. I also dedicate rounds of applause to the management of 8M Construction Digest, for continuing to dedicate exemplary service in publishing this Journal.

Last but not least, I congratulate and thank all the contributing authors and all the reviewers for the high-quality articles that we have published.

Most importantly though, I thank the Almighty God, without whom nothing can be accomplished.

Wishing you pleasant reading,

Eng. Bwanga George William

Chairman, Joint Editorial Committee.

Introduction to the Structural Engineering Design Process

By Prof Mwakali A. Jackson

Prof. Mwakali heads Trio Consultants Ltd, who are consulting engineers and planners. Prof. Mwakali holds an MSc and a PhD in Structural Engineering. He taught at Makerere University and also served as Head of the Department of Civil Engineering before taking early retirement into private consultancy. He has famously been associated with the construction supervision of the iconic 525-metre cable-stayed Source of the Nile Bridge at Jinja that was completed in 2018.

ABSTRACT:

As a background, the writer aims to contribute to continuous professional development, particularly to graduate engineers who seek to be structural engineers; hence the article. The information should refresh or add to the reader's knowledge of structural design principles. The article introduces and defines the basics used in the planning, design and construction of structures. It gives the steps involved in carrying out a detailed design, beginning with the idealization of the structure for ease of structural analysis. It explains how, before a structure can be analysed, it must be reduced to a theoretical scheme or free-body diagram. This diagram shows the spatial configuration of the constitutive components (members) of the structure, the boundary conditions (constraints) and internal and external actions on the structure. The article shows how a structure may be represented as a plane or space frame for ease of analysis and designed as simple, rigid or continuous, semi-rigid or semi-continuous. The writer then deals with the different loads that act on a structure and how they are considered in the analysis and design of the structural elements. He points out structural engineering analysis methods including the flexibility, stiffness and the finite element methods. The writer enlightens readers about the design codes and standards. A list of Eurocodes is given. The writer concludes with a recommendation to find minimum and economic dimensions of selected structural elements, followed by some references.

1.0 INTRODUCTION

The publisher of *The Engineer*, Eng. Hans JWB Mwesigwa, requested me for an article on the introduction to the structural engineering design process. By authoring this article, I hope to contribute pertinent information that may help develop the construction industry. I hope it will assist the Uganda Institution of Professional Engineers (UIPE) in its Continuous Professional Development (CPD) training programme and, in particular, the graduate engineers who seek to be structural engineers. The information should refresh the reader of what they may have skipped at the university or during the course of design and construction of structures at any level of responsibility.

1.1 What is Structural Engineering?

Structural Engineering is the branch of engineering that deals with the planning, analysis, design and construction of structures. Its main goal is to ensure that the key relevant elements that support the structures from instability and/or collapse are designed and constructed to be not only **strong and safe** but also **functionally comfortable and economical**.

1.2 What is a structure?

A structure is defined as a solid element or assembly of solid elements, arranged and supported in such a way that they can carry, transmit or resist applied loads through the mobilisation of internal forces and/or moments within the elements. A structure can be natural or man-made. Examples of man-made structures are buildings, sports stadia, monuments, bridges, towers, silos, bunkers, tunnels, earth-retaining walls, dams, tanks, pressure vessels, etc. Structures can also be mobile, e.g. cranes, space satellites, aircraft frames, ships, submarines, cars, etc.

1.3 Structural design

Structural design is a determination of member sizes for a strong, safe and economical structure, and the production of computations, drawings and relevant documentation thereof. It is a mixture of art and science, making use of concepts and intuition, standard codes of practice, manuals, handbooks, and computers to help in making quick and accurate decisions.

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1.4 Structural analysis

Structural analysis is the prediction of the response of a structure to specified external loads/actions. It requires an experienced engineer's intuitive feeling for the behaviour of a structure with a sound knowledge of the principles of basic physics, structural mechanics and design, materials and geotechnics, making use of computers to do the computations.

1.5 The Catch-22 conundrum

To analyse a structure, the member sizes and properties should be known, but the whole aim of analysis is to determine those sizes and properties! It is like the work permit dilemma many employers and employees face or used to face in many countries: you need a work permit to get a job in a foreign country, but you will not be given the job without a work permit. How was this vicious circle resolved in Uganda?

In structural analysis you have to assume initial economic or minimum member sizes and use an iterative (trial-and-error) method to arrive at the correct size. These dimensions are generally based on experience and accepted practice. My proposal is that structural engineering students and their lecturers may consider preparing a paper/dissertation of *"Minimum and economic dimensions of structural elements in the construction industry of Uganda."*

1.6 Steps to carry out a detailed design

The steps involved in the detailed design for a given type and arrangement of a structure include:

a) Idealisation of the structure for analysis and design;

b) Identification, categorization and estimation of loading;

c) Analysis for the various action/load cases and their combinations, and identification of the most severe design actions;

d) Design of the elements, structural frames, connections and foundations;

e) Preparation of the final arrangements and detailed drawings; and

f) Preparation of the materials list, bill of quantities and specifications to enable the estimates and tender documents to be completed.

Steps (a) to (e) are an iterative cycle as illustrated in Figure 1 below.

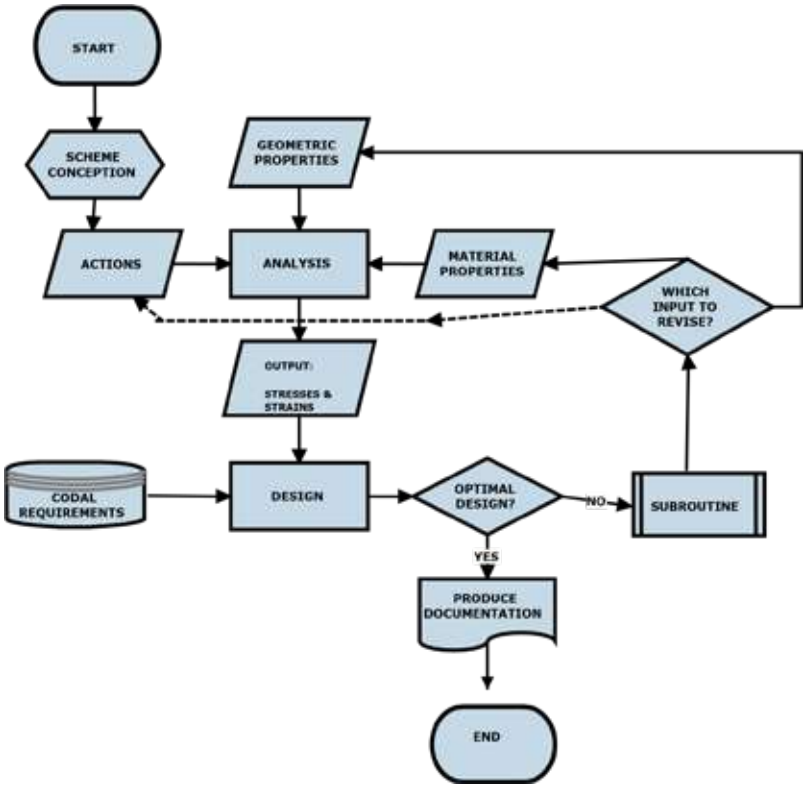

Figure 1: Flowchart showing steps followed to carryout a detailed structural design

2.0 STRUCTURAL IDEALIZATION

Before a structure can be analysed, it must be reduced to a theoretical scheme or free-body diagram showing the spatial configuration of the constitutive components (members) of the structure, the boundary conditions (constraints) and internal and external actions on the structure. The sketch of the free-body diagram needs to include only as much detail as necessary depending on the analysis to be performed and the model being employed. Often a simple outline is sufficient.

A structure may be represented as a plane or space frame and then analysed as a complete frame or a series of isolated sub-frames. The frame may then be analysed and designed as one of the following:

a) Simple – in which the joints are assumed to be pinned and not to resist moments. In this case bracing or shear walls are needed to provide resistance to horizontal loads.

b) Rigid or continuous – in which the joints are assumed to be fully continuous and moment-resisting. Therefore, there is no need to pay any particular attention to the details of the joint make-up.

c) Semi-rigid or semi-continuous – in which the joints are assumed to be partially fixed and their behaviour should be taken into account in the analysis.

Where design using any of the above methods is not practical, it is also allowed to determine the strength of a structure or member using experimental methods. In practice, most designers assume simple or rigid frames.

3.0 LOADS

Loads are actions on structures that must be designed for to ensure a structure that is safe and within acceptable serviceability limits. They include dead, live, thermal, wind, snow, seismic and accidental loads.

3.1 Dead loads

This is the force due to the static (self) weight of all walls, partitions, floors, roofs and finishes, including all other permanent constructions such as pipes, electrical conduits, air conditioning, solar panels and heating ducts, lighting fixtures, etc. and self-weight of the structural elements. Dead loads are usually known accurately but not until the design has been completed. Therefore, the weight of the structure or structural elements must be estimated, preliminary section selected, weight recomputed and member selection revised if necessary.

3.2 Live (imposed) loads

This is the load assumed to be produced by the intended occupancy, including distributed, concentrated, impact, inertia and snow loads, but excluding wind loads. Examples of live loads are human occupants, furniture, movable equipment, vehicles, and stored goods. Live loads to be taken as service loads in design are usually prescribed by building codes. These loads are generally empirical and conservative, based on experience and accepted practice rather than accurately computed values.

3.3 Wind loads

This load depends on the location and building size. Codes of practice give guidance on how to compute the wind loads.

3.4 Other loads

Other loads on structures are caused by expansion and contraction, waves, ice, seismic effects, etc. Appropriate codes for analysis and design should be consulted where these loads are anticipated.

EN 1991 (Eurocode 1): Actions on structures gives guidelines for determination of the various loads or actions on structures. Table 1 summarises the loads covered by the different parts of Eurocode 1.

Table 1: Parts of Eurocode 1: Actions on structures

Part of Eurocode 1: Actions on structures	Action/Load Covered	Date Issued
EN 1991-1-1	General actions – Densities, self-weight, imposed loads for buildings	April 2002
EN 1991-1-2	General actions – Actions on structures exposed to fire	November 2002
EN 1991-1-3	General actions – Snow loads	July 2003
EN 1991-1-4	General actions – Wind actions	April 2005
EN 1991-1-5	General actions – Thermal actions	November 2003
EN 1991-1-6	General actions – Actions during execution	June 2005
EN 1991-1-7	General actions – Accidental actions	July 2006
EN 1991-2	Traffic loads on bridges	September 2003
EN 1991-3	Actions induced by cranes and machinery	July 2006
EN 1991-4	Silos and tanks	May 2006

British Standard BS 6399 Parts 1 to 3 also give guidelines for the determination of dead and imposed loads, wind loads, and imposed roof loads, respectively.

4.0 STRUCTURAL ENGINEERING ANALYSIS METHODS

The points below are followed for a proper structural engineering analysis

4.1 Introduction

For *statically-determinate* structures, analysis is dependent on the fact that all unknown forces can be determined by applying equations of static equilibrium to free-body diagrams to determine external and internal forces using such techniques as the method of sections, method of joints, etc. and then substituting these forces back into the member stress-strain relationships (such as Hooke's Law) to determine the deformations.

For *statically-indeterminate* structures, equations of equilibrium are fewer than the number of unknowns, the difference being known as the number of redundancies. There are several available methods for analysing such, including the compatibility method, slope-deflection method, moment-distribution method, etc. However, the advent of computers brought about the development of modern methods based

on matrix algebra, in which the problem is reduced to the solution of a set of simultaneous equations with as many unknowns as there are redundants or degrees of freedom.

There are two types of matrix methods of structural analysis

4.2 Flexibility Methods

The joint displacements are expressed in terms of joint actions by means of the flexibility matrix, and the number of simultaneous equations to be solved is equal to the number of redundants of the system.

4.3 Stiffness Methods

The joint actions are expressed in terms of unknown joint displacements by means of the stiffness matrix, and the number of simultaneous equations to be solved is equal to the number of degrees of freedom (d.o.f.) of the system. The equations can be represented as:

K.d=w

where

K – stiffness matrix of the structure (square matrix of dimension dxd)

d – displacement vector of the system (no. of elements is the same as the no. of d.o.f.)

w – load vector of the system (same length as d)

In general, the matrix stiffness methods are more amenable to programming on computers than the matrix flexibility methods. This is because the stiffness equations are easy to derive and reveal the kinematic stability or instability of the structure. The analysis requires a large amount of linear algebraic manipulations and the most suitable branch of mathematics for representing such manipulations is that of matrix algebra. Typical manipulations involved are:

- Matrix inversion
- Linear transformation
- Matrix transposition
- Matrix multiplication, subtraction and addition

There are many methods of solving the simultaneous equations, such as the classical direct Gaussian elimination followed by back-substitution. There are also many more accurate and efficient iterative methods such as Gauss-Seidel, Gauss-Jordan, Newton Raphson and Jacobi methods that reduce cumulative rounding-off errors.

It is worth noting that the stiffness matrix K has the following characteristics:

- It is square
- It is symmetric
- It is banded
- It is positive definite (**if all its eigen values are positive** for a hermitian or symmetric matrix)

For a kinematically stable structure, the stiffness matrix is invertible and has a determinant. The bigger the value of the determinant, the more robust the structure is.

The above characteristics help with efficient assembly, storage and solution of the structural systems.

The degrees of freedom (representing the number of simultaneous equations) for most structures run in excess of thousands or even tens of thousands. Solving that number of equations by hand would take years and most probably result in wrong answers! That's why the advent of the computer made such a big difference in structural engineering, because the analysis could now be carried out in hours in the 1970s and 1980s when mainframes were the order of the day. In the 21st century, the cheap but fast desktops will solve a large structure in seconds.

4.4 The Finite Element Method (FEM)

A structure is an assemblage of members or elements, namely

- *Columns, struts and ties* – elongated straight members that resist axial forces (member axial stiffness k=EA/l), but in some cases bending moments also. These cases are found in buildings, bridges, etc.
- *Beam* – elongated straight, rigid element which resists transverse loadings primarily by bending or flexure (member flexural stiffness k=EI/r) and shear (member shear stiffness=Ay/Ib), but in some cases also axial forces and torsion. Found in buildings, bridges, etc.
- *Shaft* – elongated straight rigid members which resists torque or torsion or twisting moment (k=GJ/l). Found mostly in mechanical engineering applications.
- *Plates and shells* – flat rigid elements where the thickness is small in comparison with the other two dimensions. It resists bending, shear and twisting moments. Plates occur as building floor and roof slabs, bridge decks, ship decks, working platforms in industrial structures. Shells occur in pressure vessels, boilers, liquid filled tanks, cooling towers, domes, roofs, ship hulls, aircraft, missiles, etc.

The finite element method simply refers to the fact that a big structural member is more accurately analysed if it is broken down into smaller discrete or finite elements. In this way the behaviour of closely spaced points in the entire length or area of the member is computed, giving a sense of a spectral continuum. This is especially important for members that resist moment so that the most stressed sections can be identified.

The finite element stiffness method is well described by Livesley (1975 & 1983) and Zienkiewicz et al. (2005) and may be summarised as follows:

a) Break down the structure into simple geometric finite elements with displacement compatibility and stress continuity at nodes.

b) From the stress-strain relationships of the element material, derive equations between nodal loads and nodal displacements for each element.

c) Derive nodal compatibility equations by equating the appropriate nodal displacements of those elements which share a common node.

d) Derive nodal equilibrium equations by equating, at each node, the external load with the sum of the "internal" nodal loads acting on the elements which meet there.

e) Apply the condition necessary to keep the structure in overall equilibrium.

Conditions (2) to (5) generate a system of simultaneous equations represented by the expression K.d=w that can be solved by any appropriate method to give the nodal displacements and the member forces by any appropriate method. The support reactions are evaluated by considering equilibrium of forces at the constrained joints.

The entire process above is called **Finite Element Analysis** (FEA). There are many structural analysis programs that are based on the FEM. Popular ones include ANSYS, GENESIS, ABAQUS, STAAD, Prokon, LUSAS, ProtaStructure, Revit, SAP2000, RISA, SAFE, MIDAS, Orion, Tekla, etc.

Some of the programmes are for analysis only. Others have design modules as well. Some have modules for detailing. Some will produce outputs that are exportable to AutoCAD, Word, Excel, etc.

4.5 Creating Finite Elements

Breaking down a structure into finite elements is a feat in its own right. Fortunately, engineers have developed branches of algebra that help with the generation of finite elements. An example is Formex algebra developed by Prof. Hoshyar Nooshin of the University of Surrey, UK (Nooshin, 1975; see also Mwakali, 1990).

5.0 DESIGN CODES AND STANDARDS

Design codes or standards codes and standards provide guidance to the designer as to what constitutes good practice and ensure that the product conforms to applicable legal requirements. Some of the popular design standards/codes are from UK, Europe, USA, and India. For structural design, British and European standards are the dominant ones in Uganda.

There are 10 European standards for structural design, popularly known as Eurocodes. These are listed below with their British equivalents.

List of Eurocodes *(Read the full table from the website www.theengineer.co.ug)*

6.0 RECOMMENDATIONS AND CONCLUSION

This article may not be exhaustive in describing the structural engineering design process. It however throws enough light for the reader to add more knowledge and progress to plan, design and construct strong, safe but economic structures. I recommend a study on minimum and economic dimensions for structural elements of buildings and other infrastructure components in Uganda.

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Utilisation of E-waste Plastic as a Partial Replacement for Coarse Aggregate in Concrete

By Atukunda Mercy Sabiiti

Atukunda Mercy Sabiiti graduated in 2020 with a BSc. in Civil and Environmental Engineering from Uganda Christian University. She is currently studying a dual master's degree in Civil Engineering/Engineering Project Management at Griffith University and doing a graduate internship with Blackstorm Engineers in Brisbane, Australia. She is also a co-founder of Avrateq, an engineering visualization brand being nurtured by 8M Forum.

ABSTRACT

The increasing use of electronics in Uganda has in turn greatly influenced the large amounts of electronic waste plastic generated every year. This increases the landfill cost; yet if e-waste plastic were utilised as a construction material, it can reduce the depletion of natural resources and serve as a disposal mechanism for the electronic waste plastic. This experimental study investigated the utilisation of electronic waste plastic as a partial substitute for coarse aggregate in concrete. Electronic waste plastic was locally sourced, mechanically shredded and sieved through a 14mm sieve. Conventional coarse aggregate in concrete was then partially replaced by the E-waste plastics in percentages of 0, 5, 10 and 15 in M25 grade concrete. The properties of the concrete were then tested and evaluated. The study showed that partial replacement of up to 10% was possible and that the optimal replacement was 5%. Incorporating e-waste plastic reduced the self-weight of the concrete which indicated that it can be applied as a lightweight concrete in non-load-bearing elements of structures. The utilisation of this waste as a construction material not only reduces the amount of waste effectively but is also a sustainable method of e-waste plastic disposal.

Keywords: *Concrete, Coarse aggregate, E-waste plastic, Compressive strength.*

1.0 INTRODUCTION

E-waste is the fastest growing waste stream worldwide with an annual growth rate of 3-4%. This can be attributed to the growing population and urbanisation coupled with continuous and accelerating technological advancements (Vivek and Damal, 2015). It was estimated that by the end of 2021, 52.2 million tonnes of E-waste would have been produced, thereby posing a serious environmental challenge (Vaihav et al, 2018).

Electrical and electronic equipment are an integral part of everyday life since they provide comfort, security and ease exchange of information (Karthikeyan, 2017). Unfortunately, after their useful life (3-5 years), they become Waste Electrical and Electronic Equipment (WEEE) which presents an environmental challenge especially due to their composition of heavy metals which are classified as hazardous (Julander et al, 2014). E-waste plastics, which make up 20-24% of the total weight of a computer, also contain hazardous materials such as Brominated Flame Retardants (BFRs), Chlorine, Antimony and Cadmium, among others (Vaihav et al, 2018).

One of the main goals of sustainable waste management that ranks high in the waste management pyramid is maximization of recycling and reusing waste materials. With increasing environmental pressure to reduce waste pollution, the cement and concrete industry has started adopting several methods to achieve this goal. Waste Electrical and Electronic Equipment can be viewed as a possible avenue for resource recovery through recycling and re-use (Kiddee, 2013). There have been attempts to utilise E-waste plastic as a construction material for example in the partial replacement of coarse aggregate in concrete (Karthikeyan J, 2017). Utilising these modern, complex, valuable but hazardous elements comprising e-waste by application as fine or coarse aggregates in concrete is an innovative and revolutionary concept in the direction of sustainable and cost-effective concretes .(Luhar, 2019).

2.0 METHODOLOGY

The content scope and objectives of the study informed a procedure that involved characterisation of computer-based E-waste plastic, characterisation of conventional concrete mix ingredients, determination of the proportion mix design and evaluating the performance of the synthesised E-waste plastic concrete. The materials and procedure are explained in depth in this chapter

2.1 Materials

E-waste, specifically computers, were obtained from local electronic recycling retailers and carefully dismantled. This is shown in Figure 1. The plastic casings were then carefully extracted and shredded mechanically using a plastic shredding machine. The pieces were sieved through a 14mm sieve. Locally available sand, coarse aggregate, Ordinary Portland Cement (OPC) and portable water were used in this study. All tests were conducted at the Central Materials Laboratory (CML) of the Ministry of Works and Transport in Kireka-Uganda.

Figure 1: Plastic casings of electronic waste

2.2 Characterisation of computer-based E-waste plastic

The mechanically shredded e-waste plastic was tested for its strength (Aggregate Crushing Value), toughness (Aggregate Impact Value) and flakiness. Table 1 shows the standards used to test these properties.

Table 1: Test methods of the E-waste plastics

Test	Standard	Specifications BS 882: 1992 (Concrete)
FI	BS 812	35% Maximum
AIV	BS 812-P110	30% Maximum
ACV	BS 812-P112	30% Maximum

2.2.1 Characterisation of the Constituent Ingredients of Conventional Concrete and Determination of the Proportion Mix Design

All materials used in the study conformed to BS 812. A concrete mix design for M25 was obtained for the control mix (0% replacement) as guided by the design of normal concrete mixes for natural aggregate which comply with BS 5328 (Teyvhenne et al, 1998). Partial replacement at 5%, 10% and 15% was done by weight; and cubes were cast for different samples. In accordance with BS 812, samples from each mix were collected. Both fresh and hardened concrete samples were tested for various properties.

2.3 Evaluation of the performance of fresh and hardened synthesised E-waste plastic concrete

A sample of fresh concrete was obtained as guided by the BS 1881 Part 101 (Method of sampling fresh concrete) and the workability was determined to obtain a slump value.

For hardened concrete, samples with different percentages of E-waste plastic were placed in 150mm x 150mm x 150mm concrete moulds. The percentages of E-waste plastics in samples of the synthesised concrete were 0 (control mix), 5, 10, and 15. After being left to set, the concrete cubes were then placed in a water bath for curing and compressive strength tests were conducted after 7 and 28 days.

3.0 PROPERTIES OF CONSTITUENT MATERIALS

The synthesised E-waste plastic concrete's constituent material properties were studied and are explained in this chapter.

3.1 Physical properties of E-waste plastics aggregate

The recycled electronic waste plastic which was used to replace some of the coarse aggregate in the casting of concrete cubes was subjected to some of the basic tests conducted on conventional coarse aggregate with the results as indicated in Table 2. The physical properties were determined while the e-waste plastic was in its natural shredded state and not under any kind of load. These properties included maximum size, specific gravity and water absorption.

Table 2: Physical properties of E-waste plastic

Number	Characteristics	Value
1.	Type	Shredded
2.	Maximum size	14mm
3.	Specific Gravity	1.1
4.	Water absorption	0%

Specific gravity is not necessarily related to aggregate behaviour. But it was observed that aggregates which are compounds of shale, sandstone, and chert have a somewhat low specific gravity and are therefore likely to display poor performance, for example, of low per-

meability, which is an indicator of poor durability (Legg, 1998).

Aggregate porosity may affect durability in cold climates since freezing of water in pores in aggregate particles can cause surface pop-outs (Popovics, 1998). Water absorption can also be used as an initial indicator of soundness. Aggregates with low absorption tend to reduce shrinkage and creep (Washa, 1998).

3.2 Mechanical properties of E-waste plastic

The mechanical properties were obtained when the shredded electronic waste plastic was subjected to the different loads. The Aggregate Impact Value (AIV) measures the resistance to sudden impact whereas the Aggregate Crushing Value (ACV) gives a relative measure of resistance to crushing under a gradually applied compressive load. When load is applied on a rock, part of it breaks off. The mass which breaks off is then sieved through a 0.623mm sieve and expressed as a percentage of the total original mass which then gives an indication of the aggregate's strength. The plastics, however, when subjected to these tests did not form any fines which translated into values of ACV and AIV that were generally below 1%. This implies that they, in this respect, showed better mechanical properties than those of natural aggregate.

3.3 Fine aggregate characteristics

The physical properties of the fine aggregate were compared with BS EN 12620 specifications to ensure that they were suitable for use in concrete and the results are as indicated in Table 3. The material was considered suitable because the values lay within the recommended ranges.

Table 3: Physical properties of fine aggregate

Number	Characteristics	Value	BS EN 12620 Requirement
1.	Type	Uncrushed (Natural)	Uncrushed (Natural)
2.	Silt content	3.07%	4% Maximum
3.	Organic matter content	Lighter than standard reference colour	Lighter than standard reference colour

Table 4 shows the gradation of fine aggregate which was compared with the BS EN 12620 requirements to ensure that they lay within the recommended ranges. This was indicative of a uniform grading which is a prerequisite for fine aggregates. The results implied that they were suitable for use as concrete constituents.

Table 4: Gradation results of fine aggregate

Sieve size (mm)	Mass retained (g)	Percentage Passing	BS EN 12620 Requirement (%)
10.0	0.00	100	100
5.0	1.99	100	89-100
2.36	26.57	97	60-100
1.18	97.60	88	30-100
0.600	203.26	68	15-100
0.300	413.45	29	15-70
0.150	228.62	7	0-15

3.4 Physical and mechanical properties of coarse aggregate

The results for physical properties of coarse aggregate were obtained in accordance with the BS EN 12620 specifications as indicated in Table 5. The values were all within the recommended parameters deeming the coarse aggregate suitable for use in concrete.

Table 5: Showing physical properties of coarse aggregate

Number	Characteristics	Value	BS EN 12620 Requirement
1.	Type	Crushed (Natural)	Crushed (Natural)
2.	Maximum size	20mm	20mm
3.	Flakiness index	29%	35% Maximum
4.	Water absorption	0.17%	2% Maximum

Uniform grading with proper amounts of each size is required because it results into aggregate blends with high packing in concrete with low water demand. Table 6 indicates that the coarse aggregate was uniformly graded since the percentages passing lay within the BS EN 12620 envelope specifications.

Table 6: Showing gradation results of coarse aggregate.

Sieve size (mm)	Mass retained (g)	Percentage passing	BS EN 12620 Requirement (%)
37.5	0.00	100	100
20	435.61	88	85-100
14	1919.17	33	0-70
10	1129.07	1	0-25
5.0	38.45	0	0-5

The mechanical properties of coarse aggregate gave an

indication of how the concrete would perform under action of various loads. Table 7 shows the test results of the parameters indicated and their corresponding specifications. The comparison indicates that the aggregates were a suitable material as per the standards.

Table 7: Showing mechanical properties of coarse aggregate

Number	Characteristics	Value	BS EN 12620 Requirement
1.	AIV	13%	30% Maximum
2.	ACV	17%	30% Maximum
3.	TFV	230kN	100kN Minimum
4.	LAAV	20.2%	50% Maximum

3.5 Cement

The cement used in construction is usually inorganic, often lime or calcium silicate-based and can be characterised as being either hydraulic or non-hydraulic depending on its ability to set in the presence of water. Tororo Ordinary Portland Cement of grade 42.5 was chosen and used in this experimental study.

4.0 THE MIX DESIGN

Mix proportions of the constituent ingredients of concrete were determined in relation to the cement, fine aggregate and coarse aggregate that would achieve a specific target strength after 28 days. The mix design for M25 grade concrete was done as per BS 5328 and the following data was required for the concrete mix design.

i. Characteristic compressive strength at 28 days is 25 N/mm^2
ii. Cement used was 42.5kN OPC (Tororo cement)
iii. Coarse Aggregate – crushed aggregate of size between 12.5 mm to 20 mm in length and 2-8 mm thickness, free water absorption of 0.17%.
iv. Fine aggregate river sand was used (less than 5mm in size).

The various proportions of the materials used in the concrete mix are indicated in Table 8. Replacement of the coarse aggregate with the E-plastics was then done by weight as indicated.

Table 8: Mix design proportions (kg/m^3)

E-waste plastic (%)	0	5	10	15
Water (l)	5.2	5.2	5.2	5.2
Fine Aggregate	21.2	21.2	21.2	21.2
Coarse aggregate	30.5	28.97	27.45	25.59
Cement	7.55	7.55	7.55	7.55
E-waste plastic (kg/m^3)	0	1.53	3.05	4.58

5.0 RESULTS AND DISCUSSIONS

The results obtained from the different tests carried out in the laboratory were collected, graphed and analysed. They were also discussed to make sense of their meaning to the general objective of the research. This chapter shows illustrations and detailed explanations of the results obtained from the laboratory.

5.1 Workability

As the percentage of E-waste was increased, the workability (slump values) decreased as shown in the Figure 2. This behaviour is partly attributed to shape (flaky) and size (14mm maximum) of the E-waste plastic aggregate which influence the consistency of the concrete mix by an interlocking mechanism. The flakiness and light weight of the E-waste plastic aggregate influenced the decline in the slump and fresh concrete density. Figure 2 shows the slump cone test results with the general trend of workability of the concrete reducing with introduction of the e-waste plastic aggregates.

5.2 Compressive strength results

It was observed that concrete cubes containing E-waste plastic failed at lower compressive loads as compared with those made of control concrete. However, the target strength after 7 days was achieved for all samples.

After 28 days, the target strength of 25MPa was not attained by the 15% replacement. This can be attributed to the higher percentage of electronic waste plastic which reduced the self-weight of the concrete. The packing density was also affected, and the flakiness of the plastics might have caused lines of weakness due to the ineffective interlocking with other constituent ingredients. This is illustrated in Figure 3.

5.3 Discussion of results

From the results obtained in the experimental study, it is evident that E-waste plastic can be used in concrete as a partial substitute for coarse aggregate. Similar results were obtained by Shamir *et al* who suggested that only partial substitution was viable since complete substitution significantly reduced the self-weight of the concrete. Various other studies have emphasised that complete substitution would significantly reduce self-weight of the concrete. According to Shamir *et al*, the strength of the concrete decreased when the e-waste plastic content was more than 20% substitution.

Manjunath highlights that as the e-waste plastic percentage is increased, the flexural values and the split tensile strength tend to decrease. He attributes this to the decrease in adhesive strength between the materials and the hydrophobic nature of plastic which may restrict hydration of cement. His optimum mix had 20% e-waste plastic waste and gave averagely better results than the control mix (Manjunath, 2016).

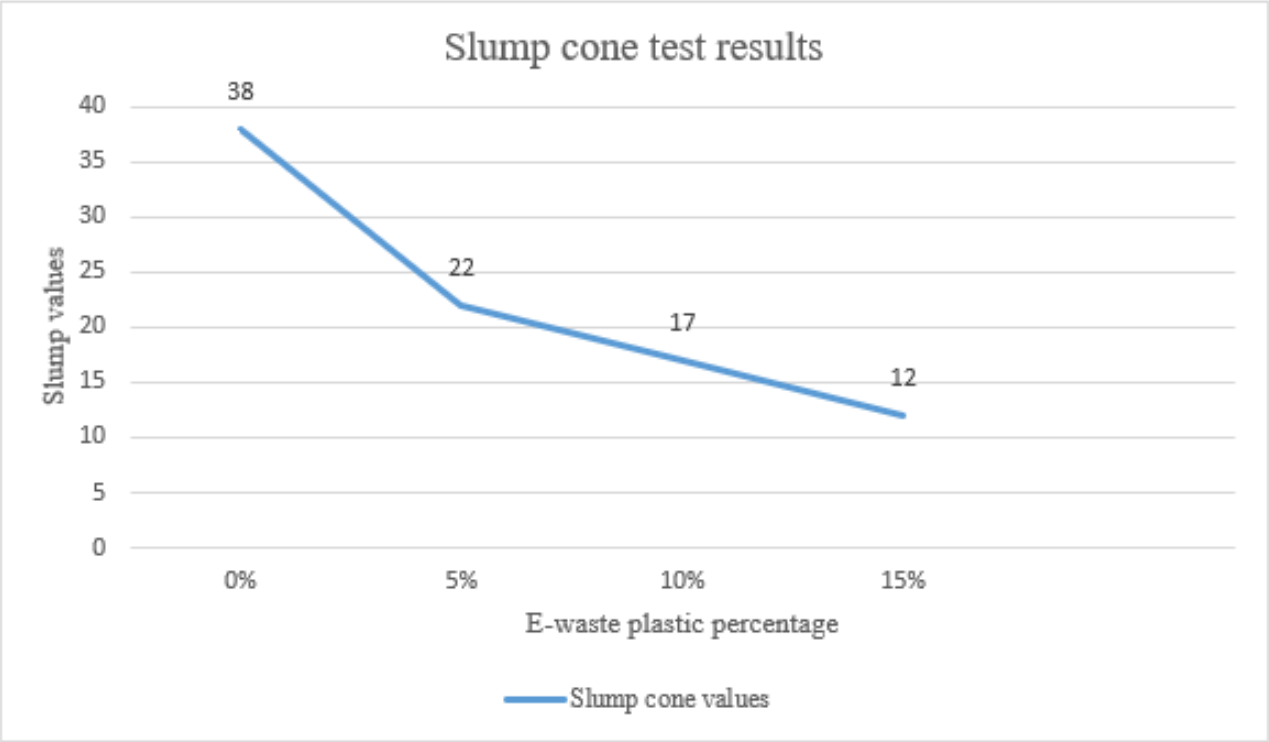

Figure 2: Trend of slump cone values at different percentages

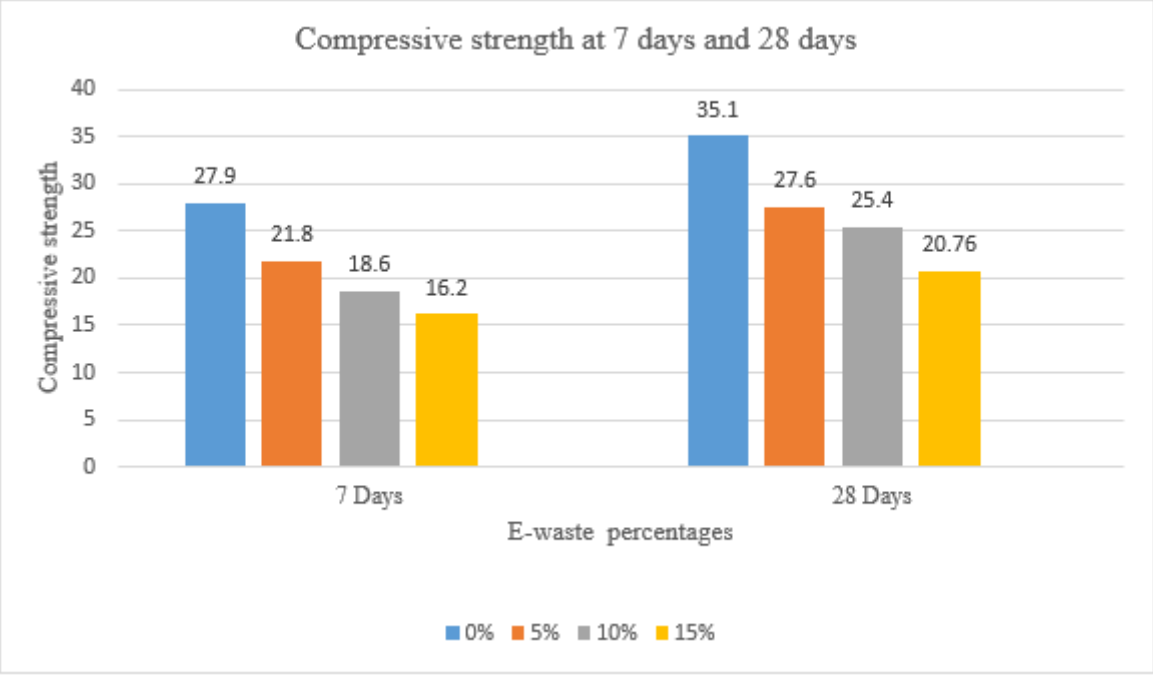

Figure 3: Compressive strength results

6.0 CONCLUSION AND RECOMMENDATIONS

The objectives of this experimental study were achieved. The results obtained showed that it is possible to utilise shredded E-waste plastics as a partial substitute for coarse aggregate in concrete. The results also indicated that E-waste plastics are a viable alternative material and this has the potential to reduce natural resource depletion. Substitution of up to 10% was achieved with the optimal replacement as 5%. The self-weight of concrete reduced when there was an increase in E-waste plastic percentage. This is reflective of its effectiveness in application of lightweight concrete especially in non-structural elements that carry very little to almost no load, for example suspended ceilings, light non-load-bearing partitions, pipework, non-load-bearing walls and many others.

E-waste plastic can be used as coarse aggregates by replacing the conventional coarse aggregates in concrete by weight in percentages (5 and 10). However, the compressive strength decreases with increase in the e-waste.

The E-waste plastic is flaky, and this is considered a poor shape in aggregates because it hinders effective interlocking and bonding with other components. Plastics also have a smooth surface which may affect the crisp and solidified properties of cement.

Recommendations include carrying out split tensile tests. If carried out, they could be included in another experimental study to assess the effect of electronic waste on the tensile strength of concrete. Only plastic casings were used and therefore other studies could be conducted to assess the utilisation of other components besides the plastic casings especially the internal components. A durability study may also be conducted to assess the performance of electronic waste over longer periods of time.

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Will Artificial Intelligence replace Architects?

By Mukyala Cynthia Clare

Cynthia Clare Mukyala is an Architectural Designer (Part I- RIBA), graduate of Uganda Martyrs University, Nkozi. Above all, she loves concepts, taking project data such as building site conditions and client needs to develop strategic concepts for the overall design; with problem-solving as her main goal. She believes in architecture as both an art and a science—a multidisciplinary vocation with various dimensions such as psychology, sociology, human experience, construction, materials, etc. Therefore, until AI can automate art, creativity and innovation, the role of an architect continues to be relevant.

ABSTRACT:

Artificial Intelligence (AI) has been a mark in technology advancement in the 21st Century. With every advancement in technology, what we work on and how we work changes. Machines become more and more able to do the work faster and even more efficiently than human beings. Human labour is therefore displaced and reshuffled. Artificial Intelligence machines have abilities such as visual perception, speech recognition, and decision-making that normally requires human intelligence. In architectural practice, AI has the potential to make work easier and more efficient with features such as 'Big data', Parametric Design, BMI, Augmented Reality, Virtual Reality and Robot crafters. In addition, AI will change the scope of work as smart systems and how they are experienced by users become a part of the considerations in design. However, among creatives, there is rising concern that AI will take their place. This article discusses the impact of Artificial Intelligence on architectural practice and whether it is possible that AI will replace architects.

1.0 INTRODUCTION

From the days of the early caveman to our present day in the 21st Century, human beings have been involved in production as a means of survival; to thrive; to feed; for shelter; for clothing and civilisation. And just as human beings have evolved, so have the means of production. The past centuries saw the revolutonalisation of production systems that featured the Industrial Revolution (18th-19th Century), the Digital Revolution (mid-20th Century), and currently, the "Industry 4.0". The "Industry 4.0" marks a shift from the 'digital era' of the 1990s and 2000s to a period where the physical world and the digital world are merged and working symbiotically with each other. It features technologies such as Artificial Intelligence (AI), Virtual Reality (VR), Augmented Reality (AR) the Internet of Things (IoT), Robotics, Block Chain etc. It goes without saying that with every shift and advancement in technology, human labour is displaced and new roles come in demand. The machines are more and more able to do the work faster and even more efficiently than human beings. The question now: Who will be displaced and who will remain relevant?

To put you up to speed, Artificial Intelligence is a computer system that is able to perform tasks normally requiring human intelligence, such as visual perception, speech recognition, decision-making, and translation between languages. This means that AI machines are advancing beyond formerly simple machine abilities, and now are able to process, analyse, respond, and create just like a human being. They are, in fact, majoring in many professional fields that require intelligence, creativity and critical thinking.

2.0 POTENTIAL OF AI VERSUS A HUMAN INTELLIGENCE

In architectural practice, AI has the potential to make work easier and more efficient. AI is still far from its full potential. However, it is developing fast and in future it will grow even more powerful, making it even more valuable. When you look as far into the future as 2050, at the anticipated "singularity" moment in AI, human intelligence and AI merge. Human intelligence will experience an extensive integration with AI, forming an interdependent relationship where AIs are complemented by human talent for creative thinking; and human beings will be complemented by AI's memory and rapid computing. We can only imagine the kind of the design that can come out of this kind of integration. We might begin to create designs we do not yet have the capacity to fathom.

Meanwhile, take the case of an architect starting out on a new project. They spend countless hours on research about various parameters that affect the project.

These may include factors such as climate and weather, soils, zoning data, material ratings, case studies, etc. AI comes in quite handy at this point because of its ability to take in vast amounts of data in a short time, wielding its massive processing power. It has the ability to utilise tons of previous data in a millisecond: collecting, combining and sharing "big data" along with research, analysis, analytics and computations. This means that with an AI system, an architect could pull all zoning data and building codes and generate design variations that follow a given design language. The burden of research is then taken off the architect and they can now focus on the work of creating and innovating. In addition, offices can share ideas and projects across the board rather than the traditional emailing between firms and clients. Environmental sustainability can also be built right into the design with solutions such as smart-lighting or smart-stormwater management systems being worked direct into blueprints.

Another way AI will simplify the work of architects is increasing workflow with software such as those that allow Parametric design. It is a design system that allows architects to play with various building and design parameters to create various outputs of forms and structures. A Parametric design system uses geometric programming and algorithms to allow architects to reshape a building and optimize it to fit their needs. Architects are able to set constraints, plug in data, and create countless iterations of a building within minutes. With a tool like this an architect can be free to play, think and create while the Parametric system does the menial work. And with BIM (Building Information Modelling), things move even faster. BIM can work with other programmes to give the architect a complete picture of the building including everything from concept design to maintenance and operation making the planning process easier and faster.

AI also has the potential to improve overall client satisfaction. With technologies such as Augmented Reality and Virtual Reality, clients will be able to walk through a structure before it is built. Clients can have real-world experience with their proposed building without having to break ground. It is possible to simulate everything from aesthetics to sounds, and feedback can be implemented into the design immediately—before money has been spent on materials or construction.

When it comes to construction, AI can actually construct something with little or no manpower. Picture a world where robots work in teams to build structures, drones fly overhead and scan the site, sending instructions to robotic cranes and diggers and automated builders with no need for human involvement. The "builder" then becomes an "overseer" and projects can be remotely managed. This world is coming and is already with us; in the not-so-far future. Some companies already have machines that can do some of the repetitive construction tasks such as bricklaying, concrete pouring, demolition and 3D printing tools— "robot crafters" that can construct every detail of the project from nothing. AI can also predict overflows by using factors such as project size, and competence and the skill of project managers to make its calculations and create cost estimates. It can also analyse sites and identify potential risk factors, decreasing safety hazards and the delays they might cause. However, it is worth noting that in terms of appreciation for craft, we are likely to lose the "human touch" and the haptic qualities of construction.

AI will not only transform the productivity of architects but also reframe the scope of design. Besides thinking about wiring and plumbing like they did before, they will have to also consider the smart systems of our living environments such as cities and homes. When smart cities and smart homes become ubiquitous, it is inevitable that the new technology and system will have to go into consideration. With smart cities, a major task of the architect will be to understand how a city flows. Smart cities will be places driven by real-time data and feedback, communicating with themselves like a living organism. The buildings, smartphones, cars, and public places will communicate with each other to improve living conditions, limit waste, increase safety, and limit traffic. This trend already exists in some of the world's most advanced cities like Singapore and London. With smart homes, the architect will have to think about how AI could enhance the user experience. Smart homes, just like the smart cities will be complex living data-driven organisms. A smart home has appliances and devices that can be automatically controlled remotely from anywhere with an Internet connection using a mobile or other networked device. Users will be able to control functions such as security access to the home and lighting remotely. Smart home appliances also come with self-learning skills so they can learn the user's schedules and make adjustments as needed. As an architect, the challenge will be how to fit AI into the design of a home.

3.0 WILL ARTIFICIAL INTELLIGENCE REPLACE ARCHITECTS?

According to *The Economist*, 47% of the work done by humans will have been replaced by robots by 2037, even those traditionally associated with university education. These jobs will be lost as "artificial intelligence, robotics, nanotechnology and other socio-economic factors replace the need for human employees". When you think about past generations, during the 20th century, several businesses and professions emerged and disappeared as new technologies developed and got adapted. Microsoft co-founder Bill Gates, however, believes "AI is just the

latest in technologies that allow us to produce a lot more goods and services with less labour". The implication is that not only will people be displaced, but how we work, and what we can work on, will change; all work will be shaped by AI before 2050.

In the creative industry, AI adoption has pros and cons. Some designers are concerned about their role being taken up by AI. And considering that the aim of AI is to create machines or software capable of self-direction and learning, this concern is valid. The idea of "robot architects" taking over the jobs of the real architects raises many discussions about the future of architectural practice. One would imagine that clients will soon be able to tell software what kind of building they want, style and preferences, size, location and budget, and get a variety of options in no time. They might even be able to move things around in augmented reality, see how they fit and take on what fits within their budget. The software would then recommend a contractor or even robot contractors to build the project.

However, architecture requires intense collaboration; and has an emotional aspect that cannot be interpreted by computers. A computer cannot tell when a client is happy or when a contractor disagrees with a decision. Computers are not good at open-ended creative solutions; that is still reserved for human beings. They can only solve what they already know. Architecture is a multi-disciplinary practice that engages the architect on various aspects of human living such as psychology, user-needs and experience, "implicit" individual preferences, social needs, circulation; artistic aspects such as proportions, balance, contrast, patterns, concepts, themes and scientific aspects such as building materials and their alternatives, and strengths, all encompassed within the fact that design should be innovative. AI systems in the end still depend on inputs collected by humans to function properly.

In addition, according to *The Telegraph* newspaper (2013), architects have one of the lowest replacement rates (1.8%), in a comfortable position with stylists (2.1%), aerospace engineers (1.7%), curators (0.7%) microbiologists (1.2%), theatrical makeup artists (1%), anthropologists (0.8%) and choreographers (0.4%). What these roles have in common is that they require a high level of human interaction, creativity, a dynamic multi-disciplinary approach, and have a low percentage of repetitive tasks. They will be the last to be replaced, but there will also be new roles required necessary to monitor and coordinate intelligent machines and systems.

4.0 CONCLUSION

As technology evolves, it serves as a tool to assist architects; and as it evolves, architects too need to shift; but it will only solve a small piece of the puzzle. Artificial intelligence with its human-like abilities will eliminate tedious, repetitive activities, optimising the production of technical material which implies that each time fewer architects are needed to develop more complex projects. For example, you do not need to pay for people to decide where the plumbing will go. This makes it easier for small firms to compete for ambitious projects because they can focus on the art and design. It will alleviate architects of various burdensome tasks that come in the way of creativity like research, drawing and menial construction work. And when smart cities become common, the scope of work for architects will change as well. But until computers can automate creativity and innovation as well as reproduce the design-creative and human touch, the role of an architect will continue to be relevant.

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Modern IT Applications for Project Planning and Management

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ABSTRACT

Modern infrastructure projects are a subject of frequent change, high risk and uncertainty, creating complexities in planning and execution. Unlike traditionally where projects were measured based on the project triple-constraint triangle (Cost, Scope, and Quality), the metrics with which projects are currently determined to be successful are based on set-out objectives of these undertakings. Aspects like safety, health, environment, sustainability, schedule, and local content form pertinent objectives against which project managers are measured. Even further, projects are subject to newer regulations, political scrutiny and vastly changing cross-cutting issues. To spur competitiveness, advance in project analytics and enable business value-creation, organizations are utilizing IT tools and technologies to assist decision-making in planning, monitoring, and executing projects. This paper details current modern IT applications that can be used for project planning and management along with opportunities of advancements in current traditional technologies to improve overall management of projects.

1.0 INTRODUCTION

Projects are temporary endeavours to create unique products, services, or results whether tangible or intangible. They can have lasting social, economic, and environmental impact depending on the objective for which they were commissioned.

The PMBOK defines project management as the application of knowledge, skills, tools, and techniques to activities of a project so as to meet the project requirements or objects. It follows five key process groups being initiation, planning, executing, monitoring and controlling and finally closing. Managing a project involves identifying the specifications or requirements of the project, managing expectation of various stakeholders, and balancing competing constraints such as cost, quality, risk, scope, and schedule. These constraints have traditionally been a subject of change within the project environment, requiring frequent iteration and progressive elaboration of the project aspects so as to meet project targets.

In the modern age the factors influencing changes in projects are vast, varying from changing technology, competitive forces, political and economic changes as well as newer regulations environmentally or socially.

The recent COVID-19 pandemic has also caused several projects in Uganda to be managed virtually, pushing the expansion of collaboration technology that has brought together individuals from across the world with obvious cultural differences and different time zones in the management of global multi-location projects. These factors and changes put a spotlight onto business owners demanding them to adapt to this dynamism, create predictability in light of such factors, respond to risks and issues in a timely manner and manage the project constraints to satisfy stakeholders and meet business objectives.

The planning phase, which involves processes required to establish the scope of a project, refine objectives, and define the course of action required to attain these objectives is quite critical in managing such existing and emerging risks. It is at this stage where project managers can anticipate and mitigate change factors that could potentially affect the project. The planning phase involves detailed analysis, definition, preparation, coordination, and several iterations to develop a robust project management plan that can be used to guide implementation right through execution, monitoring, controlling and project closure.

These responsibilities uniquely fall on the project manager, who provides leadership of the project team responsible for delivering the multiple project objectives. The work on a project involves several stakeholders and requires proper organisation and integrated systems to ensure success. The project manager is expected to perform communication roles, stakeholder management

alongside managing elements of organisational politics in delivering the project. He/ She has to apply different skill sets such as recognising interdependencies amongst technologies, budgets, and people, planning the project to amplify productivity, motivating the project team, and controlling risks in execution. It becomes obvious that the breadth of responsibility of the project manager provides unique and vastly divergent interpersonal communication challenges (Johansen & Gillard, 2005).

Naturally dynamic project environment presents significant human challenges and limitations in decision-making, ensuring trust, avoiding unnecessary diversity, smoothening communication, and building team maturity. This calls for the use of modern tools and technologies that complement the human effort in planning and management of projects. Technologies in physical infrastructure projects are viewed to be a major factor contributing to economic growth in various countries, preventing cost overruns.

Be it in collaboration, workflow automation, project tracking, information gathering, scheduling, budget or resource management, modern ICT tools ease these processes, remove ambiguity, and improve decision- making in project execution. These packages, tools and software can provide us with added insight into the current state of affairs of the project, refining our definitions on elements such as duration, costs, and resourcing in the management of these projects making the project managers execution much simpler, more intuitive, and easily adaptable to the risks and changes. Modern infrastructure executions are increasingly involving such technologies especially with the participation of various foreign players, in what is becoming a global economy with a technologically advanced business environment.

The construction industry has suffered for decades from remarkably poor productivity relative to other sectors which have transformed themselves and boosted productivity. Despite the proven ability of new technologies, including digital technologies, and other innovation to lift productivity in other industries, construction lags significantly behind other sectors in the implementation of such tools. (McKinsey Global Institute, 2017). This paper highlights the technological opportunities available to Engineers and Project managers, their benefits and how they can change the project management landscape and bring predictability in implementation. The discussions are broken down into five thematic areas, being scheduling, workflow automation, project tracking and reporting, information gathering, and collaboration.

2.0 SCHEDULING

Scheduling comprises of processes required to manage the timely completion of the project. It involves provision of a detailed plan that represents how and when the project will deliver the products, services, and results defined in the project scope of work. The project teams select a scheduling method, such as the critical path or an agile approach. They then input data such as the activities, planned dates, durations, resources, dependencies, and constraints, to create a schedule model for the project.

The scheduling method originated in the shipbuilding industry during World War I, when Henry Laurence Gantt developed what is now known as the Gantt chart, a bar chart deploying use of resources over time. Creating an accurate or as built schedule using traditional methods from daily site records, engineers' diaries and other on-site documents is a daunting task as several changes in sequencing and duration tend to occur during site execution. (John Conlin, 1997)

As organisations now tend to have several projects, scheduling of activities and resources requires computerised systems for achieving best results. This improves reliability, accuracy, and promotes high speed, in formulation of projects, and resource allocation, lessening incidences of cost and time over-runs. **Excel spread sheets** have been a revolutionary invention allowing for input of different formulae to provide insight and analytics on schedule performance. In a bid to complete time-sensitive tasks, the importance of scheduling software to ensure successful project management cannot be underestimated in this era, as making certain that project teams are in unison on calls and deadlines, could mean the difference between meeting project objectives or project failure.

Modern project management software has simplified the scheduling process enabling project managers to automate and iterate reporting of the project performance. One of these software is **Microsoft Projects**, a product from Microsoft designed to assist project managers in developing a schedule, assigning resources to tasks, tracking progress, managing the budget, and analyzing workloads. It is an easy-to-use application and provides detailed reporting on resource loading and execution progress of the project. **Primavera** is another robust solution, used worldwide for prioritizing, planning, managing, and executing projects of any scale be it large or individual. A number of easy-to-use tools are also available online such as click-up, Monday.com, Microsoft Power BI, providing project managers with the opportunity to accurately schedule activities within the project. Similar to how the cloud allows businesses to update and communicate in real time, modern scheduling software benefits from being built into certain social and chat platforms, bringing team accountability, project progress tracking and collaborative communication.

3.0 PROJECT TRACKING AND REPORTING

Project reporting involves collecting and distributing project information to stakeholders, in appropriate format, presentation and detail depending on the project. These reports can be informed of ad hoc reports, project presentations, blogs, and other types of communication about the project. Such reports allow stakeholders to track and understand the current state of the project, identify and address issues, along with having a view of the performance of the projects.

Solutions like **Microsoft Projects,** and **Primavera,** do provide excellent reporting platforms for organisations to communicate project statuses and progress.

Advanced tools such as **smart sheets**, and **Microsoft Power BI** as well give project managers' ability to present in better more precise details on intricate dashboards, with respect to the stakeholder consuming the information. Cloud-based software also gives opportunity to project managers to track progress and update team members in real time on the status of each other's executions. Having such technologies that are constantly updating and adapting themselves to the changing market is an essential component of project- tracking.

4.0 INFORMATION GATHERING AND ANALYSIS

Raw observations and measurements gathered from project activities such as work percentage completed, quality defects, start and finish dates of schedule activities and actual costs are analyzed, given context, and integrated to form information on the health of the project. This information has typically been generated manually by recording and input for analysis in applications like excel. The collected data are analyzed in context, aggregated, and transformed to become project information during various processes. Information is communicated verbally or stored and distributed in various formats as reports. For example, information on financial performance, lessons learned, performance metrics and issues, and defects are continually updated throughout the project.

For more complex construction projects where lots of data is required to inform the planning and feasibility as well as monitor the execution, information gathering tools like sensors are used to create an accurate, wide-ranging census of data critical to project implementation. Mobile and computer-based applications are becoming common in construction; such Apps enable data collection, assisting companies to gather faster, more accurate and higher quality data from the construction sites. These apps save time and reduce data entry errors, sometimes providing added analysis. Such apps can also be tailored to collect safety information such as near misses and lost time injuries, and providing instant daily reports, improving safety compliance and performance on sites. Project management apps provide for central document storage systems making it easier to share files and documents with team members. This, when integrated with a calendar, enables tracking of individual deadlines, meetings, and the entire project as a whole.

Advanced technologies like predictive analytics and pattern recognition have facilitated even more complex monitoring of construction projects, an example being the network of sensors installed to track the impact of tunnelling works for London's Cross rail project (McKinsey Global Institute, 2017). As regards surveying, the industry is moving away from traditional highly labour intensive, electronic distance measurement for surveying, to photogrammetry and satellite positioning systems such as Light detection and Ranging **(LiDAR)** laser scanners which produce high-resolution images by using of lasers to detect thousands of points per second and then provide a 3D output. This enhances the accuracy and quality of surveys of even inaccessible terrain (McKinsey Global Institute, 2017)

Communication technology is now being used to monitor asset utilization and performance of construction assets and equipment, capturing real-time data from personnel, equipment, and stores to enabling contractors streamline their supply chains, reconcile material plans with physical availability, and analyze efficiency. Organizations now have the capacity to use this vast amount of data collected and execute trend-based analytics, generating insights into the productivity of projects and day-to-day decision-making on budgets and schedules, productivity, and wage rates. (McKinsey Global Institute, 2017)

Some larger firms have started to build and use **Artificial intelligence (AI)** to help with internal decision-making processes and operations, improving efficiencies and effectiveness in managing aspects like cost and safety.

5.0 COLLABORATION

Collaborative project management processes work across departmental, organizational, and national boundaries and help, especially with complex transboundary projects. Project collaboration involves working together with diverse project teams to success, through innovative practices. This is made possible by technologies and tools that promote communication, idea-sharing and transparency for local and remote teams (landau, 2021).

Building Information Modelling (BIM) is one of the tools leading collaborations in the construction industry. BIM is an intelligent model-based process for business and industry transformation. It involves creating a digital representation of the physical and spatial di-

mensions of a project, enabling those involved to make more effective and quicker decisions. The use of BIM allows for better collaboration because each person and expertise area can add their piece to the same model, instead of broken out onto multiple versions of a 2D paper drawing. These streamlines work processes and creates efficiencies in execution. It further allows for automated clash detection, smoothening the problem-solving process on the projects. The collaboration and transparency BIM provides improves building quality, reduces building cost, and optimises operational efficiencies.

The industry is adopting BIM alongside use of digital collaboration tools, drones, and unmanned aerial vehicles for scanning, monitoring, and mapping. Such technology is enabling transparency in design, costing, and progress visualization. Further, governments around the world are taking steps towards making BIM compulsory for large-scale facilities projects, including in India, Hong Kong, France, South Korea, Germany, and Italy. In the United Kingdom, BIM is already mandatory for government construction projects (McKinsey Global Institute, 2017).

BIM can be accessed through software we already commonly use such as AutoCAD and ArchiCAD. BIM is also available through Autodesk Revit, Tekla BIM, Protostructures and Navis works, among others.

Virtual reality technology commonly known as VR is also used in lieu of BIM to help better understand complex projects and give stakeholders a near-life feel of how a project shall look. It enables one to have an actual walk around through the project at the design stage and provide changes to the configuration, reducing on such variations during construction.

Even with less advanced technologies as above, collaboration is now possible through Microsoft office suite on one drive. Teams can work together on the same document tracking changes and making iterations to their final product from different areas of the world. Free online services such as google sheets are also changing the landscape in information gathering, analytics and collaboration.

6.0 WORKFLOW AUTOMATION

This is a process that uses software or digital tools to automate a series of actions to complete a task with little to no human intervention. Project managers are able to save time, effort, and money through workflow automation, delivering quality work quickly, accurately and boosting productivity.

Teams save time through automation of redundant processes and shifting energy to the more complex tasks. Some examples of commonly used workflow automation tools include SAP Workflow Management and Process Maker.

There are plenty of workflow automation software in the industry that deliver productivity benefits, freeing members of your team from ongoing administrative tasks such as meeting scheduling, and certain internal communications. One can automate data collection workflows so the submission of one form triggers another form to be sent, and so on, until a particular task is completed with all necessary signoffs and collected data.

7.0 CONCLUSION

The infrastructure industry is rapidly evolving as firms, contractors, and individuals across the value chain realize the benefits of, using technologies in planning and execution. Such technologies bring assets, people, processes, and job sites onto one platform, making everyone and everything work smarter, reducing and increasing efficiency (Deloitte, 2021)

With the sophisticated and dynamic nature of the construction industry, coupled with our limitations as humans, there is an urgent need to adopt technologies as a driving force for planning and implementation. With the vast number of tools available in the industry, it is upon us as engineers to research and challenge the status quo into adoption of such tools.

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Rural Electrification for Socio-Economic Development

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ABSTRACT

Access to electricity is important for the socio-economic development of any society as documented in the Sustainable Development Goals, and Uganda's Vision 2040. Rural electrification is not economical since the costs outweigh the benefits. That is why it is undertaken by the Government which is interested in service delivery, not profits. Successful implementation of rural electrification projects starts from the design and planning stage, procurement, execution and contract management. A good project needs the expertise of a competent contract manager who will apply different skills to ensure that the different stakeholders are managed. Access to electricity, according to the World Bank, is still very low at 42%. The Government of Uganda has implemented a number of projects to increase access to electricity especially for the rural communities. Examples of such government projects are: Energy for Rural Transformation, Uganda Rural Electricity Access Project, Electricity Connections Policy, and the proposed Uganda Energy Access Scale-up Project in partnership with the World Bank. The materials and equipment that are used for the various rural electrification projects should meet the standards to ensure value for money. A successful project starts with a clearly defined technical specification of materials and equipment to be utilised before manufacturing. Tests are conducted on the materials and equipment during manufacture and before use. All projects should undergo commissioning tests before usage and then be monitored for any defects during the Defects Liability Period.

Keywords: *Rural Electrification, Contract Management, Stakeholders, Materials Testing*

1.0 INTRODUCTION

Electricity is a very important factor of production and has been included under the UN's Sustainable Development Goal (SDG) No. 7. Most developing countries in Arica are below the world average percentage access rate to electricity as illustrated in Figure 1. The Third National Development Plan of Uganda, just like the UN's SDG also emphasizes the extreme importance of electricity. "The aspiration of Agenda 2030 is to achieve universal access to electricity by 2030" (1, p. 144)

The Rural Electrification Agency (REA) has been undertaking various projects with the aim of increasing access to electricity. "Rural electrification is the cornerstone in poverty alleviation and is widely recognised as the first step of modernisation." (2, p. 36). Rural electrification projects can either be on-grid or off-grid. On-grid projects include extensions of the existing power lines while off grid is mainly for solar photovoltaic systems where the networks are isolated. "For most of the developing countries in the world, the usual manner for rural electrification has been grid extension." (2). However, the Ministry of Energy and Mineral Development is now responsible under the Rural Electrification Programme abbreviated as REP (3). Projects undertaken by the Government of Uganda include Energy for Rural Transformation, Uganda Rural Electricity Access Project and the proposed Uganda Energy Access Scale-up Project. (4).

According to the *UBOS Report*, 51% of urban households and only 5% of rural households used grid electricity for lighting. In terms of region, 93% of Kampala households and only 1% of households in the Karamoja Sub-region used grid electricity for lighting (5, p. 144). According to the World Bank, Uganda is among the top 20 access-deficit countries.

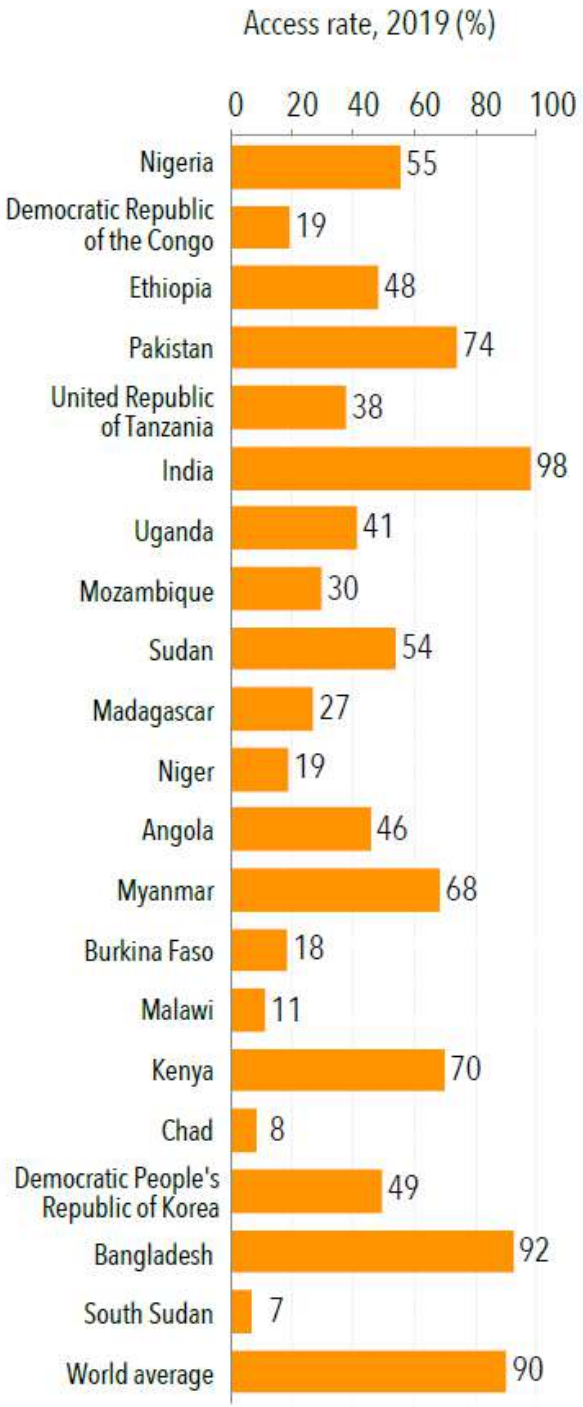

Figure 1: Electricity access in deficit countries

Source: (6, p. 36)

2.0 MANAGEMENT OF RURAL ELECTRIFICATION PROJECTS

Nearly all the operations under REA are project-based. "A project is a temporary endeavor undertaken to create a unique product, service, or result." (7, p. 3). After contract signature, contract management which is technically project management takes place. "Project management is the application of knowledge, skills, tools, and techniques to project activities to meet the project requirements." (7, p. 5)

2.1 Contract Management

A contract is a binding agreement between parties; key elements include an offer made by one party, on acceptance by the other party, the intention to create a legal relation and consideration i.e., the price for the offer (8). A contract manager should have the right qualifications, skills, experience and be able to multitask. A contract manager should be able to handle a multitude of tasks as illustrated in Figure 2. "Contracting is an integral part of doing business in the public sector with both private partners and other public agencies." [10]

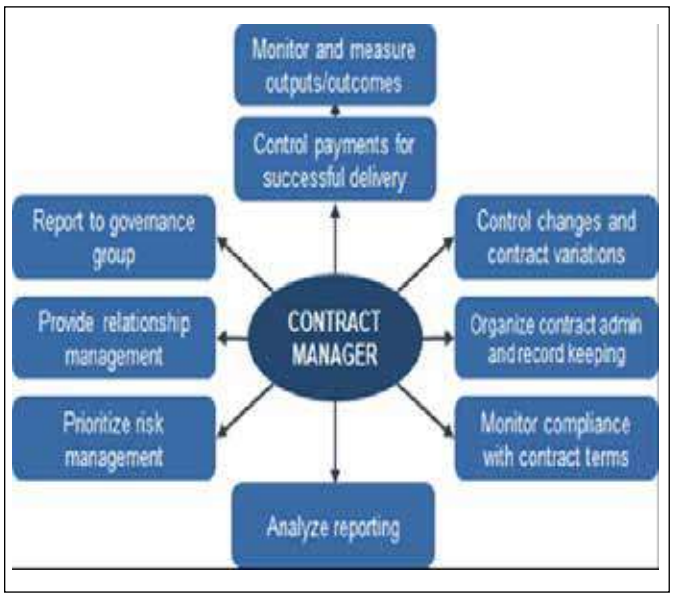

Figure 2: A contract manager's responsibilities. Source: (9)

2.2 Stakeholder Management

Stakeholders refers to individuals or groups that influence or can be influenced by a project (11). Primary stakeholders have vested interest in how the organization performs while secondary stakeholders can influence the organization both positively and negatively according to Herevi, Coffey & Trigunarsyah (2015) as cited in (12). A contract manager has many stakeholders to deal with at different levels e.g. management, funders, community, politicians, contractor and local leaders. For this to be effective, there is need for engineering ethics while undertaking projects. "An engineer driven by both technical knowledge and considerations of social/political impact will be much more productive in developing long-lasting solutions." (13). The different types of engineering ethics are illustrated below.

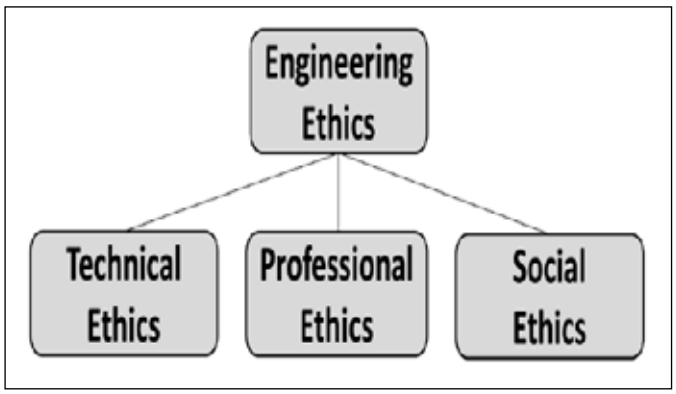

Figure 3: Major types of engineering ethics

Source: (13)

The contract manager works closely with environmentalists and sociologists who are knowledgeable about the environmental and social safeguards of the project. Involvement of the relevant stakeholders reduces conflict, fosters acceptance and increases social absorption in renewable energy schemes (11).

3.0 RURAL ELECTRIFICATION PROJECT LIFECYCLE

The various projects under REP undergo various stages as outlined in the subsequent sections of this chapter.

3.1 Project Initiation and Planning

This is the initial stage of rural electrification projects whereby the intended beneficiaries and project location are identified. Scoping is done to estimate the project cost and preliminary survey drawings are produced.

This project stage is normally carried out by the Planning and Investment Department who package the project for the prospective funder. After identifying the funder, then the procurement process starts as well as technical specifications of materials and works for the projects.

3.2 Technical Specifications

This is normally done by the User Department which defines the desirable features of the material and equipment to be used. Materials which need proper technical specifications include conductors, poles, overhead accessories, etc. while equipment include switchgear, transformers, etc.

The specifications also show the desired construction of the line. Legal and financial aspects are included in the specifications which form the bidding documents and later the contract for implementation.

3.3 Procurement and Contracting

Procurement is the process of getting a contractor to undertake the project. The contractor will then undertake to acquire the materials and equipment from the different manufacturers.

Project Procurement Management includes the processes necessary to purchase or acquire products, services, or results needed from outside the project team. Project Procurement Management includes the management and control processes required to develop and administer agreements such as contracts, purchase orders, memoranda of agreements (MOAs), or internal service level agreements (SLAs). (14).

3.4 Manufacturing

This is the process of turning raw materials into finished products. It can also be extended to the process of assembling finished products from different manufacturers into a new product by another manufacturer. For instance, copper ore which is a raw material can be turned into copper wire which is a finished product. The copper wire is then used by another manufacturer to make transformer windings. The transformer windings together with other components are later assembled into a complete transformer.

The quality of the manufactured product depends on the technical specifications provided during procurement. It is therefore important to ensure that all the desired parameters and features are carefully included during this stage since some aspects cannot be easily changed after manufacture.

3.5 Testing of Materials and Equipment

This chapter expounds on the different tests that are carried out at the different stages of the Rural Electrification.

3.5.1 During Manufacture

There are three major tests that can be conducted on equipment, namely type tests, routine tests and special tests.

- Type tests are carried out in Specialised Laboratories for the prototype before mass production can commence. This can also be a destructive test.
- Routine tests are the normal tests carried out during and after manufacturing of the product. These are the same tests that can be carried out during commissioning of the equipment and power lines.
- Special tests are those tests not normally done. They can be done to ascertain equipment performance in case the routine tests are not adequate.

3.5.2 Factory Acceptance Tests (FAT)

When the manufacturer has completed the manufacture of the materials and equipment, he normally invites the client to witness routine tests. Some of the tests that were carried out included the FAT for concrete poles

as shown in Figure 4 and the FAT for transformers as shown in Figure 5

Figure 4: FAT for concrete poles

Figure 5: FAT for transformers at ECS, Kawempe

3.6 Delivery and Inspection

After witnessing of the Factory Acceptance Tests (FAT) by the client, the manufacturer proceeds to ship and deliver the materials and equipment. On arrival, the materials and equipment are again inspected to ensure that they are not damaged and are the ones witnessed during FAT. This is shown in Figure 6.

Figure 6: Project materials inspection

3.7 Project Implementation

This is carried out by the Contractor with the Contract Manager supervising the implementation. Implementation of rural electrification projects is carried out throughout the country using different contractors and funders. Figure 7 shows connections being done to the top of the poles which was one of the works covered under project implementation.

Figure 7: Ongoing works by Haso Engineers

3.8 Project Commissioning

When a power line is ready to be energised, the contractor will inform the client accordingly. Pre-commissioning tests will then be conducted on the line and installed equipment to ensure that there are no major snags (anomalies). Figure 8 shows solar panels that were to be used in the generation process of the electricity. These solar panels were one of the projects ready for commissioning and to undergo the pre-commissioning tests. After the pre-commissioning tests, final commissioning of the line is organised; it is energized ready to serve customers. The following are some of the tests carried out during pre-commissioning and commissioning:

- *Insulation resistance of transformers*
- *Insulation resistance for the surge arrestors*
- *Earth resistance measurement*
- *No-load voltage measurement*

Figure 8: Solar off-grid in Kasese

Project commissioning is the process of assuring that all systems and components of a *building* or *industrial plant* are designed, installed, tested, operated, and maintained according to the operational requirements of the owner or final client. A commissioning process may be applied not only to new *projects* but also to existing units and systems subject to expansion, *renovation* or *revamping. (15).*

After commissioning, the performance of the network is monitored for a period of 12 months referred to as Defects Liability Period (DLP).

3.9 Project Close Out

After the completion of the DLP, there is a joint inspection of the network for compliance and identification of emerging issues before final payment is made. When resolutions of all outstanding snags are made, the contractors' retention is paid and the project is closed.

4.0 IMPACT OF RURAL ELECTRICATION

Rural electrification contributes to socio- economic transformation of any community where the project has been implemented. The standard of living improves and the electricity will be used for lighting, charging phones, powering household appliances and for business purposes.

The socio-economic impacts of rural electrification can be felt in the health sector, education, households and small businesses as demonstrated from research. "People reported that electrification has had exclusively positive effects on health care. All respondents said that treatments had improved, confirming the assumption that electrically operated medical equipment leads to more comprehensive treatments." (16). "Electrification and massive access to electricity generate business opportunities, create value chains, develop economies and local communities." (17).

5.0 CONCLUSION

In order for Uganda to meet the target set by Sustainable Development Goal No. 7 of ensuring access to affordable, reliable, sustainable and modern energy for all, rural electrification projects have to continue. Rural electrification can be either by extension of the existing grid or construction of a mini grid. Electricity has more positive socio-economic impacts on society in comparison with the negative effects. Sustainable rural electrification needs a competent contract manager who is able to engage the different stakeholders as well as following all the requirements of the project lifecycle.

A good rural electrification project starts with proper technical specifications, manufacturing of materials & equipment, testing of materials & equipment, project implementation by the contractor, commissioning and handover of the project to the operator for final operation and maintenance.

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Design and fabrication of inclined continuous flow solar water distillation system to treat contaminated spring water

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Hannah Kasule is a fourth-year student at Kyambogo University pursuing a Bachelor of Science in Chemical and Process Engineering. Her research interests focus on sustainable energy and water technologies, and their potential to accelerate economic and social development. For her undergraduate thesis, she designed and fabricated an inclined solar water distillation system to treat contaminated spring water.

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ABSTRACT

The rapid growth of Uganda's population over the past two decades has placed significant strain on the current national water supply service. While some communities in Uganda use the main NWSC water supply, umbrella authorities, NGOs and other private sector organizations as their main water source, other residents depend mainly on groundwater springs to access clean water. However, due to factors like inadequate spring protection and poor solid waste management, some of these springs have become contaminated with physio-chemical and microbiological pollutants. This research project focussed on solar water distillation as an alternative method for treating contaminated spring water in Ugandan communities. A continuous flow, inclined solar water distillation system was designed and modelled using SolidWorks software, and fabricated using heat-strengthened glass, hardwood timber and mild steel as the main materials. The major methods used for fabrication were gas metal arc welding, and metal, wood, and glass panel cutting. The performance of the solar distiller was then analyzed by measuring hourly and daily distillate productivity, determination of optimum input flow rate, determination of performance efficiency, and physiochemical characterization of both the raw feed water and the distillate. From the experiments performed, it was concluded that the solar distiller has production efficiency of 36.88% and productivity of 4.71 litres/m^2, which can be sufficiently scaled up to meet domestic water needs. The solar distiller temperature and inlet flow rate also have a direct influence on the productivity of the solar distiller, with high distillate volumes being observed at higher temperatures (75.5°C) and moderate flow rates (437ml/min).

1.0 SCOPE

The research project aimed at designing, fabricating and analyzing the performance of the designed and constructed solar distillation unit. It was carried out over the course of seven months, from August 2021 to March 2022. The study area for this project was a groundwater spring located in Masajja Village, Makindye, Ssabagabo Subcounty, Wakiso District shown in Figure 1, where the implementation and performance analysis of the solar distillation system was carried out.

Figure 1. Landscape view of Masajja Village, Makindye, Ssabagabo County, Wakiso District

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2.0 OBJECTIVES

The main objectives of this project were to design the solar distiller, fabricate it and then analyse its performance using three main parameters i.e., solar distiller temperature, inlet flow rate, physiochemical and bacteriological water quality.

3.0 METHODOLOGY

This chapter covers the procedure that was followed while carrying out this research. It expounds on the sample collection, design and construction of the solar distiller, performance analysis and characterisation of the raw feedwater.

3.1 Sample collection

Field studies were conducted at the selected groundwater spring in Masajja Village to collect spring water samples. Sampling was done during both the dry and wet season to understand fully the influence of seasonal changes on the productivity and efficiency of the solar distiller. The sampling was done with the help of local authorities. Eleven samples of spring water, with a volume of 5 litres each, were obtained between 10th February 2022 and 9th March 2022 from the spring water outlet using plastic sample collection bottles.

3.2 Design of the solar distiller

3.2.1 Principles of operation

The conventional solar distiller consists of an airtight basin containing the contaminated water and enclosed by a transparent cover through which solar radiation is transmitted as shown in Figure 2.

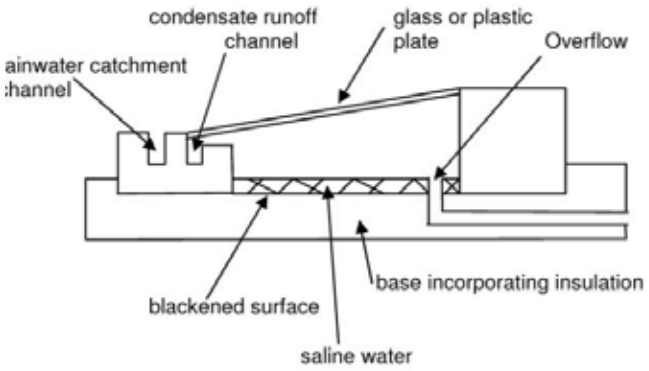

Figure 2. Schematic of a single basin solar still. Source: (Gnanadason, Kumar, & Sivaraman, 2014)

Solar radiation is absorbed by the basin plate and heat is transferred to the water, increasing its temperature to evaporation temperature. Evaporation then occurs, and water vapour rises upward to the cooler inner surface of the transparent cover and condenses as pure water, which runs down along the sloped cover due to gravity. It is then collected in a trough at the lower edge of the cover. The cover is at sufficient slope so that the surface tension of water will cause it to run down to the trough without falling back into the basin. (Gnanadason, Kumar, & Sivaraman, 2014)

3.2.2 Material selection

a) Solar distiller container

Several materials were considered for use as the basin material such as aluminum, stainless steel and galvanized steel. Aluminum and stainless steel were first considered because of their resistance to corrosion, light weight, long life and ease of cleaning. However, because of their high cost per kilogram, a solar distiller made out of these materials would be relatively expensive to build (Anil & Tiwari, 2015). Galvanized mild steel was used for this project because of its high tensile strength, high thermal conductivity, ease of cleaning and relative low cost.

b) Insulation

Considering the material (galvanized mild steel) and the thickness of the basin, there was a necessity to insulate the solar distiller in order to ensure a high system operating temperature. Insulation on the walls and bottom of the distiller will minimize the energy losses of the unit. Wood was a good option for insulating the distiller because of its relatively low price and availability in rural areas, low thermal conductivity and high tensile strength. For an effective insulation, a thickness of 2cm was chosen in order to increase heat retention capacity.

c) Glazing

The glazing cover of the solar distiller acts as the transmission medium for incoming solar radiation into the solar distiller. It is located on top of the distiller, where steam is condensed, clean water droplets are produced and then it is collected in the gutter collection container. There is varied research about glazing cover materials; it is common to use polyethylene, acrylic and tempered glass. However, these materials are expensive and would not be affordable by the residents of the study area. For this research project, ordinary glass with a thickness of 5mm was utilized because it is cheaper than other materials, has 50 years of life expectancy, has 86% of solar transmittance and 2% of infrared light transmittance (Mauricio, 2014).

3.2.3 Modelling of the solar distiller

The 3D modelling of the solar distiller was performed in SolidWorks. Modelled components included the main solar distiller container, inlet feed distribution pipe, inlet and outlet pipes, metal glass support, residual feedwater collection gutter, and distillate collection gutter.

Table 1. Detailed dimensions of solar distiller

Component	Length (cm)	Width/ Diameter (cm)	Thickness/ Height (cm)
Solar distiller basin	50	50	10
Feedwater distribution pipe	48	5	0.02
Inlet and outlet pipes	15	2	0.02
Metal glass support	50	3	0.05
Feedwater collection gutter	48	5	0.03
Distillate collection gutter	48	5	0.03
Transparent glass cover	46	46	0.05
Hardwood timber insulation	50	50	2

To obtain 3D models for the prototype, a SolidWorks part file was opened. A 2D sketch model of the metal basin was then drawn. Dimensions listed in Table 1 were then applied to the 2D sketch. The obtained basin sketch was then extruded and cut into a 3D model. The material specifications were then adjusted to mild steel. These steps were repeated for the transparent cover glass, hardwood timber insulation and mild steel support stands, along with their respective dimensions and color specifications. A SolidWorks assembly file was then used to load the part model files and combine them into a 3D model. Elevations of this model are shown in Figure 3.

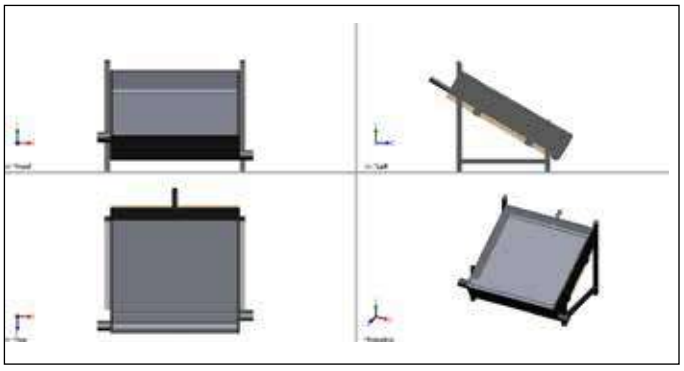

Figure 3. Front, top and side elevations of the constructed solar stull prototype 3D model

3.3 Construction of the solar distiller

This section expounds on the procedure that was followed while constructing the distiller. It breaks the procedure into the material cost breakdown, fabrication and assembly of the components.

3.3.1 Cost breakdown of solar distiller components

The estimated financial cost for all the primary and secondary solar still components is broken down in Table 2:

Table 2. Cost breakdown of solar distiller components

Item	Price (UGX)
Galvanized metal sheet (1m2)	15,000
Polycarbonate sheet (1m2)	10,000
Polyvinyl pipe (1m length)	10,000
Plastic jerrycan with tap (5l)	10,000
Flexible plastic pipe (0.5m length)	15,000
Thermocouple	25,000
Aluminium foil	5,000
Timber panels (1.5m2)	20,000
Miscellaneous	30,000
Total	**130,000**

3.3.2 Fabrication of solar distiller components

The solar distiller was fabricated in Katwe, Kampala District, Uganda. The basin, which is made out of 1.5mm thick mild steel sheets has an evaporating area of 0.25m^2 for a basin length and width of 0.5m and 0.5m respectively. Four sheets were galvanized and then cut using a jigsaw, and welded together using a 110V-210V gas metal arc welder to form the metal basin.

To create the feed water distribution pipe, a mild steel pipe of inner diameter 5cm and thickness 0.05cm was cut to a length of 48cm using a jigsaw, and perforated with 8 circular holes of 1mm diameter using an electric hand drill. The holes were spaced 1cm apart to aid in controlling the flow rate and distribution of inlet feedwater from the feed tank. The feedwater pipe was then welded to the top panel of the metallic solar distiller basin to create what is seen in Figure 4.

Figure 4. Partially fabricated metal solar distillation basin with feedwater distribution pipe

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To create the inlet and outlet pipes, mild steel pipes of inner diameter 2cm and thickness of 0.02 cm were cut to length of 15cm each using a jigsaw, and this process was repeated to make 3 identical pipes, which were welded to the inlet and outlet points. To create the distillate and residue collection gutters, one pipe with a length of 48cm and diameter of 2cm, were cut in half to create two pipes, which were welded to the top and bottom of the bottom metal panel of the solar distiller basin. All metal components were then coated with black, heat and water-resistant paint to increase heat absorption capacity, and sealed with a high temperature silicone sealant to prevent leakages coming up with what is seen in Figure 5.

Figure 5. Fabricated solar distiller with inlet pipes, outlet pipes and water collection gutters

The transparent glass cover was created by cutting a 5mm thick glass panel according to the dimensions of the solar distiller (50cm by 50cm), and an allowance of 5mm was added to enable the cover to comfortably fit on top of the basin. An additional support consisting of a metal panel 50cm long and 3cm wide was welded to the middle of the basin, in order to reduce the possibility of crack formation and propagation in the glass panel, which would reduce its transmissivity.

Hardwood timber insulation was created by cutting a 1cm thick wooden panel using a circular hand saw, according to the metal basin dimensions (50cm by 50cm). It was then coated with a water-resistant sealant, in order to prevent rotting from constant contact with water during the experiment. In order to incline the solar distiller at an angle equal to the latitude of the study area, two square metal pipes of length 50cm and two square metal pipes of length 35cm were painted with black water-resistant paint, and welded to the top and bottom corners of the solar distiller respectively.

3.3.3 Assembly of solar distillation system

In order to facilitate the solar water distillation process, various secondary components were added to the fabricated solar distiller basin to create what is seen in Figure 6

Figure 6. Fully assembled solar distiller with secondary heating and cooling components

A 10-litre plastic tank with an outlet tap was used as the feedwater tank. It was covered with 0.5mm thick black polythene bag in order to increase the temperature of the feedwater, thus leading to more vapor production within the solar distiller. A blue feedwater absorption pad made of 100% cotton was sealed to the solar distiller basin surface, in order to increase the residence time of the feedwater from the distribution pipe, thus increasing the evaporation rate within the distiller.

Transparent seal tape was also placed on all sides of the transparent glass cover, as well as all the inlet and outlet pipes, to prevent any leakage of water vapor from the solar distiller basin. Finally, to improve the condensation rate, insulation cover made of newspapers was attached to the gutter collection area at the bottom of the distiller basin, in order to prevent double vaporisation of the condensed distillate.

3.4 Performance analysis of the solar distiller

In order to determine the efficiency and productivity of the solar distiller, 11 samples of distillate from the groundwater spring in Masajja Village were distilled over the course of 11 days, using the constructed solar distillation system.

3.4.1 Measurement of hourly and daily solar distiller productivity

The collected sample from the study area was collected at 8:00am, and then transported to the solar distillation unit to start the experiment. The water was then allowed to sediment for 1 hour, from 9:00am-10:00am, in order to reduce the amount of particulate matter in the sample.

From 10:00am to 5:00pm, the amount of distillate in ml, collected every hour was measured using a measuring cylinder. The corresponding temperature inside the solar distiller was also measured every hour using a digital thermometer in °C. At the end of the day, the total volume of distillate collected was also measured. Distillate volume and solar distiller temperature were used to

determine the productivity and efficiency of the solar distiller, from the equations below.

(1.1)

Where P_D is the solar distiller productivity in kg/m^2, V_T the daily volume of distillate produced in m^3, ρ the density of water in kg/m^3 and A the cross-sectional area of the transparent glass cover in m^2 (Mbadinga, 2015).

(1.2)

Where ŋ is the solar distiller efficiency, *m* the mass of distillate produced in kg, *hfg* the latent heat of vaporization of water in kJ/kg (taken as 2.26 × 10^6 kJ/kg) and the solar radiation intensity of the study area in kJ/m^2, obtained from (SolarGIS, 2021).

3.4.2 Variation of bi-hourly inlet feed flow rate

Since the solar distiller was a continuous flow system, it was necessary to determine the optimum inlet flow rate that would result in the highest value of solar distiller productivity. The feed tank was first calibrated using a measuring cylinder and a timer. Next, the inlet feed flow rate was held at a constant value of 113ml/min, and the volume of distillate collected every 30 minutes, during the peak solar radiation intensity hours of the day, from 12pm to 2pm, was recorded. The inlet feed flow rate was then varied from the lowest flow rate value (113ml/min) to highest flow rate value (623ml/min), in intervals of 30 minutes from 12pm to 2pm. The corresponding volume of distillate produced every 30 minutes was then recorded.

3.5 Physicochemical and bacteriological characterisation of the raw feedwater and distillate

This chapter covers the results that were obtained and discussions that give their rationale to the research objectives.

3.5.1 Measurement of pH

pH measurements were conducted using a pH meter. The electrode tip was rinsed in de-ionised water. Then, the electrode tip was fully immersed in a beaker containing the sample solution. The fluctuating readings were observed for a while until they became steady. The pH reading was then recorded.

3.5.2 Measurement of conductivity, TDS, salinity and temperature

Values of conductivity, total dissolved solids, salinity and temperature were recorded using a conductivity meter shown in Figure 7.

Figure 7. Conductivity meter for taking measurements of totally dissolved solids, conductivity, salinity and temperature

After the calibration process, the electrode tip was fully immersed in a beaker containing the sample solution, and left for a few minutes until steady values were obtained. The respective values of conductivity in uS/cm, totally dissolved solids in *ppm*, salinity in *psu* and temperature in °C were recorded.

3.5.3 Measurement of turbidity

The turbidity value of the samples was conducted using a turbidity meter shown in Figure 8.

Figure 8. Turbidity meter used for taking turbidity measurements

The turbidity meter was first calibrated, and once the values had stabilized, a cuvette was filled to the black mark with sample water and placed in the meter. The "CAL" button was then pressed. Once the value stabilized, the turbidity of the sample was then recorded in NTU.

3.5.4 Measurement of total and faecal coliforms

Fifteen test tubes containing 10ml each, of single strength McConkey broth culture medium and E. coli medium were prepared. Dilution series of 1, 1/10 and 1/100 were then created using both sample volumes and buffered dilution water, to make a total of 15 tubes. The tubes were then placed on a rack in an incubator for 48 hours at 37 °C. After the 48 hours elapsed, the tubes were removed from the incubator and observed for growth. Those tubes that showed turbidity/gas production were regarded as positive. The number of positive tubes at each dilution series was recorded, and the cor-

responding total coliforms were determined from the Most Probable Number Table. Positive tubes were then inoculated in E. coli medium and incubated for another 24 hours at 44 °C to determine the faecal coliforms.

4.0 RESULTS AND DISCUSSION

This chapter covers the results that were obtained and discussions that give their rationale to the research objectives.

4.1 Hourly volume of distillate produced from 10:00am to 5:00pm

The hourly volume of distillate collected by the solar distiller from 10:00am to 5:00pm on 12th February 2022, and the corresponding solar distiller temperature, can be seen in Figure 9.

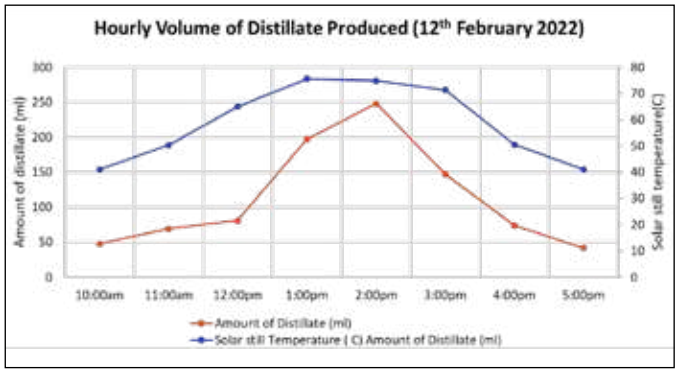

Figure 9. Hourly volume of distillate collected on 12th February 2022

From the graph, it was observed that the increase in distillate volume was directly proportional to the increase in solar distiller temperature, which is in agreement with the findings of (Abu-Arabi et.al., 2012). From this analysis, it can be concluded that the amount of distillate produced directly depends on the temperature of the solar distiller. This is because higher temperatures increase the kinetic energy of the incoming feedwater molecules, thus leading to an increase in evaporation rate.

4.2 Daily solar distiller productivity

The daily volume of distillate collected by the solar distiller for 11 days spanning 10th February 2022 and 9th March 2022 from 10:00am to 5:00pm, and the corresponding solar distiller temperature, can be seen in Figure 10.

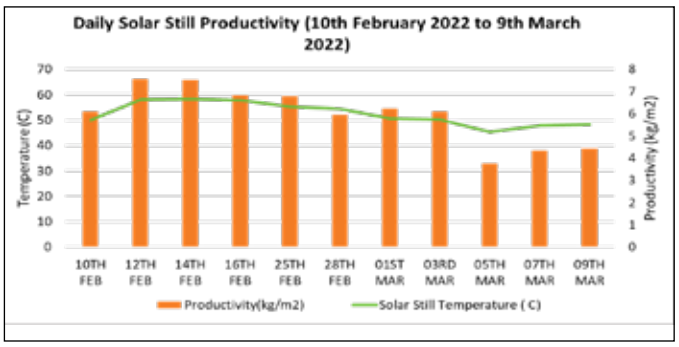

Figure 10. Daily solar distiller productivity from 10th February 2022 to 9th March 2022

It can be observed that the daily solar distiller productivity was higher during the first 6 experiment days in the month of February, and lower during the last 5 experiment days in the month of March, with the lowest productivity being recorded as 3.77kg/m^3 on 5th March 2022. This data agrees with the conclusion that variation in monthly and seasonal weather conditions will affect the productivity of the solar distiller, since according to (Spark, 2021), the dry season in Wakiso District, when solar radiation intensity and thus ambient temperature is highest, ends in late February of every year, and the wet season begins in early March, where the solar radiation intensity is much lower.

4.3 Bi-hourly variation of feed inlet flow rate from 12:00pm to 2:00pm

It can be observed from Figure 11 that when the inlet feed flow rate was varied, the amount of distillate produced rose exponentially at a much higher rate than the amount of distillate produced at a constant inlet feed flow rate. The highest distillate volume observed was 390ml at 1:00pm, for an inlet feed flow rate of 473ml/min, which is higher than the distillate produced for the constant flow rate by 90ml. However, as the flow rate was increased from 473ml/min, the amount of distillate produced began to drop moderately, reaching the lowest volume of 55ml at a maximum inlet feed flow rate of 673ml/min. This can be attributed to the fact that an increase in inlet feed flow rate decreased the residence time of the feed water in the basin, thus decreasing the evaporation rates.

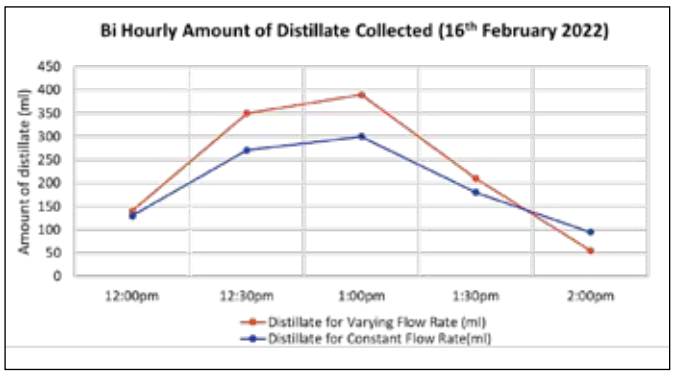

Figure 11. Bi-hourly Amount of Distillate collected for both constant and varying feed inlet flow rate.

4.4 Daily solar distiller production efficiency

The daily solar distiller efficiency from 10th February 2022 to 9th March 2022 was calculated from Equation 1.2.

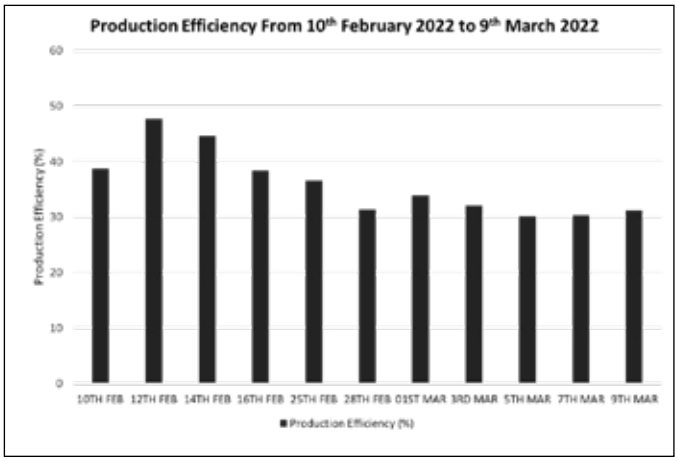

Figure 12. Production efficiency of the solar distiller from 10th February 2022 to 9th March 2022

It can be seen from Figure 12 that daily solar distiller efficiencies varied between 47.8% on 12th February 2022, and 30.2% on 5th March, with an average production efficiency of 35.99% over the course of the 11 days. This relatively low efficiency can be explained by the high heat losses from the sides of the metal solar distiller basin, as well as the evaporative leakage from the area between the edges of the glass cover and the sides of the solar distiller basin.

4.5 Physicochemical and bacteriological analysis of feed water and solar distillate

From the Table 3, the first observation is that none of the major water quality parameters above were within the permissible limits of the East African Potable Water Standard (EAC, 2017). The spring feed water was had an average pH of 4.24, conductivity of 2538 uS/cm and TDS value of1728 ppm. These values are relatively high when compared to East African Potable Water Standards of 6.5-8.5, 1500uS/cm and 700ppm for pH, conductivity and total dissolved solids respectively. These high values imply that the spring may be inadequately protected from environmental contaminants like agricultural runoff, stormwater runoff, and decomposing organic matter.

From the Table 4, the first observation is that most of the major water quality parameters above were within the permissible limits of the East African Potable Water Standard (EAC, 2017). The distillate produced was neutral with an average pH of 7.01, low conductivity and TDS values of 466.80 uS/cm and 61.20 ppm respectively, and an average turbidity value of 1.63 NTU, which confirmed that most of the physical and chemical contaminants had been successfully removed.

Table 3. Main water quality parameters for untreated spring water feed.

Sample No	01	02	03	04	05	Average
pH	4.75	4.41	3.08	5.14	3.82	**4.24**
Conductivity (uS/cm)	2540	2550	2570	2490	2540	**2538.00**
Total Dissolved Solids (ppm)	1728	1731	1724	1759	1734	**1728.00**
Turbidity (NTU)	135	258	262	300	178	**227.00**
Faecal Coliforms (MPN/100ml)	70	90	50	70	90	**74.00**

Table 4. Main water quality parameters for solar water distillate

Sample No	01	02	03	04	05	Average
pH	6.84	7.13	6.90	7.48	7.12	**7.01**
Conductivity (uS/cm)	578	493	764	325	174	**466.80**
Total Dissolved Solids (ppm)	53	67	63	49	74	**61.20**
Turbidity (NTU)	4.58	0.61	1.54	0.67	0.73	**1.63**
Faecal Coliforms (MPN/100ml)	2	2	4	2	2	**2.40**

However, the faecal coliform parameter value was above the permissible limits of the East African Standard, which states that faecal coliforms should be absent in both potable and drinking water (EAC, 2017). This can be attributed to the fact that the distillation process requires more than one evaporation condensation cycle for less volatile solutes like faecal coliforms to fully separate from the feedwater (ChemLibre, 2021).

5.0 CONCLUSION

From the results above, the following conclusions can be drawn:

i. The experiments conducted confirmed the expected influence of solar radiation intensity and climatic conditions of the location on the amount of distillate produced by the solar distiller. In the specific study area for this project, Masajja Village, higher distillate productivities will be obtained in the dry season, and lower productivities will be obtained in the wetter seasons.

ii. High distillate productivities will be observed at a moderate flow rate of 437ml/min. Lower distillate amounts will be observed at very high flow rates, since the residence time of the feedwater in the inclined solar distiller basin will be much lower.

iii. The distillate produced from the solar distiller was determined to have a high quality, with most of the physico-chemical parameters adhering to East African Potable Water Quality Standards. However, although 96.7% of the faecal coliforms were removed from the distillate, final faecal coliform values are still above the permissible limit of the East African Standard.

iv. Lastly, the solar distiller has an average efficiency of 36.88% and a daily average productivity of 4.7litres/m^2. These values have been confirmed to be competitive when compared to results of similar research in the field. These values can be attributed to the unique design and geometry of the solar distiller basin, as well as the installation of basic secondary heating and cooling components.

6.0 RECOMMENDATIONS

i. In an attempt to further improve the performance of the solar distiller, more advanced secondary heating and cooling components e.g., external condensers, double-glass covers, solar heaters, etc. can be added to the feed tank and distillate collection containers. This could potentially improve the evaporation and condensation rates in the solar distiller, as well as the removal efficiency of faecal coliforms.

ii. A secondary re-mineralising system can be added to the distillate outlet point in order to replenish the distillate with minerals lost from the evaporation process.

iii. Possibilities of scaling up the solar distiller to meet community needs can also be explored. This can be done by integrating more unit operations into the solar distiller in order to improve its effectiveness e.g., a steeped evaporation tray to reduce the gap between the evaporation and condensing surface.

iv. Further research can be performed using alternative materials e.g. softwood timber as a more affordable form of insulation, and galvanized iron steel as a more corrosion resistant heat transfer medium. Corresponding effects on performance efficiency can also be investigated.

v. Lastly, a thermodynamic analysis of the solar distiller may be performed using computational simulation and modelling, in order to determine the optimum design parameters for maximizing solar distiller productivity.

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The Standardisation for Data Volume Measurement and Setting of Quality of Service Parameters in Uganda

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ABSTRACT

It is the mandate of the Communications sector in Uganda, to accomplish the following as enshrined in the Uganda Communications Act, 2013. Regulate the rates and charges for communications services thereby protecting consumers from excessive tariffs and unfair competitive practices. Set national standards and ensure that they are complied with at international level as laid down in international treaties to which Uganda is a party. Promote and safeguard the interests of consumers and operators as regards the quality of services and equipment they get. All this mandate would, according to the Act, guide the metering, packaging, and billing of Data services offered by Telecom and Internet Service Providers (ISPs) in the country. However, considering that different Telcom and ISPs may use different network infrastructure, configurations, and vendors to achieve better market differences through network performance and service positioning, This is likely to influence the given tariff implementation, the marketing mechanisms, and perceived quality service by the customers. There is therefore need for an indigenous standard to guide the offered data volume measurement, the achieved QoSmeasurement. This article seeks to develop a standard of Public Data Network to comply with the International Telecommunications Union (ITU-T) standards currently in force.

Key words: Data volume, Service provider, Customer, End-user, Quality of Service, QoS, Measurement, Telecom, Internet Service Provider, (ISP), Network Performance.

1.0 INTRODUCTION

Data services may traditionally be defined as all Internet-based services that are provided through the open Internet access based on the network neutrality principle and by using best-effort approach for packet delivery. This, including Over The Top (OTT) services or simply 'data' as popularly known by the user community.

However, although the Internet was initially designed to provide best-effort service (i.e., where all IP packets are treated in the same manner and considered fixed service delivery), its evolution has demonstrated that not all packets are the same and it could be delivered via mobile network as well as fixed networks. It is on this basis that the ITU-T QoS framework presented by ITU Recommendation (Rec. ITU-T E.804, 2014) (ITU-T G.1000, 2002), suggests a more application-oriented framework that relate to the data service offering by a given service provider and the need to use a service function MATRIX to facilitate identification of Communications QoS criteria.

According to (Chaesub, 2013), the Quality of Service (QoS) and the Quality of Experience (QoE) of IP-based platform(s) should be adapted to regionally agreed standards, a directive agreed by ITU. As illustrated in Figure 1, HTTP-based services (Web-browsing; and Mobile applications relying on internet access for their effective functionality) are among today's most carried and demanded services and that call for QoS for Data Services to be consistently reported by the communication sector regulator to guide both consumption and competent service provision.

2.0 THE PROBLEM AT HAND

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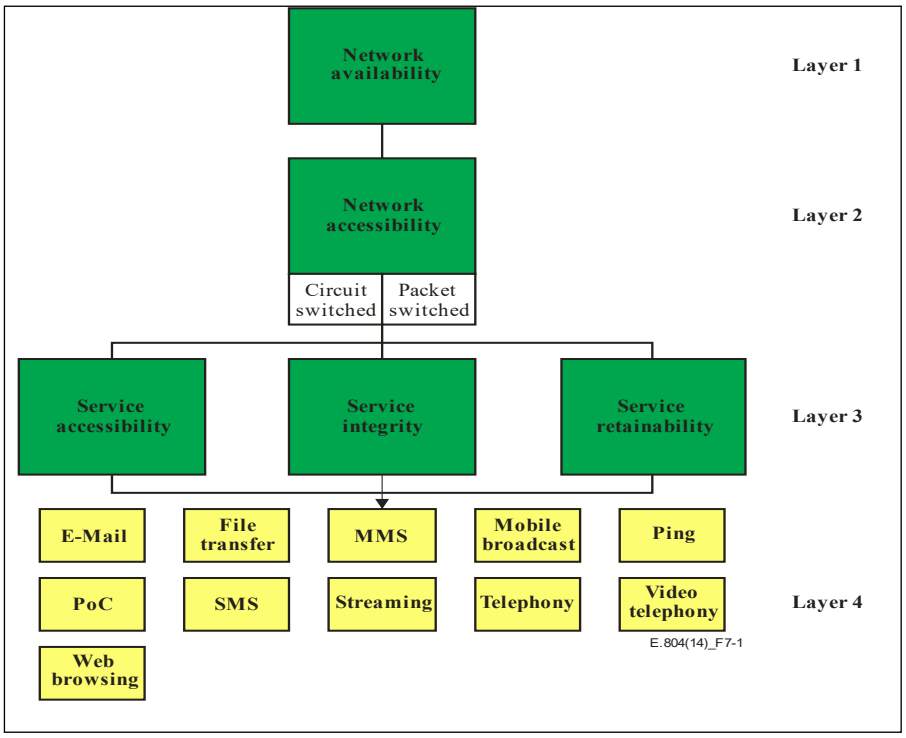

Figure 1. QoS aspects and the corresponding QoS param eters [Extracted from ITU-T Rec. E.804, 201402, Fig.7.1]

Quality of service parameters (QoS), especially for the packet-switched data communication services (ITU-D, 2017; ITU-T Rec. Y.1291, 2004). However, that transition at both regulator level and service providers (subject to technical audit or verification), is yet to be appreciated in the case of Uganda. This is reflected in the consistent availability of QoS results on the national regulator's website and media publications. This implies a lack of attention to the Data/Internet Services performance metrics and the corresponding QoS results (UCC, 2020; UCC, 2014; UCC, 2018), which leaves the Data services user at the advantage of the service providers (ISPs, Telco) and yet QoS continues to be required and expected by end-users who consume the data services daily, and which calls for QoS/QoE related standardisation to protect the user(consumer) interests, even as reported by (Takahashi, 2015) .

Quality of Service (QoS) has moved from its initial definitions targeting to traditional telecommunication networks (for example, PSTN/ISDN, broadcast networks) to QoS in IP networks and services as reflected in Figure 1 above. Additionally, the data volume measured (and charged) by the telecom operators is not the data volume seen by the end- user. Moreover, it is not possible or feasible that user bitrates and user data volume could be monitored at some intermediate or edge gateway in the network, only on the end-user side. The above situation could be attributed to factors varying per network/telco/internet service provider, such as other networks on the end-to-end path, background traffic from other applications, type of network (fixed, mobile, and which technology 3G, 4G, etc.), user equipment, traffic management techniques applied by the ISP for the given tariff package, etc; necessitating the need to comply with a standard of measurement.

This transition calls for a shift from reporting only on QoS for Voice Telephony to include Data Services, embracing the required new Data Services measurement approach, Performance value metrics and

3.0 WHY IS A SOLUTION NEEDED?

ICT services' consumer stages that are outside the actual usage of the service subscribed or purchased are often left to the responsibility of the user to educate themselves. More so, these stages which contribute to the overall Quality of Services and eventually consumer experience; also referred to as the "non-utilization stages of ICT services" according to ITU-T E.803 recommendation. For example, (1) quality and content of information on a service and its features; (2) the con-

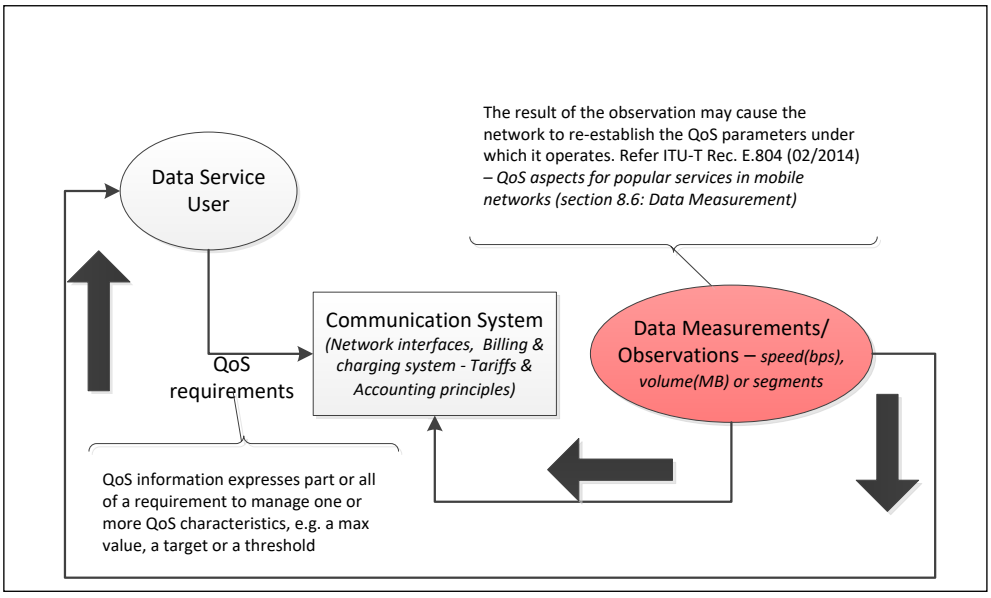

Figure 2.. A Requirement for QoS [Adapted from (ITU-T Rec. X.641, 1997)]

tractual conditions offered by the service provider; (3) provisioning facilities, (4) documentation, and (5) service support after contract with customers.

In an article published on the regulator's blogpost (UCC, 2020), it was stated that **"subscribers hold the key to their data bundle usage, only that many don't know how to use it"**, where 'Data bundles' refers to a form of data service packaging sold in volume (MegaBytes, MBs) by the service provider and measured in segments according to ((ITU-T Rec. D.12, 1988)) and as shown in Figure 2.

Thus, how Data services are measured, packaged, and billed by the different Telcom network operators and ISPs is of key interest to the End-users (consumer) as it directly feeds into their perceived QoS according to the Four-viewpoints model of QoS, recommended by (Rec. ITU-T E.804, 2014). Here it is noted that, on the side of the Service provider, differences are likely to occur between QoS offered and QoS delivered concerning data services due to parameters that influence measurement of data such as network bandwidth, propagation delay, queuing delay, jitter, Packet loss and Packet error ratio.

3.0 ARE CONSUMERS BILLED ACCORDING TO OFFERED SERVICE OR THAT DELIVERED (SAY, ACCOUNTING FOR ALL SERVICE PROVIDER CONSTRAINTS)?

In a bid to educate and empower consumers, the communication sector regulator has developed and provisioned Mobile application (s), social media tips, and a portal, to ease consumer understanding of their data services' packages, pricing, speed, and performance as listed in Table 1.

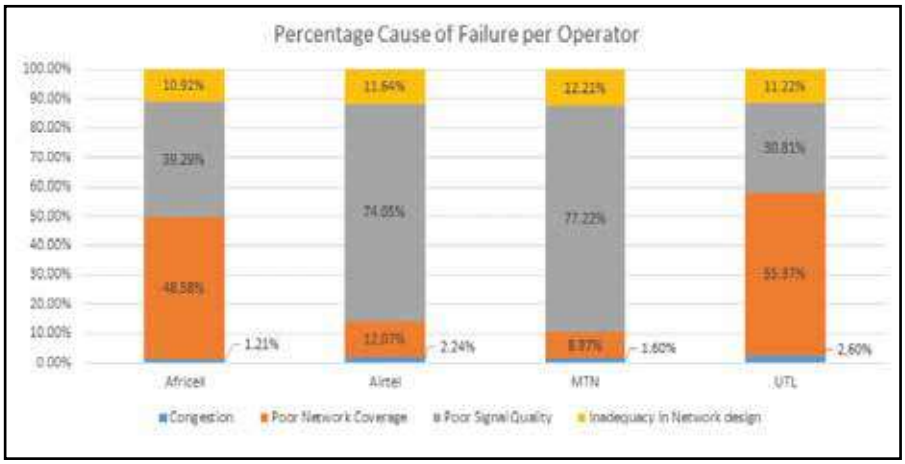

Figure 3. Proportion of causes of network failures observed [Extracted from (UCC, 2020)]

Table 1. Consumer Support mobile-applications by (Uganda Communications Commission, 2022)

End-user App/Portal	Description	Availability/ Source
KOMPARE; https://kompare.ug/	Enables consumers to compare offers from different network operators	Google Play, App Store
NetQ-UG Web Portal; https://netq.ug/speed-test/	Enables consumers to measure the data speed and other performance elements of their internet connection	Google Play, App Store
UCC Consumer Affairs; @ConsumerUCC, UgandaCommunicationsCommission on twitter and facebook respectively	Offers continuous updates to consumers	Internet access

According to the national regulator report on QoS for both telephony and mobile services shown in Figure 3, it was observed that there was a lack of network optimization from most operators, as most network failures were related to poor signal quality despite claimed coverage across the country. However, the regulator could assist the end-user by selecting QoS parameters that reflect the different service provider (SP) performance values and publishing those, as well as reporting of QoS performance levels that directly benefit the customer, such as using data held in the Telco/ISPs' systems, customer surveys, and opinion rating by expert panels.

Although it is incumbent upon the user to select a service provider of choice, based on the respective service offerings as advertised or promoted through campaigns, service providers and regulators are still required to tackle the traffic management challenges that evolve with the introduction of new service applications on the IP Network, and sufficiently protect the end-user.

4.0 GUIDING SOLUTION-MATRIX TO DERIVE THE PROPOSED STANDARDISATION FRAMEWORK

[1.] ITU-T Study Group 11 Output (Rec. ITU-T Q.3960, 2016), delivered a "Framework of Internet related performance measurements" which could be established at the national or international level, providing customers of the existing telecom operator's networks the possibility to estimate the access speed to the Internet with more satisfaction for

all parties

[2.] Design a survey to collect consumer perception/opinion of the current state of service delivery esp. internet services (data) across all ISPs in the country.

- Pricing Model frameworks
- Packaging (bundle sizing)
- Promotion packaging (Marketing campaigns)

[3.] Design a Pilot project for conformity assessment against ITU-T Rec. such as (ITU-T M.3170 series), regarding Internet Speed measurements, Service packaging & pricing, and QoS computation across service providers in the country, and in tandem with ISO committee on conformity assessment.

[4.] Design regulatory policy intervention to curb Data Service subscription terms for prepaid and post-paid customers as used by different SPs to cater for the full understanding of the user, before purchasing data package/bundle. As it must be observed that Tariffs and accounting principles once employed on PSTN networks are unable to scale to IP-based networks and services

[5.] Purpose to audit the Traffic management inventions employed by the respective SPs, regularly and guide their implementation (new SP market entrants) accordingly. Moreover, these are based on either of two types (1) Bandwidth allocation and (2) Packet prioritization

Each service provider may implement the above mechanisms differently, directly impacting the end-user negatively or positively when it comes to the overall billing of the data volume consumed, but without the sure oversight of the regulator.

5.0 AREA OF REQUIRED STANDARDISATION FRAMEWORK OR GUIDING PRINCIPLE

This chapter mainly illustrates the flow process of prepaid data volume usage billing as shown in Figure 4.

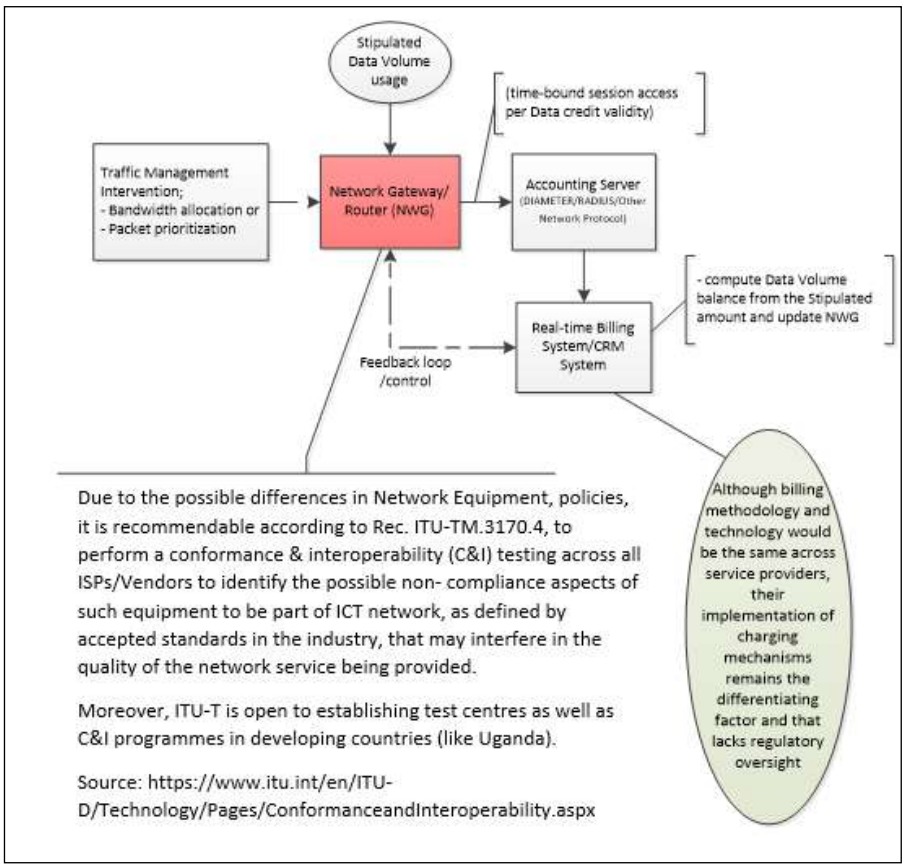

Figure 4. Basic representation of a Telecom System block diagram for Prepaid Data Volume Usage billing

6.0 CONCLUSION

According to a study across 96 Mobile Network Operators (MNOs) in 28 countries for 2017 using a Data Envelopment Analysis Model (DEA), it was realized that data volume in addition to being the second most important consideration after the data service price, its distribution and fair usage was impacted by the efficiency of mobile network operators due to factors such as the number of connections, availability of spectrum, and its utilization, which are central to the market environment and region of operation.

However, to directly address the aspect of price imposed to a data service user and the user experience it generates due to the different service providers (SP), it would serve right to tackle conformance and interoperability of SP systems that influence charging mechanisms of data services by establishing key guiding principles in form of standardization towards the selection of Data Measurement metrics (metering), tariff policies, and selection of QoS parameters appropriate for IP Networks and services as recommended by clause 7 of (Rec. ITU-T E.804, 2014).

Furthermore, according to (Reddy, Bielov, Finley, Kilkki, & Mitomo, 2019), every nation or region normally has that highly efficient and disruptive operator due to its effort for market share-growth, therefore, it would help to enact a pilot project for conformance assessment of network management

interfaces following ITU Recommendations, with the aim to set local operator benchmarks to the charging, the accounting, and the billing of data services as illustrated in Figure 4 above.

In a nutshell, what this paper seeks to address is not unique to Uganda, It is an issue that all IP-based networks face regarding the pricing of telecommunications services and must address. Moreover, considering consumer complaints on data services provision in Uganda, Network failures and lack of sufficient QoS reporting for data services in the country, there is need for an assessment or a study to be undertaken to overcome the above issues. The information and standardization framework proposed in this article shall be of importance to Service Providers (SPs) in Uganda, and the National Regulator to develop the proposed standard or suitable guidelines and establish QoS metrics matching Consumer expectations respectively.

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Gravity-driven Membrane Filtration for the Supply of Safely Managed Water in Rural Areas of Uganda

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ABSTRACT

The supply of safely managed drinking water to rural areas of Uganda is challenging and needs innovative technologies. Gravity-driven membrane (GDM) filtration offers a viable technological option to an alternative use of surface water in areas where groundwater is challenged by chemical contamination or is not available. In Eastern Uganda, the GDM water kiosks achieved filtration rates of ~ 200-800 L/h with flat-sheet ultrafiltration membrane modules of 75-80m^2 membrane surface. The membranes retained particles: bacteria, protozoa, most viruses as well as a fraction of the dissolved organic carbon. Residual chlorination was achieved using a passive in-line T-chlorinator. The cost of the used membrane modules imported from Germany was US$75 per m^2. Digital tracking of water consumption and revenue between February 2021 to May 2022, revealed that on average, including the rainy season, 2 m^3 of water was dispensed per day and revenue of UGX260,000 was collected per month. With this revenue, the GDM kiosk committee covered operation and minor maintenance expenses and realised some savings. Significant infrastructure renewal, such as new membranes, tanks and appurtenances might need alternative additional funds. The installation of Lugala's GDM system, supplying safe drinking water to about 100 households cost an estimated UGX17,500,000. With the household size of five persons in Namayingo District, the per capita CAPEX was UGX35,000 (US$ 9.56) for the GDM system, which is 7.6 times smaller than the per capita cost of US$72.6 for rural water supplies, according to the 2020 Water and Environment Sector Performance Report. As a result, GDM was accredited by the Uganda Appropriate Technology Centre (ATC) in 2021. Consequently, the Ministry of Water and Environment (MWE) recommended its promotion in 2022 as one of the technologies for safe water supply in Uganda. A user guide for GDM is publicly available free of costs (Bouman et al., 2022) and there is no patent on the GDM technology.

1.0 BACKGROUND

The Government of Uganda (GoU) aims at increasing safe water coverage in rural and urban areas from the 2020/21 baseline values of 75.9% and 79.2% to 85% and 100% in rural and urban areas, respectively, by the year 2024/25 (NPA, 2020). The Joint Monitoring Program (JMP) reported that in 2017, the national access to safely managed drinking water in Uganda was 7%, derived from 4% for rural and 16% for urban areas (WHO/UNICEF, 2019). A safely managed drinking water service is one that is located on the premises, available when needed and free from faecal and chemical contamination (WHO/UNICEF, 2017) and puts more stringent requirements than just the supply of basic drinking water. In 2020, the Water and Environment Sector Performance Report (WESPR) had no data on the access to safely managed water in rural areas of Uganda. The WESPR of 2020 reported that the access to safely managed water (available on premises) in urban areas was 57.1% (MWE, 2020). Both WESPR and WHO/UNICEF paint a grisly picture on access to safely managed drinking water in Ugandan rural areas.

The predominant improved point sources for the supply of water in rural areas comprise protected springs, boreholes, protected wells, and gravity-flow schemes, which in some cases deliver water to the yard of a dwell-

ing or to public standpipes supplying water to a number of dwellings. Populations which do not have access to improved water sources rely on unsafe sources such as rivers, lakes, and unprotected wells. Waterborne diseases include dysentery, typhoid and cholera. These diseases are responsible for a high mortality rate, especially among the under-five children. To solve these problems, there is a need to improve technologies for the delivery of safely managed water to rural populations.

2.0 PURPOSE OF THIS PAPER

The purpose of this paper is to present a new technology of water treatment using the Gravity Driven Membrane (GDM) technology. The paper presents practical experiences from a pilot scale GDM water treatment system, which has been implemented in a rural area in the Ugandan Eastern District of Namayingo for a period of six years.

3.0 WHY GRAVITY-DRIVEN MEMBRANE (GDM) FILTRATION?

Point water sources in Uganda are, to a large extent, supplied by groundwater. However, the utilisation of these sources is compromised where the groundwater is salty, contaminated or not available. Gravity-driven membrane filtration offers a viable technological option to an alternative use of surface water in these regions. The technology has been tested in water treatment at the Lake Victoria for the last six years by the Swiss Federal Institute of Aquatic Science and Technology, together with local a partner organisation in Eastern Uganda and described in detail in a user guide and a supplementary video series (Bouman et al., 2022) that is publicly available free. There is no patent on the GDM technology. GDM can treat microbiologically polluted, turbid raw water in one step. The heart of the treatment system contains ultrafiltration (UF) modules with nominal pore sizes ("holes") of 20-40 nm (Bouman et al., 2022). The membranes in combination with a biofilm that grows on the membranes retain particles, bacteria, protozoa, most viruses as well as a fraction of the dissolved organic carbon. While in the biofilm predation of pathogens by other organisms and metabolisation of organic material are mechanisms that purify the water, the UF membranes filter all particles larger than 20-40 nm. However, GDM cannot filter dissolved chemical contaminants of natural or anthropogenic origin (mining, agriculture or industry) and does not remove salts. In conventional ultrafiltration, the operation and maintenance (O&M) procedures are complex. The membranes need to be operated with high pressure, backwashed several times a day and cleaned with chemicals. Compared to conventional ultrafiltration, where mechanical and chemical cleaning is implemented to keep fluxes around 60 L/m^2/h, the water production per membrane area is lower for GDM set-ups (4 – 20 L/m^2/h). In contrast to conventional ultrafiltration, GDM uses the low pressure (30 – 100 mbar = 30 – 100 cm) of the water column and needs minimal O&M because of the biofilm that is formed on the membranes. Biological activity in the biofilm causes the formation of cavities and keeps the biofilm porous, which leads to the long-term stabilisation of the flux and prevents membrane fouling and clogging. Various parameters influence the biofilm properties. For example, feed water with higher amounts of organic matter or small clay particles forms biofilms with higher resistances and consequently lower fluxes through the membrane (Lee et al., 2019; Chomiak et al., 2014). Relaxation periods and warm temperatures (~ 25-35°C) also have positive effects on the flux. Interestingly, changing the pressure (i.e. the water head) on the membranes from 0.4-5 m did not result in a higher flux. The only recommended regular maintenance tasks for the GDM filter are flushing the membrane tank once per month and a check-up once per year. The flushing procedure removes all the sediments and suspended particles that have been retained by the membranes and removes parts of the biofilm. During the yearly check-up, the membrane and connections are controlled to avoid leakages.

4.0 PRACTICAL EXPERIENCE FROM GDM KIOSKS IN EASTERN UGANDA

In Eastern Uganda, GDM has successfully been operated by the local communities during the last six years with very minor maintenance costs for the GDM filter. The schema of the GDM water kiosks, as they were constructed in Eastern Uganda is presented in **Figure 1**. The raw water source is Lake Victoria. The water is abstracted from an infiltration well close to the shores of Lake Victoria by a solar water pump, which conveys the water through a 1-2 km pipeline to the treatment site. There, the water is filtered with UF membranes and thereafter stored in a clean water tank. In some kiosks, optional raw water tanks may be installed. After treatment with GDM, the water is safe for drinking. However, as in all water supply systems, the water may be re-contaminated during distribution and transport. Therefore, a chlorination step at the treatment site is recommended to provide residual disinfection and protect the water from recontamination until the point of consumption. Several options have been evaluated at the GDM kiosks in Eastern Uganda (Dössegger et al., 2021). An in-line T-chlorinator resulted in the best option for GDM kiosks. Finally, the water is sold at the taps of a water kiosk. To increase transparency in accountability and give customers 24/7 access to the water, automatic water vending machines were installed at some GDM kiosks. Additionally, they allow easy monitoring of water consumption and water revenues.

Since the operation started in 2016, data of 57 flux mea-

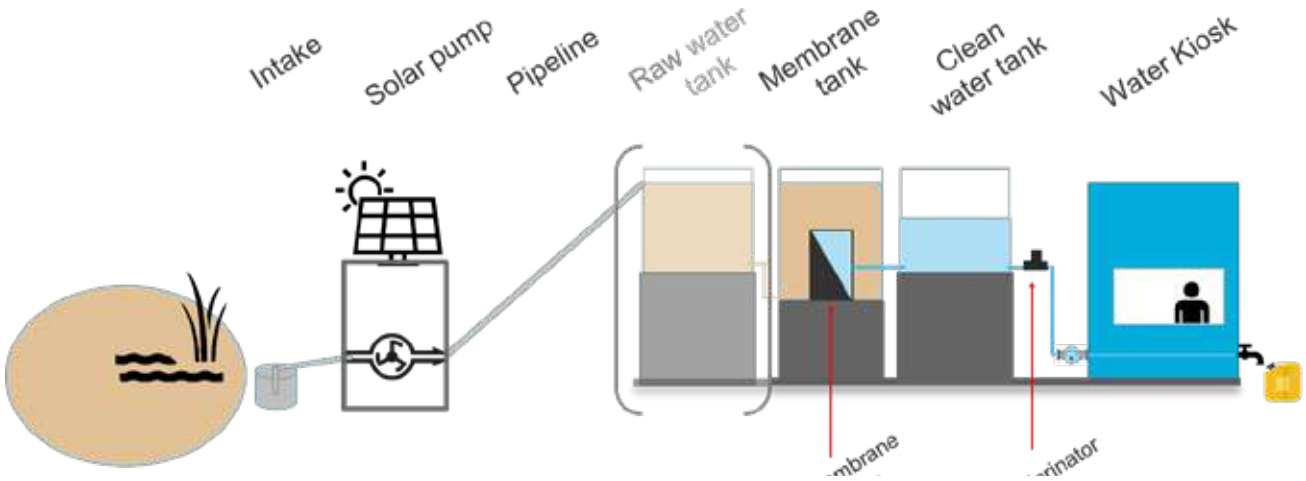

Figure 1: GDM water kiosk schema as implemented in Eastern Uganda

surements is available for the flat-sheet UF membrane modules of 75-80 m^2. The median flux was 4 $L/m^2/h$ and the median flow rate 300 L/h. The 25% - 75% interquartile range for the flow is ~ 200 - 800 L/h.

The cost of the used membrane modules was US$75 per m^2 and they were imported from Germany. The lifespan of the membranes is 10 years in conventional configuration, but is likely to be higher in the GDM configuration as they are operated with less pressure and no back-flushing is applied nor chemicals are used. The capacity of the system can be adapted according to the water needs of a community and the exact configuration should always be adapted to the local context. Since February 2021, a water ATM is operational and tracks the water consumption and revenues from the GDM water kiosk in Lugala, Namayingo District. **Figure 2** shows the community members in Namayingo collecting water at the water kiosk in Lugala. Until May 2022, approximately 900,000 litres of water were dispensed and UGX4,200,000 revenues collected. On average, this is $2m^3/d$ of water dispensed and revenues of UGX260,000 collected per month, including the rainy seasons when collections decrease. With the revenues, the GDM kiosk committee can cover operation and minor maintenance expenses and generated some savings. Significant infrastructure renewal, such as new membranes, tanks and appurtenances might need alternative additional funds. The Lugala GDM system, supplying safe drinking water to about 100 households cost an estimated UGX17,500,000. The household size of five persons in Namayingo district (UBOS, 2017) translates to a per capita CAPEX of UGX35,000 (US$9.56) for the GDM system, which is 7.6 times smaller than the per capita cost of US$72.6 for rural water supplies according to the WESPR (MWE, 2020).

Figure 2: Photograph of a GDM kiosk in Busime, Namayingo District in Eastern Uganda

Membrane integrity tests were conducted after installing the membranes that showed log removal values (LRV) of more than four. From November 2015 to December 2016 microbial water quality tests were conducted at least monthly in the first three constructed GDM kiosks. Up to 97.3% of all samples collected after the membrane and 95% of the samples collected directly from the tap corresponded to the low risk category according to WHO (1997) with most of the samples showing 0 or 1 *E. coli*/100 mL (Peter-Varbanets, 2017). From September 2019 to October 2019, samples were taken at all the five GDM kiosks. After the membrane, 100% of the 21 samples contained 0 *E. coli*/100 mL. At the tap, 84% of the 19 samples contained 0 or 1 *E. coli*/100 mL, 11% contained 2 – 10 *E. coli*/100 mL and only one sample contained over 10 *E. coli*/100 mL. Membrane integrity tests showed LRVs of over 4.5 in all the systems except for one (LRV = 2.9). In a recent water quality monitoring phase, we collected 22 biweekly samples from July 2021 until April 2022 at one of the GDM kiosks. From the 22 samples taken at the tap, 91% of the samples corresponded to the low risk category according to WHO with 19 samples being completely free of *E. coli*

contamination. A membrane integrity test conducted in April 2022 revealed LRV of more than five after more than six years of continuous operation. Additionally, water quality tests were performed by the Appropriate Technology Centre (ATC) of Uganda in autumn 2021. In the accreditation report, ATC states that no faecal nor total coliforms were detected in the treated water. The report concludes that "from the water quality results, it was apparent that the GDM filtration system is effective for improving the quality of contaminated surface water to acceptable drinking water standards" (ATC, 2021). ATC showed interest to construct a pilot plant where government engineers and water officers can be trained. In January 2022, the Ministry of Water and Environment (MWE) in Uganda issued a certificate stating that the GDM technology is suitable as an alternative of safe water supply and that the MWE recommends the promotion of the GDM technology.

5.0 CONCLUSIONS

GDM filtration offers a viable low-cost technological option to an alternative use of surface water in areas where groundwater is contaminated by chemicals or not available. The technology is not patented and a user guide is publicly available free of cost (Bouman et al., 2022). Furthermore, the technology is accredited by the ATC and the MWE recommends to promote GDM in Uganda. In Eastern Uganda, the GDM water kiosks achieved filtration rates of ~ 200-800 L/h with flat-sheet ultrafiltration membrane modules of 75-80 m^2 membrane surface and delivered safe drinking water according to WHO. Digital tracking of water consumption and revenues over a period of 16 months revealed that on average, including the rainy season, $2m^3$ of water were dispensed per day and revenues of UGX260,000 were collected per month. The GDM is low-cost in that the system constructed in Namayingo delivered safe drinking water to 100 households at a per capita CAPEX of UGX35,000 (US$9.56) which is 7.6 times smaller than the per capita cost of US$72.6 reported in 2020 for rural water supplies. Consequently, the GDM technology should be promoted to supply safely managed drinking water to rural areas of Uganda, where fresh surface water sources such as wetlands, rivers or lakes are available. Source protection measures should be developed and implemented for such sources since GDM cannot filter dissolved chemical contaminants of natural or anthropogenic origin (mining, agriculture or industry).

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Alternative Approaches and Tools for Improved Water Supply and Sanitation in Northern Uganda (AATWATSAN)

By Otim Brian

Brian Otim is a practising water resources engineer currently working with National Water and Sewerage Corporation. He has over six years of experience in the whole-of-cycle-drinking water infrastructure development and management. He has supervised construction of sanitation facilities and water mains. He graduated from Ndejje University in 2013 with a Bachelor of Science in Civil Engineering.

ABSTRACT

The project involved the following: The development of a smart borehole to augment water supply in Kitgum Municipality. (2) The construction of on-site sanitation facilities i.e. drainable pit-latrines at Okidi & Pajimo primary schools, and a state-of-the-art water-borne toilet at Pajimo Health Centre III, (3) The extension of piped water supplies to Pajimo Village coupled with the construction of five public water points, and (4) Themed training of PSP operators on financial literacy and hygiene promotion.Smart water & sanitation systems, public-private projects, integrated management best practices.

1.0 INTRODUCTION

In Uganda over 23.8 million people still lack access to potable water (WaterAid, 2018), and this is worse in northern Uganda owing to the massive damage to the water and sanitation systems in the aftermath of the protracted LRA war. It is against this background that NWSC in November 2014 sought support from different partners through the sustainable water fund (FDW), Netherlands Enterprise Agency, and eventually birthed the AATWATSAN project to facilitate its drive to increased water coverage and packaged sanitation, especially in Northern Uganda which includes Kitgum District.

1.1 Problem Statement

The yearly perennial intermittence of piped water supplies in the dry seasons and inadequate sanitation facilities in the formerly war-ravaged Kitgum District is leading to an issue of open defecation as shown in Figure 1

Figure 1: Open defecation in Kitgum town

1.2 Objectives

The project's main objectives were:

- The development of a smart borehole to augment water production in Kitgum Municipality.
- The improvement of on-site sanitation in selected schools and health centres.
- Community sensitisation and training of PSP operators on WASH best practices.

1.3 Partners and Roles

The project's partners and roles are highlighted below:-

- NWSC- Principal applicant and lead project implementer in the selected towns
- VEI- Capacity building of technical personnel through training and advisory services
- UNESCO-IHE- Research and development
- Kagga & Partners- Supervisory construction of on-site sanitary facilities
- Plan International- Training of PSP operators on WASH best practices
- Davis & Shirtliff- Supervisory construction of static facilities i.e. boreholes and/or reservoirs
- MoWE- Soliciting of donor funding and provision of additional project supervision

2.0 METHODOLOGY

This chapter covers the procedure that was followed during this research all through water supply augmentation, pipe water extension, operator's trainings and the analysis of the obtained results from each study.

2.1 Water supply augmentation

A 26kW SCADA powered motorised borehole (shown in Figure 2) was conceptualised, developed and operationalised at Lemo in Pager Division, Kitgum Municipality. This state-of-the art borehole is fitted with a series of loggers for pressure, water level, power, flow, etc., that relay real-time data to the RTC or PLC where it is micro-processed and transmitted to a satellite by a transmitter, and afterwards, further data processing by the Lorentz software found on the HMI interface e.g. computers, phones, etc, for final interpretation and, if need be, diagnosis by the operator.

Figure 2: The Lemo SCADA borehole

In tandem with this development, an operational existing motorized borehole at Mican in Kitgum Municipality was refurbished i.e. flushing and pump-testing, and re-designed to transmit piped water to Pajimo Village in Kitgum District.

2.2 On-site sanitation facilities

To improve the living conditions within Pajimo village, a modern 4-stance drainable pit latrine (Shown in Figure 3) at Pajimo Primary School, and a 6-stance water-borne toilet at Pajimo Health Centre III were constructed; a similar 4-stance drainable pit latrine was also constructed at Okidi Primary School. All these facilities are now in final stages of construction, and when fully operational will be a game-changer in improving sanitation as well a benchmark for resilience to development partners involved in the provision of WASH infrastructures in emergencies e.g. LWF, UNHCR, etc.

Figure 3: A 4-stance drainable pit-latrine at Pajimo Primary School

2.3 Piped water extension

A 10km OD110mm uPVC PN16 & HDPE PN16 transmission main (shown in Figure 4) to evacuate water from the re-designed existing motorized Mican borehole in Kitgum Municipality to a 50m^3 reservoir at Pajimo Army Primary School, coupled with a 4km HDPE PN10 distribution network of varying pipe sizes OD63 to OD90mm has been laid. Furthermore, a 1.5km OD160mm uPVC PN16 transmission main to evacuate water from the new Lemo SCADA borehole, to the 300m^3 PTC reservoir to augment water supplies to Kitgum Municipality and environs has too been laid. In addition, five public water points pending connection have been established in schools and trading centres in Pajimo to avail potable affordable water to the populace.

Figure 4: Pipe laying of Lemo-PTC transmission mains

2.4 Operators' trainings

A series of themed trainings for PSP operators were conducted in conjunction with project partners as shown in Figure 5. The aim of these training was to improve sanitation at the point-of-source through ensuring routine cleanliness, and 2) to instill a savings mindset into the operators to not only meet NWSC bill payments, but also for personal growth.

Figure 5: A PSP operators' workshop

2.4 Results & Analysis

The project's successes include the following: - 1) An augmentation of a minimum 240m^3 per day of water supply from a renewable source i.e. solar, to the existing grid that has not only improved the earlier water supply intermittence in Kitgum Municipality but also reduced the overall energy costs. 2) An improvement of the ambiance/outlook of public water points and the financial literacy of PSP operators. (3) The successful trialing and joint implementation of public-private projects for sustainable development. However, to ensure the timely execution of public-private projects, there has to be in place well-coordinated performance meetings amongst partners for reviews and for identification of any impediments to implementation. There may be need for benchmarking on the same projects elsewhere or even abroad, dependent on resources for the realisation of synchronized project management goals. The project management partner teams should ensure transparency and accountability prevail to foster mutual trust for holistic project success.

3.0 CONCLUSION

This project will set a blueprint for delivering sustainable water and sanitation services while harnessing the scarce resources in the global south; and when fully operational and all its facets e.g. toilets/latrines and water system complete, then Pajimo Village in Akwang Subcounty will, for the first time, have reliable potable water all the time coupled with improved tailored sanitation facilities.

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Sustainable HVAC Systems in Commercial and Residential Buildings

By Turyasingura Medard

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ABSTRACT

A comfortable indoor environment starts with maintaining appropriate thermal comfort and indoor air quality. HVAC (Heating, Ventilation, and Air Conditioning) systems are responsible for this function. HVAC systems consume 50-60% of global energy, necessitating long-term solutions. The researcher goes over some of the approaches that can be used to achieve long-term energy sustainability in buildings. The primary goal is to adapt energy-saving technology, and provide energy-saving solutions that combine HAVC equipment and its peripherals while preserving a building's required comfort levels.

1.0 INTRODUCTION

Climate change, population increase, and changing lifestyles are all factors that contribute to the need for heating, ventilation, and air conditioning (HVAC) systems in various types of buildings. HVAC systems play a significant role in the comfort and safety of indoor air quality. The demand for improved thermal comfort and indoor air quality in buildings (both commercial and residential) has become essential. Uganda's demand for HVAC systems is increasing at such a rapid rate that energy consumption will soar greatly in the next few decades. This raises an obvious question: How do we maintain the required thermal comfort and healthier indoor air-quality levels of buildings in a sustainable way? If this question is not answered satisfactorily, the expenses of HVAC systems will certainly outweigh the advantages.

Understanding and considering various parameters related to the sustainability of new and existing HVAC systems in buildings is vital to providing healthy, energy-efficient, and economical options for various building types. Research studies have indicated that HVAC systems account for 50–60% of the energy used in buildings (Rawat & Singh, 2021). This is due to a lack of energy-efficient designs, the usage of ineffective cooling systems, and maintenance, particularly in hot and dry climates. As per Uganda Vision 2040, hotel, construction, and real estate, among others are the key tertiary industries that are expected to expand; so will energy usage. Furthermore, the Uganda Vision 2040 expects access to the national grid to significantly increase to at least 80 per cent countrywide (NPA, 2013). The growth of the above-mentioned sectors will certainly increase the usage and penetration of air conditioning in Uganda. Better technology investment and careful design are the keys to the long-term economic, environmental, and social development of HVAC systems in Uganda. This can be accomplished through the provision of energy-saving technologies and solutions that combine HAVC equipment, their peripherals, and the buildings in which they operate.

2.0 ENERGY CERTIFIED HVAC SYSTEMS

The HVAC industry is attempting to produce environmentally friendly technology across the world. There are now Energy Star Certified HVAC units with significantly greater Seasonal Energy Efficiency Ratio (SEER) ratings on the market. The SEER rating divides the amount of electrical energy input by the amount of output to determine the efficiency of an air conditioning system. The SEER rating indicates how energy efficient your system is. Energy Star-qualified units have been independently certified to save energy while maintaining system operation and features. EER (Energy Efficiency Ratio) rating is another metric that most energy-efficient residential HVAC systems will have. EER is the ratio of an air conditioner's rated cooling or heating capacity to its power consumption under standard ambient conditions, which are a 95°F outdoor temperature, an 80°F indoor temperature, and a 50% relative humidity. The system's output in Btu/h per watt of electrical energy is precisely what is meant by EER. In contrast to SEER, EER rating tests under rigorous laboratory conditions rather than

calculating its ratios using seasonal averages. The higher the EER number, similar to the SEER rating, the more energy-efficient the HVAC system is.

2.1 Programmable thermostats and smart air conditioner controllers

Smart controllers and programmable thermostats are two of the numerous technologies in the HVAC industry that are used to provide intelligent features to central cooling systems, ducted and ductless air conditioners that not only provide convenience to the user but also help save energy. Furthermore, smart controllers and thermostats enable remote operation of HVAC equipment via a computer, tablet, or smart phone. They also include plenty of other features that can help you save energy. Intelligent triggers like the Comfy Mode and weekly scheduling are just a few examples.

2.2 HVAC Design with the greatest efficiency in mind

In this context, efficiency refers to both the design and operation of HVAC equipment. When designing these systems, designers should use a comprehensive approach with the goal of reducing energy consumption. This can be accomplished by looking at how each component of the HVAC system utilizes energy and finding ways to enhance it. Today's products include ductless mini-split air conditioners with inverter-driven variable-speed compressors and fans, variable frequency drives for ventilation fans, and commercial rooftop systems with micro-channel heat exchangers and advanced controls for economizers. Demand-controlled ventilation is also essential for lowering the cooling load and ensuring that buildings are not cooled regardless of the needs of their occupants. When possible, designers should use renewable energy sources. For optimal effectiveness, HVAC system designers should take advantage of natural conditions or by-products. For example, the system could be designed to pre-cool air using a cool exhaust (Bonacorda, 2022).

2.3 HVAC Equipment Utilisation

Assuming that the HVAC equipment is designed for maximum efficiency, the installation, maintenance, and use of the system have the biggest impact on its efficacy. To ensure that the greatest quantity of air is required to reach all specified sections of the building, every HVAC system equipment must be skillfully installed. The equipment should be maintained and repaired on a regular basis once it has been installed; this includes ventilation fans, air handling systems, and air conditioners, as well as auxiliary equipment like ductwork, which can waste a lot of energy.

2.4 Building Design for High Performance

While increasing HVAC systems' efficiency reduces the amount of energy used to meet the building's cooling loads, high-performance building designs can reduce the overall load. For example, utilisation of international performance standards such as ASHRAE 90.1 for commercial buildings, and the International Energy Conservation Code (IECC) for residential buildings can significantly reduce cooling demand and subsequent energy consumption (Goetzler et al., 2016). Standards provide for reducing cooling loads by reducing heat and improving the building envelope, which includes walls, floors, roofs, and fenestrations (i.e., windows and doors). The requirement for an air conditioning system is reduced by reducing heat transfer into the building envelope via conduction, radiation, filtration and infiltration. Several building energy efficiency studies conducted in hot, humid climates found potential annual cooling load reductions of up to 38% from improved insulation alone, and up to 12% reductions from external shading (Al-tamimi, 2010). In pilot projects, dynamic solar glazing reduced cooling loads by up to 20% (Goetzler et al., 2016). Increasing the efficiency of lighting and other appliances that give off heat has the compound benefit of reducing cooling demand as well as direct energy consumption (Litiu & Assistant, 2014). The roof structure is a critical part of any building and is always directly exposed to sunlight. Heat gained through the roof is the highest on a sunny day in low-rise buildings. Modifying roofing surfaces to increase their radiant energy reflectivity in the solar spectrum and high emissivity in the earth's atmospheric transparent window (Mandal et al., 2019). This can reduce the cooling load and save energy.

3.0 CONCLUSION

The engineering community can help to accelerate the adoption of sustainable HVAC systems. The development of a cohesive set of solutions that are interdisciplinary and collaborative with all building functions will be necessary to achieve this sustainable future of HVAC. Embracing efficient HVAC technologies and standards throughout the design stage, as well as using efficient building codes, can help to encourage best-practices for long-term and cost-effective HVAC systems. For enhanced HVAC equipment reliability and sustainability, users must also be proactive and implement effective preventive actions.

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Assessing the Feasibility of a Materials Recovery Facility in Enhancing Solid Waste Management in Urban Areas of Uganda

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ABSTRACT

The purpose of the study was to examine the economic feasibility of applying a Material Recovery Facility to Mukono Municipality. The case study was Katikolo composting and landfilling site. The study was guided by the following specific objectives: to assess the current solid waste management status in Mukono Municipality, to perform a waste characterization study, to design an economically feasible MRF for Mukono Municipality. Mukono Municipality manages its solid waste by disposing it at Katikolo Landfill and Composting Site. The study revealed that approximately 44 tonnes/day of solid waste is received at Katikolo Landfill and Composting Site. Mukono Municipality, generates approximately 15.2 tonnes/day of this waste contributing 34.4% of the total waste received. This study further revealed that the per capita waste, generation for Mukono Municipality is estimated at 0.19kg/person/day. The individual compositions within this waste was determined as: organics 73%, paper and pulp 4.52%, glass 1.53%, metal 2.5%, plastics 9.53%, textiles 5.47%; other waste 3%. Furthermore, when compared with the WACS performed by Mukono Municipality in 2017, organics showed a negative percentage drop of 15.72%, paper and pulp showed a positive percentage gain of 2.28%, glass showed a positive gain of 10.28%, metal showed a positive gain of 1.21%. The facility design was based on the results gathered in regard to Solid Waste Management Practice and Waste Characterization from Mukono Municipality. The type of the MRF designed is a single stream/mixed waste MRF since the existing waste collection does not practise waste segregation at source and transportation. It was designed to operate for a 20-year period, processing at a maximum capacity of 15,000 tons/year. The facility was designed to have a total interior footprint area of 290sqm where the tipping floor area of 111.6sqm, sorting room of area 58.75sqm and storage room area of 120sqm. The facility will have a conveyor length of 24m, employing 26 sorters working one daily shift of seven hours/day. Economic analysis of the facility using the payback period analysis shows that the MRF will be able to repay its initial cost on investment within 14 years and will be achieved when the throughput waste received is 40TPD. The analysis further shows that at end of the operation lifetime, the MRF will achieve a net profit of 10,538,928,985 UGX on initial investment in its fourteenth year of operation. Investment into this project will yield a positive rate of return of 45.8% on the investment. This shows that the project will generate profit and yield positive gain upon initial investment. ROR analysis supports the analysis provided by payback analysis method, to show that investment into the project will be economically feasible.

1.0 INTRODUCTION

Globally, waste management is shifting from conventional landfill and recycling of both municipal and industrial waste towards waste management activities supported by integrated waste policy. Programmes involving zero waste targets and 100% diversion from landfill are increasingly noted with rising urban densities and land prices in major cities across the world (Andrews-Speed et al., 2012; EEA, 2014). The waste industry is now recognized as an underutilized 'resource industry' in its own right, with increasing focus on waste having inherent economic value. Formal and informal recycling activities have emerged as central to most waste management programmes in the developed world (Karani and Jewasikiewitz, 2007).

However, the waste industry in developing countries such as Uganda lags behind in implementing activities that promote zero waste targets and 100% landfill diversion from landfills. Integrated solid waste management. Katikolo Landfill and Composting Site is part of the waste management system for Mukono Municipality and its surrounding areas receiving all its municipal solid waste. Despite sustainably managing the organic fraction of the waste received through composting, Mukono Municipality still faces a challenge of sustainably managing the inorganic fraction of the solid waste it generates. Currently approximately 5% of the estimated 44 tonnes received at Katikolo is sorted to recover recyclable materials, this activity is however done by scavengers whose ef-

ficiency is determined by the level of their efforts. However, with this level of sorting and resource recovery efficiency, recyclable materials with potential economic value end up being dumped into the landfill thus reducing its existing capacity and loss of potential economic revenue to the municipality.

This project therefore seeks to assess the feasibility of a Material Recovery Facility (MRF) for Mukono Municipality hence improving sustainability of its solid waste management and solid waste recycling capacity.

. Specific objectives

- To assess current solid waste management status in Mukono Municipality.
- To perform a waste characterization study.
- To design an appropriate MRF for Mukono Municipality

2.0 METHODOLOGY

This chapter outlines the research methodology that was used to conduct the research and inform the design. It consists of geographic scope and study methodology applied to achieve the objectives of this research. It details the research design used in performing the waste characterization study and economic analysis for the MRF.

2.1 Research precedure

This section covers the different stages that were followed during the research process. It covers all the way from acquisition of information along the waste stream till the facility's economic analysis.

2.1.1 Acquiring information along the waste stream of Mukono Municipality

This information was collected through interviews using draft questionnaire. The relevant people interviewed were; licensed waste collectors specifically for those that collect solid waste around Mukono Municipality, Mukono Municipality environmental officers, and the waste sorters at Katikolo Landfill and Composting Site.

2.1.2 Study area

The ultimate disposal of waste for Mukono Municipality is Katikolo Waste Composting Plant and Landfill, located in Katikolo Village within Mukono Town Council (MTC). The site measures about 10 acres isolated from homesteads shared between a site for landfilling and a composting site with 6 windrows. A barbed wire fence surrounds the entire site to restrict access by animals and to prevent unauthorized entry. The site itself is accessed through a gate. The site is bordered in the south, southeast and west by Katikolo wetland adjacent to Lake Victoria while to the north and east it is bordered by Katikolo Hill.

2.1.3 Waste analysis and characterization study

Waste generation data at Katikolo landfill was collected for five days from 7th January 2020 to 12th January 2020. Waste generation was determined by counting the number of trucks that brought waste on each day that the experiment was carried out. Since there is no weighbridge at Katikolo, weighbridge data from Kiteezi Landfill for different truck types was used to determine the waste transported by a particular truck. The truck plate number was also recorded in order to establish the origin of the waste. For Example:

Table 1: Data collected on 11th January 2020 basing on the number of times the trucks came in.

11/1/2020	
LG 0006 129	*5*
LG 0006 129	*5*
UXE 126	*3.5*
UG 2335 S	*40*
UAD 110K	*2.5*
UAV 645 T	*2.5*
Sub total	58.5
Subtotal municipality contribution	18.5
Total Average Waste received at Katikolo	
Total (ton/day)	44
Waste received at Katikolo from Mukono Municipality only	
Total (ton/day)	15.2
% contribution	34.4

The waste characterization study was carried out according to the following two manuals:

1. ASTM - American Society for Testing and Materials - Standard Test Method for Determination of the Composition of Unprocessed Municipal Solid Waste.
2. UNEP/IETC - Developing Integrated Solid Waste Management Plan, Training Manual. Volume 1: Waste Characterization and Quantification with Projections for Future (2009).

2.1.4 Waste Characterization and Composition

This study focused on garbage trucks only operating within Mukono Municipality and targeted a 70% confidence level of the data collected. Therefore eight waste samples were picked in accordance with UNEP/IETC. Developing Integrated Solid Waste Management Plan, Training Manual. Eight random samples were picked at

different depths of the waste heaps dumped by the garbage trucks and collected in sacks. The waste was transported to a sorting area lined with HDPE plastic sheet measuring 3m by 3m and demarcated prior to receiving of the sampled waste. The waste received at the sorting area was mixed and the quartering technique applied to reduce the waste to 100-200kg manageable samples. To obtain the sample to sort, two diagonal quarters of the quartered waste heaps was chosen and the other heap placed aside to determine the waste density. The heap chosen for sorting was done so under the researcher's supervision into eight different categories shown in Table 2. These were weighed and their different weights recorded.

Table 2 ***Showing material category and sub-categories***

Material category	M**aterial subcategory**
Organic	
Plastics	PET HDPE containers HDPE film PP
Paper	This was not sub-categorized
Cardboard	This was not sub-categorized
Glass	This was not sub-categorized
Metals	Ferrous Metals Non Ferrous Metals
Other wastes	This was not sub-categorized
Textiles	This was not sub-categorized

2.1.5 Waste density

The waste density was obtained by use of a weighed container (W2) of volume V1, the waste was placed into the container and dropped from a height of 30cm to settle the waste, and its weight would then be recorded (W1) and the waste density determined from the formula

Waste density = (W1-W2) /V1.

Where:

V1 = 0.02m^3

W2 = 0.7 kg

2.2 Facility Economic Analysis

2.2.1 Engineering costs

Evaluating a set of feasible alternatives requires that many engineering costs be analyzed. Examples include costs for initial investment, new construction, facility modification, general labour, parts and materials and many other. The types of costs experienced in engineering are fixed, variable and marginal costs.

2.2.2 Methods of Facility Economic Analysis

To assess the economic feasibility of carrying out an engineering project, economic analysis must be carried out. There are various methods that can be used to assess economic feasibility. To assess economic feasibility of the MRF, this research focused on two methods:

a) Payback period

Payback period is the period of time required for the profit or other benefits from an investment to equal the cost of the investment (Donald G. Newman, Ted G. Eschenbach, 2004).

However, payback period might in some cases give inaccurate results that may lead to the wrong decisions. Nevertheless, it does provide an estimate to when capital invested into the engineering project will be made available again such that it can be invested into other revenue generating projects. Therefore, payback period will be used to give a clearer picture of the economic feasibility of the project. It will be used together with Rate of Return (ROR) analysis method (Donald G. Newman, Ted G. Eschenbach, 2004).

b) Rate of return

Rate of Return (ROR) analysis is probably the most frequently used exact analysis technique in engineering projects, it is useful in comparing the financial advantages of alternative systems using the cash flow (Donald G. Newman, Ted G. Eschenbach, 2004; Ardalan, 2000). In ROR analysis, no interest rate is introduced into the calculations. Alternatively, the ROR is calculated from the cash flow and the calculated ROR compared with a preselected minimum rate of return termed simply as MARR as well (Donald G. Newman, Ted G. Eschenbach, 2004).

ROR can be determined from the formula below.

ROR = $\frac{\text{Current Value} - \text{Original value}}{}$ X 100

3.0 RESULTS AND DISCUSSIONS

This chapter covers the results obtained from the general research and discussions that explain the rationale of the data acquired. It covers the results obtained from the waste management situation in the scope and the facility design components.

3.1 Waste management situation in Mukono Municipality

This section covers the different situations of waste management. It covers the collection, transportation,

storage, resource recovery, ultimate disposal till waste with economic value.

3.1.1 Temporary Storage

The study revealed that people temporarily store their waste in garbage bags, polythene bags, sacks, buckets and waste heaps. The garbage bags are provided by the private waste collectors. However, for those who cannot afford them, sacks and polythene bags are used. The study also revealed that all waste collectors gather unsorted waste.

3.1.2 Collection

The study revealed that waste collection is carried out under a public private partnership, five licensed waste collectors operate within the municipality while the municipality employs two tipper trucks and one tractor to collect waste within the municipality. The municipality collects waste everyday apart from Sundays while most waste collectors collect waste on Saturdays only. The study also revealed that the collection activity is carried out by males only.

3.1.3 Transportation

The study revealed that the municipality uses the following vehicles to transport waste: Mersey Ferguson tractor, FAW tipper truck. The private waste collectors use the following vehicles: Mercy Ferguson tractor, Isuzu Elfs and ISUZU Forwards and Nissan Fuso to transport the waste.

3.1.4 Resource recovery

The study revealed that metal is the most recovered material from the municipal waste during collection and transportation of the waste to Katikolo. This explains the low amounts of metal that was discovered during the waste analysis and characterization study. This is because of metals high market value. The study also revealed that plastics especially HDPE and PET containers are also recovered during transportation and collection activities.

3.1.5 Ultimate disposal

From the study, it was determined that all waste collectors ultimately dispose their waste at Katikolo Landfill and Composting Site. This site does not have a weighbridge and inspection area. Therefore, there is no control of the type of waste that comes into the site. At the site, compositing and landfilling activities take place, resource recovery is also carried out by scavengers.

3.1.6 Waste generation

Waste generation is the amount of waste produced by a community in units of volume and weight per capita per day. The study revealed that approximately 44 tonnes/day of municipality waste is received at Katikolo, Mukono Municipality generates approximately 15.2 tonnes/day of this waste contributing 34.4% of the total waste received. The per capita waste generation for Mukono Municipality was calculated as approximately 0.19kg/person/day. This was estimated with a population of 79,598 people at a population growth rate of 2.7% (UBOS, 2014).

3.1.7 Waste composition

This study was carried out in ideally the first dry season of the year in the month of January. The solid waste sorting at Katikolo resulted in eight components (illustrated in Figure 6) of waste that consisted of paper and cardboard, textile, plastics, construction and demolition waste, organics, metals, glass and other waste.

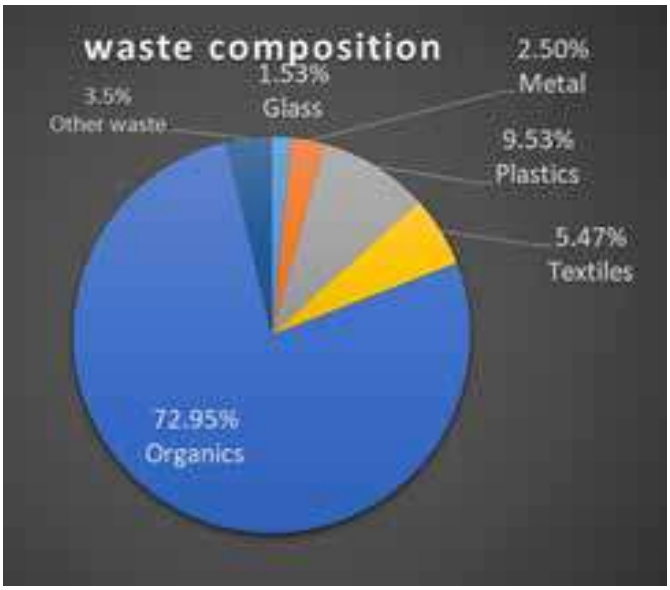

Figure 6: Pie chart showing waste composition

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3.1.8 Waste with economic value

This section illustrates the economic value of the waste collected from the Municipality using tables 4 and 5. Table 4 shows the material buyers and cost for the materials obtained from the waste whereas Table 5 shows the revenue generated from the recycled materials.

Table 4: Showing material buyers and prices

Material	*% composition*	*Recovery status*	*Amount (kg/day)*	*Market prices(Shs/kg)*	*projected Annual revenue*
Paper	1.03	Recyclable	88.374	500	UGX 16,128,255
Cardboard	3.49	Recyclable	299.442	200	UGX 21,859,266
Glass	1.53	Recyclable	131.274	0	UGX 0
Ferrous metal	2.34	Recyclable	200.772	1000	UGX 73,281,780
Non Ferrous metal	0.16	Recyclable	13.728	3800	UGX 19,040,736
LDPE	0.59	Recyclable	50.622	150	UGX 2,771,555
LLDPE	1.98	Non-Recyclable	169.884	0	UGX 0
HDPE containers	2.38	Recyclable	204.204	600	UGX 44,720,676
HDPE film	2.22	Recyclable	190.476	600	UGX 41,714,244
PET	1.15	Recyclable	98.67	400	UGX 14,405,820
PP	1.21	Recyclable	103.818	800	UGX 30,314,856
Textile	5.47	Non-recyclable	469.326	0	UGX 0
Organics	72.96	Recyclable	8430.09024	100	UGX 307,698,294
Construction & Demolition waste	0	Non-recyclable	0	0	UGX 0
Other waste	3.49	Non-recyclable	499.07	0	UGX 0
Total	**100**		**10949.75024**		**UGX 571,935,481**

Table 5: Showing the revenue generated from recycle materials

Materials	**Buyers**	**Prices /Kg (UGX)**	**Time of collection**
Plastic bottles	Rwenzori (Coca Cola)	250	Every Saturday
LPDE	Community	150	Every Saturday
Metallic scraps	Steel and Tube Industry	1000	Every Saturday
Sacks (PP)	Linda Recycling Industry	250	Every Saturday
Cardboard	Global Paper Company	200	Every Saturday
HDPE containers	Rwenzori (Coca Cola)	600	Every Saturday
HDPE Film	Rwenzori (Coca Cola)	600	Every Saturday
Compost	Farmers	100	Every Day
Milk Packs (1 liter)	Fishermen	100	Every Saturday
PP	Community	800	Every Saturday

NB: The organic material loses mass by about 19.2% during decomposition

3.1.9 Recycling Potential

The recycling potential was estimated based on a materials revenue generation. Recycling potential for the different materials is a function of it's composition in the waste, the estimated waste received at Katikolo and the market price of the material. The formula used to calculate recycling potential was;

Recycling potential = ***(%waste composition*Mukono Municipality waste generation*market value).***

From Figure 8, organics showed the highest recycling potential, LDPE plastic had the lowest recycling potential which justifies its low level of resource recovery activity at Katikolo. The economic value of Organic waste can created by processed it into compost, paper and cardboards economic value can be derived by drying it and selling it to paper recyclers, PET, PP and HDPE plastics can be shredded into resin, baled (compacted) or sold in their original form to plastic recyclers. HDPE and LDPE film can baled and sold to recyclers, Metals are sold as scrap to recyclers and don't necessarily need to go through any processing.

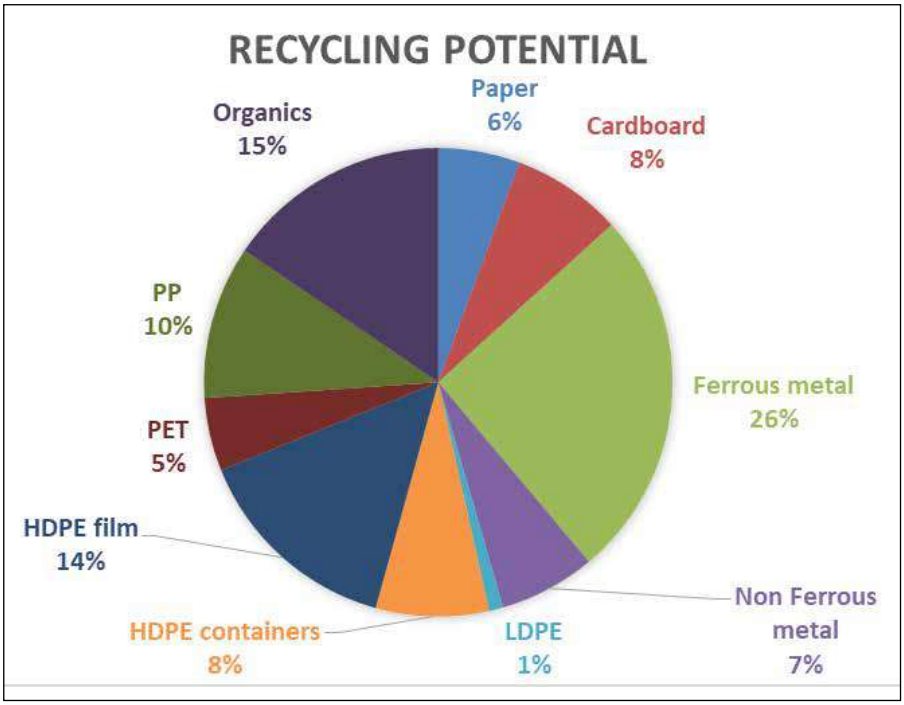

Figure 8: Showing Pie chart representing the recycling potential

3.2 Material Recovery Facility Design

This section explains the design and operation of the material recovery facility all the way from the process to the type.

3.2.1 Flow process

The preliminary design was based on the results gathered in regard to Solid Waste Management practice and waste characterization from Mukono Municipality.

3.2.2 Type of the Material Recovery Facility

The type of the MRF is a single stream/mixed waste MRF since the existing system basically encounters collection of mixed waste from the customers. The sorting system is mostly manual since there is labour available at the site.

The flow process at the Material Recovery Facility is illustrated in Figure 9 and summarised below.

It consists of

a) Registration

This is where the vehicle trucks are registered before dumping the waste. Here the management can check if the truck bringing in the waste is from a registered collector or not.

b) Inspection

This is where bulk materials are assorted, weighed and then taken to storage. Such materials may include furniture, large scrap materials, market residue that are homogenous, and others.

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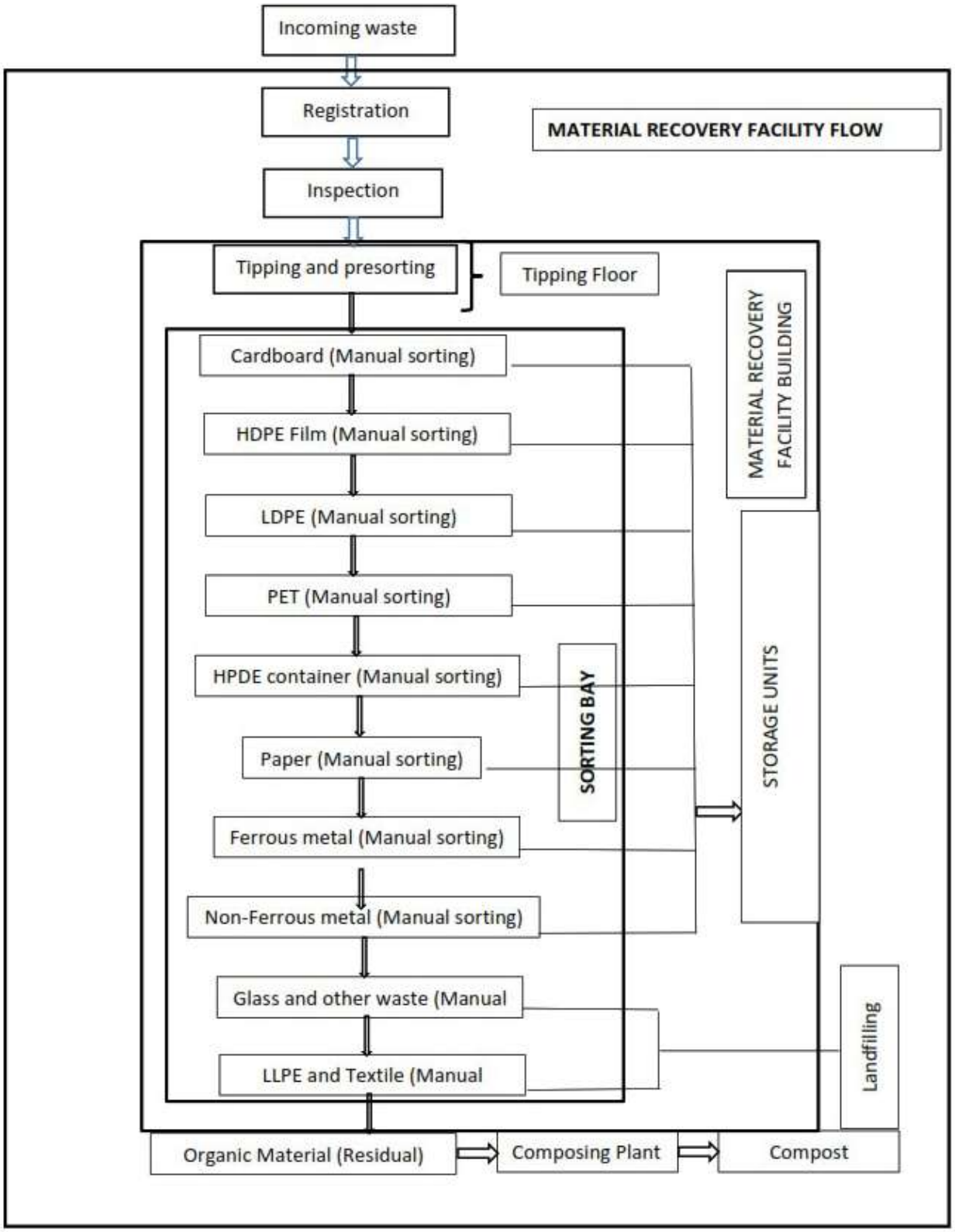
Figure 9; Flow process at the Material Recovery Facility



3.3 Design capacity

The facility is considered to be designed for a 20-year period, thereby considering a projected population for a 20-year period from the current population. So considering a constant population growth rate, waste generation and waste generation rate, the projected waste situation is illustrated in Table 6;

Table 6: Showing the projected waste situation

Current situation		Projected situation	
Population 2014 census (people)	69,671	Projected Population (People)	145876
Population growth rate (%)	3.0	Amount of waste generated in 2040(kg)	65,108
Current population (people)	80,768	Additional amount of waste (kg)	11527.39066
Waste generation (tons/day)	14.3	Additional amount of waste (ton)	11.52739066
Waste generation rate (kg/day/person)	0.18	Above amount In terms of truck capacity	2.5*(3)+1*(5)

Assumptions considered include:

a) Constant waste generation rate of 0.18 kg/person/day;

b) Constant population growth rate of 3%;

c) The same capacity of trucks are used;

d) There is no change in waste composition.

This meant that the trucks wouldl be taking two trips per day in the next 20 years. So assuming that all trucks that collect waste from Mukono Municipality will be taking 2 trips/day; Table 7 shows the weights expected from the trucks as per the consindered assumptions.

Table 7: Showing waste trucks and their weights

Vehicle	weight (tonnes)	Two trips Weight (tonnes/day)	Two trips Weight (tonnes/2 days)
Municipal truck (Fuso Nissan)	5	10	20
Municipal truck	4.5	9	18
Waste masters (Elf)	2.5	5	10
Asante Waste collectors (Elf)	2.5	5	10
Municipal tractor (Mercy Ferguson)	3.5	7	14
Waste masters (Elf)	2.5	5	10
Total	**20.5**	**41**	**82**

3.4 Summary of all the components

This section expounds on the components considered during the design process are summarised and illustrated in Table 11 showing components like capacity, lifespan, sorting types, number of sorters and much more.

Table 11: Summary of the Concept Design

Design Components	Details
Design Waste capacity	15,000 tons per year
Design Life	20 years
Sorting types	Mostly manual
Tipping floor dimension (m^2)	57.64 (from the drawing)
Total conveyor length (m)	32.5 m
Sorting room (m^2)	87.5
Number of sorters	26
Sorting rate (tonnes/person/hr)	0.250
Number of shifts	1
Number of working hours (hrs)	7
Storage room area (m^2)	240

3.5 Architectural Design Drawing

After consideration of the different design parameters, an architectural design (shown in Figure 10 and Figure 11) was proposed illustrating how the different design components would fit into one structure.

3.6 Cost estimating

To perform cost estimating, rough cost estimating was used. Cost estimates were derived from EPA Handbook for MRF design for Municipalities, Material Recovery Facility Toll kit by Asian Development Bank, quotations from equipment vendors in Uganda and Alibaba e-commerce platform.

Capital, operation and maintenance, collection, and disposal costs comprise the total costs of the MRF. Capital costs will include the construction, equipment and equipment installation costs. The construction costs include the costs associated with site work and structure works.

The major O&M cost components include the following:

1) Salaries for operation and administration.

2) Electricity and water bills

3) Fuel and oil consumption

4) Equipment and facility maintenance

i. Capital cost

Capital cost consists of construction, land acquisition, engineering and equipment cost, as expressed in the equation below.

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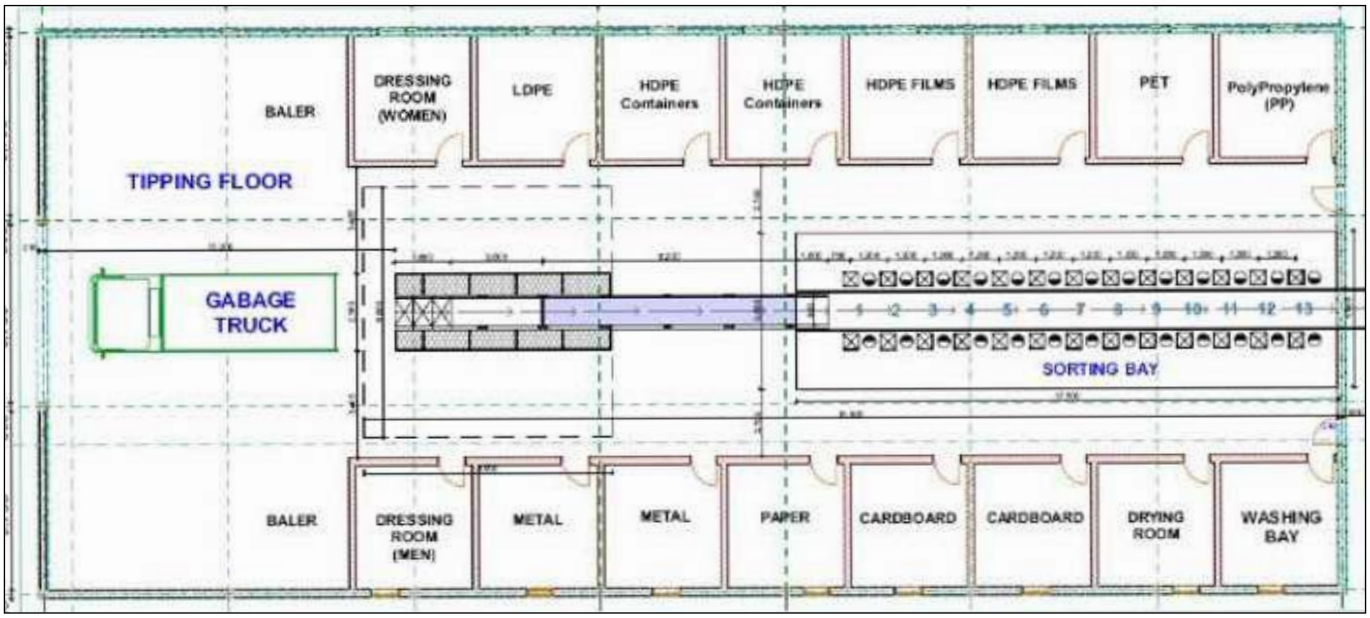

Figure 10: Material Recovery Facility Plan View.

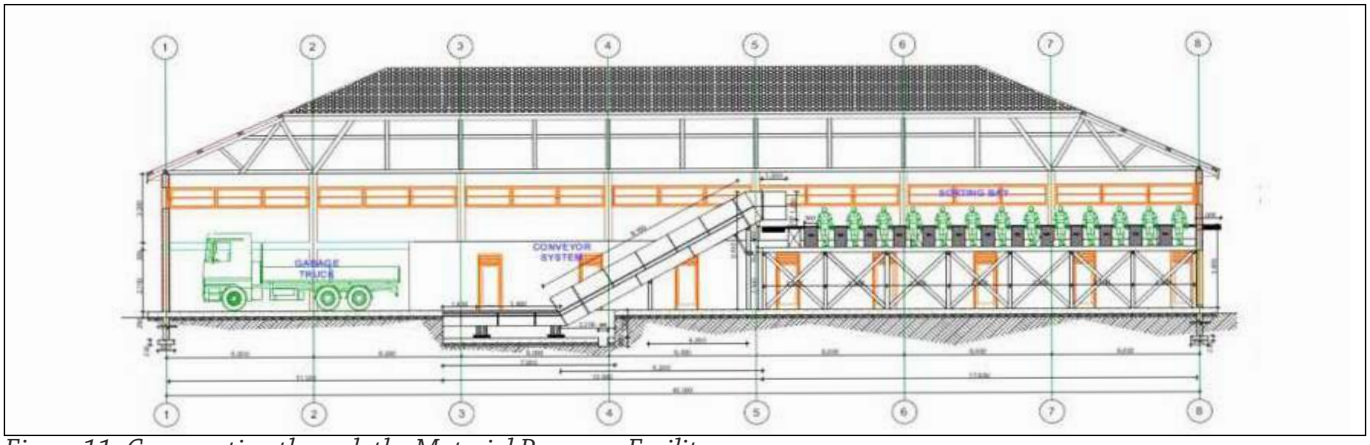

Figure 11: Cross section through the Material Recovery Facility

Capital Cost = Construction cost + Equipment cost + Engineering cost

= 4,082,442,258 + 2,736,985,336 + 408,244,226
= **7,227,671,820 UGX**

ii. Annual operating cost

Operating cost is the total cost of labour, maintenance of equipment and utilities cost for processing material.

Operating Cost = Labour cost + Maintenance cost + Utilities Cost

= 96,690,000 + 95,480,350 + 144,248,000 + 8,234,400 + 361,383,591

= **706,036,341 UGX/year**

3.7 Economic Analysis

The facility is designed to handle 80 tonnes of waste per day. However, the current amount of waste received at Katikolo is 15.25 tonnes per day. Economic analysis therefore will be performed for different case scenarios that involve the amount of waste that could be gradually be received before it starts to operate at its maximum design capacity (shown in Table 12). The different case scenarios assessed will be the current capacity, 25%, 50%, 75% and 100% of the design capacity.

Table 12: Showing scenarios of revenue for the different throughput waste at the MR

Waste generation (tons/day)	**15 (current)**	**20 (25%)**	**40 (50%)**	**60 (75%)**	**80 (100%)**
Gross Annual revenue (UGX)	468,952,332	1,044,301,500	2,088,603,000	3,132,904,500	4,177,206,000
Annual Operating costs (UGX)	706,036,341	706,036,341	706,036,341	706,036,341	706,036,341
Net Annual revenue (UGX)	-237,084,009	338,256,159	1,382,566,659	2,426,868,159	3,471,169,659

3.7.1 Payback Period

Payback period analysis shows that the MRF will be able to repay its initial cost on investment within 14 years. This will be achieved when the throughput waste received is 40TPD. At the end of the operation life time, the MRF achieves net profit on investment in its fourteenth year of operation, generating a profit of 10,538,928,985 UGX at the end of its design life.

Table 13: Showing payback analysis performed for the MRF. NB: (values) in Net revenue column reflect expense.

Year	Waste Processed (TPD)	Capital cost	Equity	Annual operating cost	Gross Annual revenue	Net Annual revenue	Repayment
0	15	UGX 7,227,671,820	UGX 7,227,671,820	UGX 706,076,341	UGX 508,695,357	UGX (197,380,984)	UGX 7,425,052,804
1	15		UGX 7,227,671,820	UGX 706,076,341	UGX 508,695,357	UGX (197,380,984)	UGX 7,622,433,788
2	15		UGX 7,227,671,820	UGX 706,076,341	UGX 508,695,357	UGX (197,380,984)	UGX 7,819,814,772
3	15		UGX 7,227,671,820	UGX 706,076,341	UGX 508,695,357	UGX (197,380,984)	UGX 8,017,195,755
4	15		UGX 7,227,671,820	UGX 706,076,341	UGX 508,695,357	UGX (197,380,984)	UGX 8,214,576,739
5	20		UGX 7,227,671,820	UGX 706,076,341	UGX 1,096,423,500	UGX 390,347,159	UGX 7,824,229,580
6	20		UGX 7,227,671,820	UGX 706,076,341	UGX 1,096,423,500	UGX 390,347,159	UGX 7,433,882,421
7	20		UGX 7,227,671,820	UGX 706,076,341	UGX 1,096,423,500	UGX 390,347,159	UGX 7,043,535,262
8	20		UGX 7,227,671,820	UGX 706,076,341	UGX 1,096,423,500	UGX 390,347,159	UGX 6,653,188,103
9	20		UGX 7,227,671,820	UGX 706,076,341	UGX 1,096,423,500	UGX 390,347,159	UGX 6,262,840,944
10	40		UGX 7,227,671,820	UGX 706,076,341	UGX 2,192,847,000	UGX 1,486,770,659	UGX 4,776,070,285
11	40		UGX 7,227,671,820	UGX 706,076,341	UGX 2,192,847,000	UGX 1,486,770,659	UGX 3,289,299,626
12	40		UGX 7,227,671,820	UGX 706,076,341	UGX 2,192,847,000	UGX 1,486,770,659	UGX 1,802,528,967
13	40		UGX 7,227,671,820	UGX 706,076,341	UGX 2,192,847,000	UGX 1,486,770,659	UGX 315,758,308
14	40		UGX 7,227,671,820	UGX 706,076,341	UGX 2,192,847,000	UGX 1,486,770,659	UGX 1,171,012,351
15	60		UGX 7,227,671,820	UGX 706,076,341	UGX 3,289,270,500	UGX 2,583,194,159	UGX 3,754,206,510
16	60		UGX 7,227,671,820	UGX 706,076,341	UGX 3,289,270,500	UGX 2,583,194,159	UGX 6,337,400,669
17	60		UGX 7,227,671,820	UGX 706,076,341	UGX 3,289,270,500	UGX 2,583,194,159	UGX 8,920,594,828
18	60		UGX 7,227,671,820	UGX 706,076,341	UGX 3,289,270,500	UGX 2,583,194,159	UGX 11,503,788,987
19	60		UGX 7,227,671,820	UGX 706,076,341	UGX 3,289,270,500	UGX 2,583,194,159	UGX 14,086,983,146
20	80		UGX 7,227,671,820	UGX 706,076,341	UGX 4,385,694,000	UGX 3,679,617,659	UGX 17,766,600,805

3.7.2 Rate of return Analysis

Rate of Return can be calculated from the formula below.

$$ROR = \frac{\text{Current Value} - \text{Original value}}{\text{Original Value}} \times 100$$

Where:

Current Value = Current value of Investment. Capital appreciation of the structure will not be used in analysis and only the revenues from the investment will be considered.

Original Value of investment: Value of Investment. Capital investment is considered.

$$ROR = \frac{8,568,065,859 - 7,227,671,820}{7,227,671,820} \times 100$$

$$= 18.54\%$$

Therefore, investment into this project will yield a rate of return of 18% on the investment. Furthermore, the projected ROR will be higher than the average 7% ROR for public and private projects in Uganda by 11.54%.

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4.0 CONCLUSION AND RECOMMENDATION

In conclusion, we have been able to achieve all our objectives The design was in accordance with Material Recovery Facilities Process Model published by Research Triangle Institute in partnership with and North Carolina State University. Economic Analysis on the facility was performed in accordance with EPA Handbook for design of MRF for municipalities and Material Recovery Facility Toolkit by Asian Development Bank. Economic analysis revealed that investment into such a facility will be economically profitable and beneficial to Mukono Municipality generating revenue of UGX10,538,928,985 within its years of operation. We therefore recommend for further research on cheaper local methods of sorting, feasibility of further sorting of organic material categories into wet fiber with low calorific value such as food remains and dry fiber with high caloric value and exploring the possibility of manufacturing the machinery locally in the country under the Uganda Industrial Research Institute.

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Design of a Wastewater Treatment Plant for Paint Factories

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ABSTRACT

In order to improve the health and livelihood of the public, there is a need to treat wastewater from the different sources which include municipal, agricultural and industrial areas. The main purpose of this project is to design a treatment system that could treat wastewater from Chromatic Paints Factory to dischargeable standards. Sampling was carried out at the factory, the quality of the wastewater was determined through conducting both in situ and laboratory tests, flow measurements using a bucket method. The jar test was also carried out to determine the optimum alum dosage in the wastewater. The different results from the tests were discussed in relation to the quality and the quantity of the wastewater generated. Therefore, the different objectives of the research and design project were met. This report provides an engineered design of the proposed treatment system which comprises the mixing unit, sedimentation tank, filtration unit. However, the company is advised to continuously monitor the quantity and composition of their wastewater in order to develop better informed design parameters such as flow rate. It is also recommended that a better sludge disposal method should be researched about.

1.0 INTRODUCTION

The paper reports on a systematic process to investigate the quality and quantity of wastewater from Chromatic Paints Factory and design a system that treats it to discharge standards.

The study was guided by the following specific objectives.

a) Determining the wastewater characteristics and the volume of wastewater generated.

b) Determining the optimum dosage of alum to be used.

c) Designing a treatment system for the wastewater from Chromatic Paints Company.

Paint can also be referred to as a liquid solution composed of different pigments and solvents which is applied on different surfaces for decorative or protective purposes (Talbert, 2008). After continuous revolution and introduction of different raw materials especially the synthetic ones have posed a threat to the environment. Paint wastewater contains toxic compounds and was considered as inhibiting bacterial development (Fent, 1996). In addition to chemical treatment, an appropriate biological technology is required. The biggest problem at hand is poor disposal of paint and paint wastewater into the environment without treatment. This is the genesis of all paint wastewater problems because it introduces toxic waste into the environment.

Worldwide, different countries have come up and set regulations for the paint manufacturing industries and also minimum standards for effluent disposal into the environment. The paint industry is one of the most highly regulated industries in the world. So the producers have been forced to adopt low solvent and solventless technologies in the past 40 years and will continue to do so in the near future (International, 2017).

Almost all the surface and groundwater in Kampala City is polluted and the inhabitants of the city are highly exposed to health risks associated with water pollution. According to the Ministry of Health and KCCA, the recent outbreak of typhoid was partly due to polluted surface and groundwater (KCCA, 2016).

In addition to the above, an Industrial Wastewater Management Guide for Uganda provides that every paint factory/industry facility should have a wastewater treatment plant for effluent discharge to treat all

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the waste from the facility including that collected after washing and cleaning. pH adjustment, coagulation, aeration, sedimentation and disinfection are some of the processes that can be employed in paint wastewater treatment (KCCA, 2016).

Uganda is a developing country. This implies that more different infrastructure is yet to be set up or constructed. With increased construction, the demand for architectural coatings (paints) is increasing and has opened up new ventures of new paint manufacturing industries to join the business. This has also created a battle of paint in Uganda (Adengo, 2017).

1.1 Problem Statement

Chromatic Paints Factory lacked an efficient treatment system for its wastewater. This led to poor disposal of untreated wastewater into an underground pit (shown in Figure 1) and on land. According to Part 5(1) of the National Environment Regulation for Discharge of Effluent into water or onto land, every industry must have a treatment facility and a regulation of the amount of waste generated to standards that are not harmful to the environment (NEMA, 1999).

The current method used to manage the wastewater presents a big threat of leakages of wastewater into the surrounding environments including water channels and streams downhill which people depend. (Olayinka, 2015). Approximately 35% of the population around the world depend on different groundwater sources which are mostly from shallow aquifers to meet their water needs (UNEP, 2002), and this exposes people to the poisonous pollutants in this wastewater which includes heavy metal, eutrophication especially in water channels. Furthermore, some of the components of these wastes contain chemical elements which are likely to infiltrate and percolate into the subsurface environment upon discharge, and these subsequently accumulate into the soil pores (Idzelis, et al., 2006). The composition and quality of surface and groundwater has been declining due to the high increase in the industrialization and human activities (Kumar, et al., 2013). In addition, as paint wastewater flows as runoff into storm drains, the organic solvents and inorganic compounds are slowly broken down in water, depriving aquatic organisms of the oxygen they need to survive. The toxic nature of chemicals in solvent-based paints may also cause tumours to form in animals such as fish.

Figure 1: Showing the underground pit

This study was aimed at finding a solution to this problem by designing a treatment system for the factory through wastewater sampling, field and laboratory tests, analysis and design.

1.2 Justification

The paint factory does not have a proper effluent disposal management facility for its wastewater. This method of using an underground pit is not sustainable and efficient since in the long run it might affect the soil productivity and its concentrations, hence affecting the plant life (Jolly, et al., 2008). In addition to this, some inorganic waste is not decomposed by anaerobic processes/digestion, these pits are also ineffective at removing phosphorus and nitrogen compounds that have the potential to cause algal blooms in waterways in case there are leakages (Ground & America, 2008).

Despite the fact that there are regulatory bodies such as National Environment Management Authority (NEMA) in charge of ensuring proper wastewater disposal, Chromatic Paints company does not conform to these set regulations for effluent discharge.

Therefore, treatment of this waste water using an appropriate design in place, effluent will be treated before it is discharged, thus reducing the potential risk of contamination of underground water and land, hence protecting human and plant life.

2.0 METHODOLOGY

This chapter outlines the research methodology that was used to conduct the research and inform the design. It consists of geographic scope and study methodology applied to achieve the objectives of this research.

2.1 Geographical and time scope

Chromatic Paints Uganda Limited is located on Plot 5, Kasubi-Kawala, off Hoima Road in Kampala District.

Time scope: September 2018 to April 2019

2.2 Content scope

Investigation of the quality, quantity of the wastewater from Chromatic Paints Limited. Laboratory and field tests were carried out to determine the quality of the wastewater. The wastewater flow rate was also carried out to determine the quantity generated. The results from these tests informed the design of the wastewater treatment system.

2.2.1 Flow Rate measurements

The amount of wastewater produced was determined through measurement of wastewater flow at the factory. Flow varies from one day of the week to another month or season. Most of the wastewater was generated in the evening when there was cleaning of floors and mixing tanks, leading to high volumes of wastewater during that time.

The flowrate was determined using a bucket method (shown in Figure 2). The bucket method was chosen in preference to others because it is suitable for small flows and irregular channels and also due to the availability of the equipment required to carry out its procedure.

Figure 2: Determining the flow rate using the bucket method.

2.2.2 Field/in situ tests

In order to assess the wastewater quality parameters, in situ measurements were taken at 2 sampling points for the preliminary tests, which were carried out on 20/12/2018.

Before the wastewater goes into the underground pit, it is first screened to reduce on the suspended solids. Hence sampled the wastewater both before and after screening.

The first sampling point was at the outlet point of the wastewater from the factory (before screening) and also the wastewater in the underground pit (after screening). This enabled the researcher to know the variations between wastewater parameters and those that needed improvement. These measurements were carried out between 4:00 – 5:00 pm with the help of a technician.

The parameters determined included temperature and dissolved oxygen. The above parameters were measured using a Mettler Toledo and a DO MRC.

At each sampling point, the measurement for each of the above parameters was conducted in triplicate.

2.2.3 Laboratory tests

The samples obtained from the field were analysed for parameters such as colour, BOD_5, COD, TSS, TKN, Total Phosphorus, Alkalinity, Sulphate. These tests were carried out to check whether the parameters of the wastewater are in relation to the NEMA standards of the effluent to be discharged to the environment.

The jar test was carried out to determine the optimum coagulant dosage for clarifying the wastewater. All the laboratory tests were carried out at NWSC-Central Laboratory-Bugolobi.

3.0 RESULTS AND DISCUSSION

After carrying out field and laboratory tests, the following results were obtained, represented and interpreted as shown below.

3.1 Wastewater quality characteristics

Table 1: Showing the preliminary results of the wastewater from the factory.

PARAMETERS	UNITS	BEFORE SCREENING	AFTER SCREENING	NATIONAL STANDARDS OF EFFLUENT DISCHARGE
SAMPLE No.		K5983/2018/C/B	K5984/2018/C/B	
Alkalinity: Total	mg/L	1500	300	800
B.O.D	mg/L	519	372	50
C.O.D	mg/L	5000	5700	100
Colour(apparent)	PtCo	47300	33700	500
Dissolved Oxygen	mg/L	5.53	0.23	>2.0
EC	µS/cm	347	570	1500
Sulphate	mg/L	0	0	500
Temperature(C)		23	23	20-35
TKN	mg/L	1750	2721	20
Total phosphorus	mg/L	14375	16525	10
pH		8.06	7.23	6.0-8.0
TDS	mg/L	223.36	364.8	1200
TSS	mg/L	11700	6000	100
Turbidity	NTU	14425	9025	300
Lead	mg/L		0	0.1
Chromium	mg/L		0	1
Cadmium	mg/L		0.025	0.1

The researcher carried out preliminary tests to determine the quality of the wastewater as shown in Table 1 and the parameters that needed to be improved.

Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Colour, Total Phosphorus (TP), total kjeldahl nitrogen (TKN), Total Suspended Solids (TSS), and Turbidity. All these were above the effluent discharge standards both before and after screening.

The high levels of BOD and COD were as a result of the different organics used in the manufacture of the paint, for example, titanium dioxide, calcium carbonate, magnesium silicate, cellulose (Gulin, et al., 2004). The colour was as a result of the organic material that has dissolved into solution, which leads to high values of the turbidity (Ibrahim & Gabr, 2014).

Alkalinity and Potential of Hydrogen (pH) were above the discharge standards before screening, and within the range after screening (Gulen, et al., 2006). This is because before screening, the wastewater is still rich in paint while after screening, some paint is taken off by the screen, hence the low pH.

Sulphate, lead, chromium were not detected. This is because these are water-based paints where water is used as a solvent. These paints have less traces of heavy metals.

Dissolved Oxygen (DO) was within the discharge range before screening, and out of range after screening. This is because after screening, the wastewater is stored in an underground pit which is always covered, hence limited oxygen supply (Metcalf & Eddy, 2003). Dissolved Oxygen is required in adequate amounts for survival of aquatic life and prevention of offensive odours.

3.2 Wastewater flow rates from Chromatic Paints Factory

Below are the results obtained during both production days and days when cleaning activities took place (Saturdays).

Table 2: Showing the varying flow rates

Day	Flow Rate (m^3/day)
Monday (4^{th})	135
Wednesday (13^{th})	140
Friday (21^{st})	130
Saturday (9^{th})	180
Saturday (16^{th})	190
Saturday (23^{rd})	185
Average flow rate	**160**

From Table 2, it is observed that during production days the flowrate was within the range of 130-140 m^3/day while during Saturdays the flowrate was within the range of 180-190m^3/day.

The peak flow rates were obtained during Saturdays when cleaning activities take place. Therefore, for proper design, calculated the average flow rate which was 160m^3/day. This flow rate catered for both minimum and peak flow rates.

The flowrate measurements kept varying from day to day and time. This is because the factory works on a batch process where wastewater only flows when activities like production, cleaning are being carried out. Days from Monday to Friday are normal working days where more production of paint is carried out than cleaning activities. On such days, less is generated therefore leading to low values of flow rate.

Saturday is a day of general cleaning of the drums, flows, buckets. On this day more wastewater is generated, therefore leading to high/peak values of flow rate.

There was no constant flow rate, and therefore to enable proper design of the treatment system, calculated the average flow rate from the values obtained. Hence, Chromatic Paints Factory produces an average flow rate of 160m^3/day of wastewater.

3.3 Determining the optimum dosage

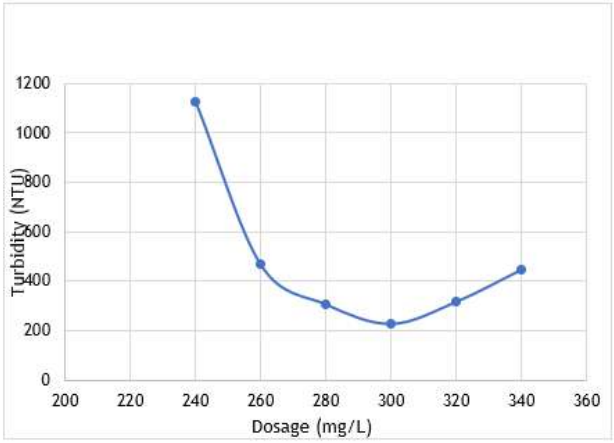

Figure 3: A graph of turbidity against dosage of Alum

Figure 3 shows the average values of turbidity and dosage of alum. The jar test was carried out two times using the same dosages and the average of the results was taken.

A graph of turbidity against the dosage was plotted and appeared as above. From the graph, the optimum dosage is 300mg/L. This is the dosage which gives the least turbidity.

The jar test was carried out to determine the optimum coagulant dosage for clarifying the wastewater. The optimum dosage obtained was 300mg/L at a pH of 7.68. The pH of the wastewater kept increasing per dosage between the range of 7.5-7.8. The pH kept increasing because of the different salts used in the manufacture of paint for example calcium carbonate, magnesium silicate and their reaction with alum. Since the pH did not go above 7.8, that means it was still in the neutral range and therefore we did not need to adjust it (Philip, 2016).

4.0 LABORATORY SCALE DESIGN

The results from the tests carried out informed the design. A prototype or laboratory scale design was set up and the wastewater was run through the system as shown in Figure 4. The effluent from the system was tested and results obtained to determine its efficiency. The design was important in achieving the last specific objective.

Figure 4: Design prototype of the treatment unit for the paint factory

The wastewater had to flow from the mixing unit where we had agitation of the wastewater and alum, then to the sedimentation tank to enable settlement of the suspended solids. Lastly, to the filtration unit where we had adsorption of the contaminants by the Granular Activated Carbon (GAC). The GAC was placed above the sand because it has a large surface area onto which the molecules can stick, and therefore enabling the adsorption process to take place (Summit, et al., 2015).

The purpose of the sand being placed below the GAC was to trap other suspended solids that remained after sedimentation and also prevent breakthrough of flocs (EPA, 1995). The gravel worked as the base layer to support the filter media as recommended by (MWE, 2013).

4.1 Sampling of the prototype

In order to obtain the sample for effluent, the researcher used composite sampling method. The collected four individual samples (2 litres) at regular intervals after two hours during a 24-hour time span. Each individual sample was combined with the others in proportion to the rate of flow when the sample was collected. The mixture resulting from the composite sample formed

a representative sample which was analysed.

From the results of the influent and effluent, the researcher calculated the percentage removal of the system in order to determine the efficiency of the system.

Table 3: Percentage removals for the different parameters

Parameter	% Removal
Colour	99.6
Turbidity	99.8
COD	98.6
BOD	91.4
TKN	99.2
TP	99.8
TSS	99.4

From all the calculations, the percentage removal for all the parameters was above 90% as seen in Table 3 and within the discharge standards, meaning that the system was efficient in treating the wastewater from Chromatic Paints Factory.

There was improvement in the water quality attributed to the presence of a sedimentation tank and filtration unit.

The sedimentation tanks allow settlement of solids, thereby reducing BOD and TSS since it enhances the removal of about 50-70% of TSS and 25-40% of BOD (Metcalf & Eddy, 2003). From this, we agree with a study carried out by (Metcalf & Eddy, 2003) since after sedimentation the water was clearer hence showing a reduction in colour, turbidity and hence BOD as shown in Figure 5. In addition, the reduction in colour is attributed to the flocculation as result of the addition of alum. The adsorption of the contaminants in the wastewater by the activated carbon helps in maximum removal of COD, TKN, colour, phosphorus (Peta, 2006). In addition to this, the filtering unit using activated carbon and sand also aided the retention of the suspended solids in the water thereby causing a reduction in the turbidity thus further reduction in the BOD.

Comparing this design to other designs used in treatment of water-based paints, for example; combination of a chemical coagulation/flocculation step with an aerobic biological process by (Souabi, et al., 2006) which removes 92% of COD, 97% of colour and 44.5% of BOD. From this, the proposed system is more efficient than the one of (Souabi, et al., 2006) because it has a higher percentage efficiency.

Figure 5: Showing the samples of wastewater from the mixing, sedimentation and filtration units

From the laboratory scale design (prototype), developed the actual design considerations and calculations of the treatment system as shown in Figure 6.

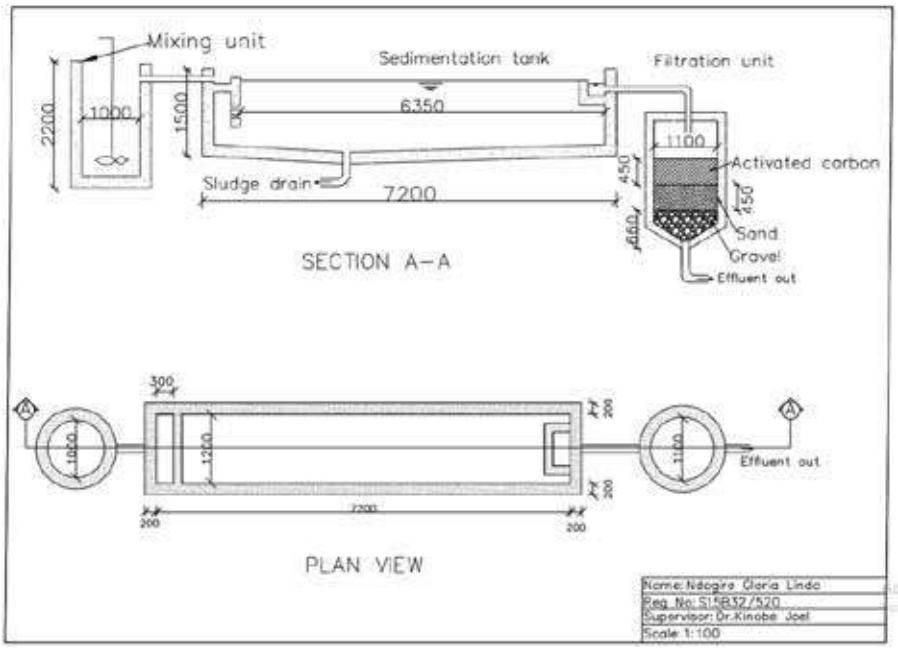

Figure 6: Cross sectional design, plan view of the treatment system

5.0 CONCLUSION

The objectives of the project were met within the proposed time schedule. Releasing these loadings directly into the environment leads to a deterioration of land, water quality in the receiving environment.

The factory's wastewater showed high levels of COD, BOD, TSS, colour, turbidity, TP and TKN. The system was able to treat the wastewater up to a percentage removal of above 90% for all of the parameters hence making the system efficient for treatment.

Chromatic Paints Factory produces approximately an average flow rate of 160 m^3/day, and this was used in the designing the size of the sedimentation tank and other units. The optimum dosage of alum obtained from the jar test was 300mg/l.

6.0 RECOMMENDATIONS

- It is also necessary to continuously monitor the quality of effluent from the treatment system in order to verify that its quality complies with the national discharge standards.
- It is recommended that more research should be carried out in order to get the best way to dispose of the sludge to the environment.
- It is recommended to carry out continuous measurements for the flow rate so as to obtain records of at least one year in order to develop an accurate peak to average flow rate factor.

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Challenges a Graduate Engineer Faces in the field in Uganda

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ABSTRACT

Young engineers in the country battle with various tests of finishing school life and transitioning into the work environment. However, it is not as fast as they expect it to be because they have to go through various training to append on their theoretical knowledge obtained from the university. That is how the majority first adapt to having graduate training which, however, is a big test to them. Nevertheless, there are some remedies that can be embraced by various regulating bodies to ensure that some of these challenges are minimized and the future great engineers of the country are not left in despair.

1.0 INTRODUCTION

Education is the key to the future. That saying has been used a million times while we go through school right from nursery till the day, we finish formal studies. Career guidance is one thing that does not miss from this exciting journey because we go through numerous counselling throughout the education journey that sets off from nursery, primary, secondary and university that is supposed to mould and shape us up fully. The construction industry is diverse with a range of ages groups including the young generation like those in Figure 1.

The work opportunities are available out in the field but the reverse is true. The guidance and counselling given to students, such as those in the engineering field is not easy. This is because a lot of hardships are there along the way.

Figure 1: Graduate interns on site levelling concrete

In fact, the end of university is also the beginning of another journey into an engineering course of its own that is not for the faint-hearted because it requires a lot of patience and resilience since it is tougher out there in the field than in the walls of schools.

Uganda has only 942 registered engineers collectively where 874 are Ugandan nationals with full operational licenses and 68 are foreigners with temporary registration (ERB website, 2020). Despite the fact that over 600 engineers graduate from different universities all over Uganda (Observer, 2019), the registration process and number of engineers issued with licences to practice are still alarm-

ingly low set side by side to our East African neighbours under the mutual recognition agreement arrangement (MRA) (Odong, 2022). In addition, 95 of the 136 districts that make up Uganda do not have registered engineers. Uganda has more than five organizations regulating engineers in the country and other engineer-related fields. The most commonly known being the Engineers Registration Board (ERB), Uganda Institution of Professional Engineers (UIPE), Uganda Association of Consulting Engineers (UACE), Uganda National Association of Building and Civil Contractors (UNABCEC), the Institution of Surveyors of Uganda and the Uganda Society of Architects (USA) to see the performance of engineering in Uganda blossom. ERB is mandated with regulating the practice of engineering in Uganda and advise the government on all engineering matters with jurisdiction obtained from the Engineering Regulatory Act of 1969 (ERB, 2020).

The Uganda Institution of Professional Engineers (UIPE) is also on the forefront of regulating engineering activities in the country and has various roles and responsibilities but the catchy one to a graduate is to co-operate with universities, institutions and educational centres for the furtherance of education and training in engineering, science and practice. UNABCEC is a contractor regulatory body that is dedicated to fostering improved performance in the construction sector by presenting genuine contractors in the field. UNABCEC is in the limelight for graduate engineers because it offers graduate training programmes to these champs and this program is known by almost half of the graduate engineers especially those from public universities. With all these regulatory bodies in place, graduate engineers are lucky to graduate because they will find guidance waiting in the field.

2.0 CHALLENGES FACED BY GRADUATE EN GINEERS IN FIELD

This chapter breaks down in detail some of the challenges faced by graduate engineers as regards to the information collected from the internet, papers and informal personal conversations.

2.1 Insufficient practical experience

A university equips students with skills of research and having intense self-driven reading skills because most of the times they will develop their personal reading material and take control of their learning. However, the practical experience is neglected which affects students especially those from practical courses like engineering. Engineering students are given some practical field experience through recess and internship but it is usually just a sneak peek of what the actual field requires; they end up having just the general knowledge about what needs to be done in field. This affects them when they get to the field because they are practically not competent enough for the on-site jobs.

2.2 Work without training assistants

Often most graduates realize they do not have practical skills so they cut back on the pressure of searching for jobs and decide to first get the practical skills through a programme called graduate training. Usually, students apply for this training from different companies and one of the problems they face while training is that some of them go to sites where there are no engineers or tutors to nurture them. The challenge is that they just have to find their way and look for personal training while at sites.

2.3 Limited training places

Graduate training is the first activity that students have adopted to undertake after university and most of them are eager to have it because it gives them the practical skills they missed while at university. But this does not come to everyone easily because it is as hard as getting a job after university. Some students miss out on the training and find themselves in other fields that are not related to the engineering field.

2.4 Lack of Personal Protective Equipment (PPEs)

Construction sites usually provide their workers with personal protective equipment for their safety but they find it hard to provide for graduate students reasoning that the equipment is for company workers only; graduate students should facilitate themselves with safety gear yet some of the students cannot even afford some gear like safety shoes.

2.5 Inadequate financial support

Some construction companies don't consider graduate students especially on graduate training as their workers since they are more of learning the practical skills; they do not even pay them. In fact, some companies go ahead and ask for some money from the students claiming that they are equipping them with skills just like how they pay tuition or school fees to institutions. This affects the graduate students since they have to cater for their lunch and transport as some of them might not be in position still to get financial support from their parents. This demoralizes them from working and some resort to quitting graduate training before they actually fully attain the necessary practical training because they are struggling to keep afloat.

2.6 Shortage of employment even after training

Some construction companies can retain some of the graduate trainees who work with them during their training period and those are the lucky ones but to get to the other side, some graduates don't attain employment especially with the companies they have worked with and end up with the engineering skills but working in other fields that are not engineering-related.

2.7 Lack of trust from some engineers in the activities carried out by graduates individually

Usually, graduates are eager to acquire knowledge and practical skills and as soon as they get an opportunity at site and those that are well conversant with the practical skills want to

hit the ground running while carrying out the various tasks that they have learnt. However, it is discouraging when they put in a lot of effort and hardwork to deliver what is supposed to be done but then the engineer at site does not appreciate their toil even when they have made some mistakes which are unforgivable.

2.8 Demoralization from some professions in the field

Construction sites face the challenge of where every profession believes their accomplishments are better than others. Comments like "your course is not of much importance in the engineering field." This is a big challenge that graduates of construction management face, making them think they are not of any importance in the engineering field.

2.9 Monetary Exploitation

Most graduates fresh from university and other institutions are usually excited to practice the profession they've just graduated in. Sadly, this often challenges them in a way that some organisations or individuals exploit this desperation by seeking money from the graduates for them to practice in their organisations. This money is usually covered with the excuse of being used to facilitate the graduates and also fix the mistakes they are likely to make while practicing.

2.10 Language Barrier in the field

The engineering field has a variety of levels responsible for different roles in the field. These different levels can include, artisans, technicians, technologists and engineers. There is a general language that joins these levels together to ensure proper communication essentially for proper supervision (Border States, 2020). This language is often not taught in institutions or universities but rather learnt in the field. Most graduates get into the field without having properly grasped the language and this makes it complicated for them to carry out proper supervision and comments on work in the field.

3.0 RECOMMENDATIONS

Despite the fact that these challenges may seem heavy, they can also be solved if the institutions and work environment work together to support the graduates. Some of the recommended ways forward are explained below.

The university can equip students with basic skills needed to face the professional world but more practical skills need to be imparted so that they hit the ground running while they are done with school.

The college of engineering can partner with different companies so that these companies employ graduate engineers after university through graduate training as they get the practical skills to combat the challenge of some students missing out on obtaining graduate placement due to the various problems that the country is facing including the *"gamba nogu issue."*

Different engineering regulatory bodies like UNABCEC have tried to establish graduate training programs but some eligible students end up not benefiting because of the unawareness disease that is with the program therefore these organizations need to widely inform students about these opportunities to facilitate young engineers.

Universities should establish a university company made of students but regulated by their lecturers to also participate in bids and winning contracts while they have partnered with other construction companies that have delayed in the engineering field.

The engineering regulatory bodies in the country should establish and enforce sensitization of their roles through carrying out seminars, workshops and other means of getting closer to these young engineers while they are still at universities.

Students should create an initiative amongst themselves as a group of small numbers or individually and visit sites regular during holidays and any free time they get off campus to instill more practical knowledge to them and as well be familiar with the whole construction process before they are out of campus.

The regulating bodies should also encourage their subordinates like contractors under UNABCEC to provide to students who come for training with supervisors who trains them one on one on the practical skills in the field and also monitors their assessment through-

out the training period. Also, these companies shouldn't bounce back the students from their sites due to safety reasons otherwise they should just provide PPEs to the students.

4.0 CONCLUSION

University students are believed to be grown-ups who can handle and face challenges in the world on their own; but they need more professional support, especially just after campus because most of the times they do not actually know what they need to do especially in fields that are broad like engineering. Some students do not even know about these regulatory bodies like UIPE, ERB, UACE, among others, yet they can actually help the graduate engineers during their professional development. This implies that these bodies are not doing enough to reach out to the graduates. yet this should be done while the students are still at university, perhaps even in their first year so that they get a bigger and better picture of the professional world ahead of them. How are they are going to face it to minimize issues of engineers getting lost in thin air with the aim of keeping themselves afloat in a country short of engineers? While students acquire all the necessary theory necessary for engineering, the practical skills are of very much importance to them to enable them contemplate and make meaning of everything that they are taught in class. While the saying that the young generation is the future of tomorrow, the regulating bodies in the country should endeavour not only to put emphasis on engineers practicing in the field, but also consider monitoring young engineers and thoughtfully grooming them into superior engineers who are far from offering shoddy works to the country and the world at large.

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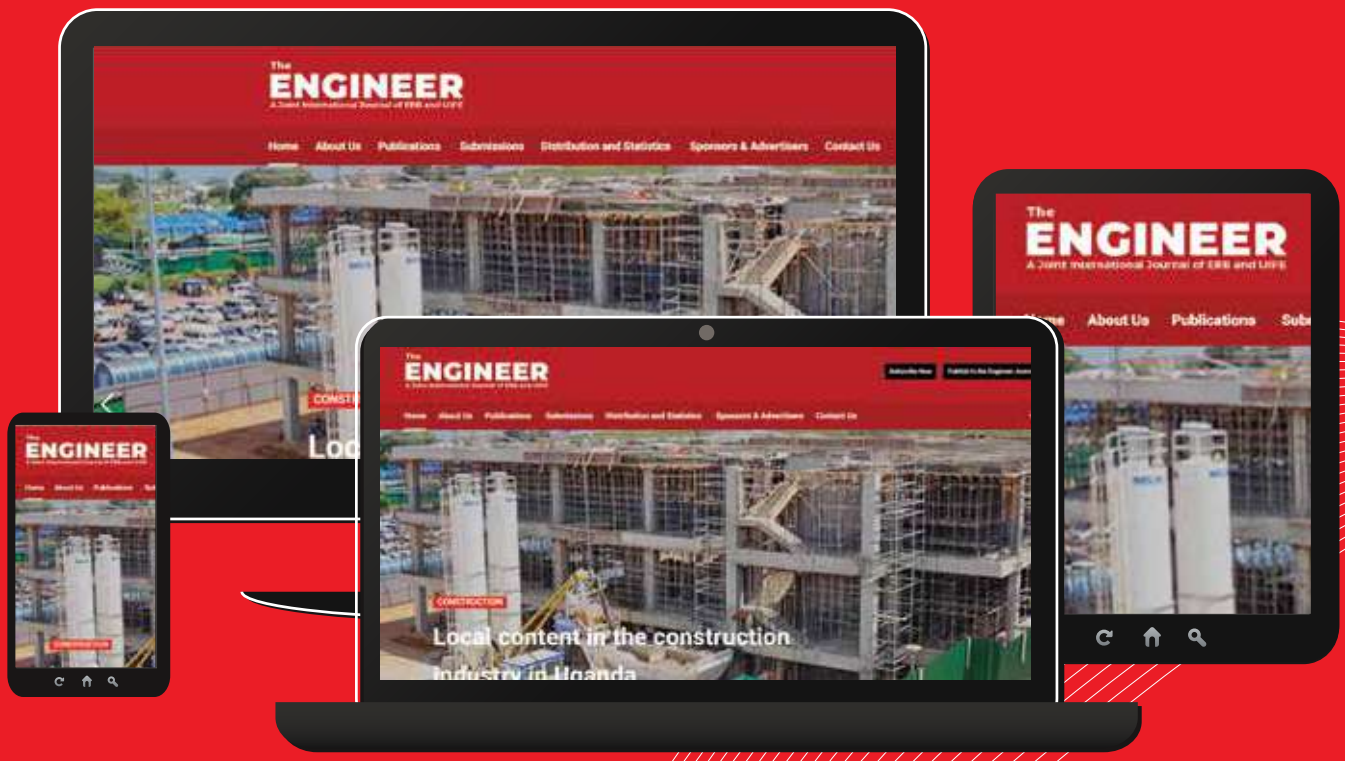

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