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ENGINEERS BOARD OF KENYA
Enhancing Professionalism

ENGINEERING PARTNERSHIPS CONVENTION | 2025

THE 6TH ENGINEERING PARTNERSHIPS CONVENTION

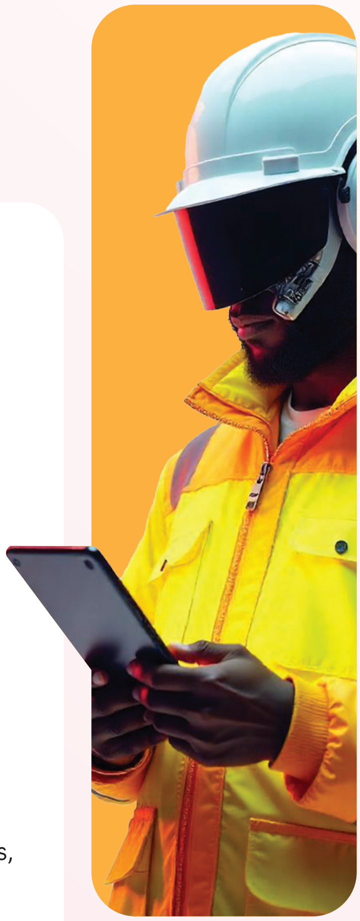
Theme: Engineering a Digital World

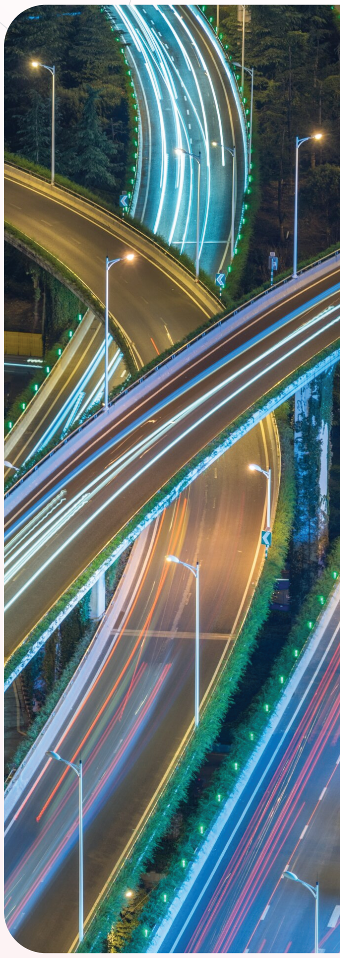
7th - 9th May 2025

Nairobi, Kenya

Objectives of the Convention

- Develop strategies for engineering green technology that promotes sustainable economic growth and address disparities
- Establish a digital platform that promotes engineering interconnectivity and access to technology solutions across the region
- Highlight the latest technological advancements across the regions, facilitating an exchange of ideas and showcasing homegrown innovations at the expo.





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In this Issue

Engineering in KENYA

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Call for Papers

Engineering in Kenya Magazine - Issue 021
The Institution of Engineers of Kenya (IEK) publishes Engineering in Kenya magazine, whose target audience includes engineering professionals, practitioners, policymakers, researchers, educators and other stakeholders in engineering and related fields. The publication is distributed to its target readers free of charge through hard and soft copies.
IEK invites you to contribute articles for our next and future editions. Articles should reach the Editor not later than 20th April, 2025 for our next issue, whose theme shall be "Materials Engineering" and related sub-themes, across all engineering disciplines. An article can range from engineering projects to processes, machinery, management, innovation, news and academic research.
The articles must be well researched and written to appeal to our high-end readers in Kenya and beyond. The IEK Editorial Board reserves the right to edit and publish all articles submitted, in line with standing editorial policy. All articles should be in Word document format, 500-700 words, font type Times New Roman and font size 12.
Send your article today, and get a chance to feature in the magazine!
Send your article to: editor@iekenya.org

Eng. Prof. Lawrence Gumbe

Message from the Editor

Biomedical and Health Systems Engineering

Biomedical and Health Systems Engineering is the application of the science and art of engineering to the planning, design and management of systems for healthcare in society. It combines expertise in engineering with expertise in medicine and human and animal biology so as to develop technologies and techniques for healthcare and patient care. The field addresses engineering concerns of: Biotechnology; Health Care Systems; Amenity; Human Biology; Pharmaceutical industries; and The Environment.

The specialisation areas depend on specific academic and professional traditions of varies countries and universities. Some of these specialisation areas include:

Clinical and Instrumentation Engineering

The application of engineering principles in the design of hardware and software, measurement principles and techniques to develop devices used in the diagnosis and treatment of disease. It combines the design and problem-solving skills of engineering with the medical and biological science to help improve patient health care and the quality of life of healthy individuals

1. Biomedical and Rehabilitation Engineering

The application of engineering principles to design, develop, adapt, test, evaluate, apply, and distribute technological solutions and devices to assist individuals with disabilities as well as to aid the recovery of physical and cognitive functions lost because of disease or injury.

2. Hospital and Health Systems Engineering

The application of engineering principles and engineering management to design, analysis and evaluates various medical production systems, delivery systems, waste control and disposal systems in the hospital, occupational and safety systems and other infrastructure amenity systems in the hospital.

3. Public Health Engineering

The application of science and art of engineering in the design management of wastes control and disposal systems aimed at the prevention and control of disease and disability, environmental management, disease vector control, prolonging life and promoting health and the promotion of physical and mental health of the population.

4. Pharmaceutical and Biomolecular Engineering

The application of engineering principles, practices, science and technology to the purposeful manipulation of molecules of biological origin in the production of medicines and medical supplies. It involves the interface of molecular biology, biophysical chemistry aimed at developing and manufacturing products, processes, and components in the pharmaceuticals industries.

Biomedical and health systems engineering is crucial to the world as it significantly improves healthcare by developing innovative medical devices, diagnostic tools, and treatment methods, leading to better patient outcomes, extended lifespans, and tackling complex health challenges through advancements like prosthetics, tissue engineering, drug delivery systems, and advanced imaging technologies, ultimately enhancing quality of life for individuals across the globe.

According to the Business Research Company The bioengineering technology market size has grown rapidly in recent years. It will grow from US$320.38 billion in 2024 to US$361.95 billion in 2025 at a compound annual growth rate (CAGR) of 13.0%. The growth in the historic period can be attributed to increasing aging population, increasing prevalence of chronic diseases, bioengineering technology market growth, favorable government initiatives, growing genetic engineering strategies.

The bioengineering technology market size is expected to see rapid growth in the next few years. It will grow to US$591.25 billion in 2029 at a compound annual growth rate (CAGR) of 13.1%. The growth in the forecast period can be attributed to increased focus on cell therapies, rapid growth of synthetic biology, precision medicine advancements, increasing application in agriculture, expanded use in environmental solutions. Major trends in the forecast period include advanced gene editing techniques, convergence of technologies, advancements in precision medicine, global collaboration and partnership, synthetic biology applications.

The Kenya Medical Training College, KMTC, has had certificate and diploma courses for the past few decades. Technical University of Mombasa, TUM, has been a pioneering institution in East Africa that offers medical engineering courses and attracts experts from around the world. Kenyatta University has recently established a degree course in Bachelor of Science in Biomedical Engineering. The University of Nairobi has been trying to develop a degree course in Biomedical Engineering since 1989. Technical University of Kenya, TUK, is also developing a degree course in this are.

The Institution of Engineers of Kenya has a vibrant Biomedical Engineering discipline group. Association of Medical Engineering of Kenya, AMEK, which is professional association registered in 1998. The Engineers Board of Kenya has provisions to register biomedical engineers as professional engineers.

This issue of ***Engineering in Kenya*** magazine is devoted to Biomedical and Health Systems Engineering. We hope that you will enjoy the articles. We are here to inform educate and entertain you.

Eng. Luka Kimani, representing the Chief Guest, Principal Secretary of Roads, Eng. Joseph Mbugua, officially launches a procession to celebrate World Engineering Day at the University of Nairobi on 4th March 2025.

IEK Policy Research Manager, Joseph Anvar Alot, was among the key members who took part in the World Engineering Day celebrations at the University of Nairobi on 4th March 2025. As part of the event's activities, he participated in a tree-planting session, reinforcing the theme of Sustainable Engineering for a Sustainable Future. The tree planting symbolized engineers' commitment to environmental conservation and sustainable development.

Eng. Margaret Ogai, Registrar/CEO of the Engineers Board of Kenya, officially launched the Graduate Engineer Registration Portal, streamlining the registration process for engineers. The launch took place during World Engineering Day on 4th March, 2025 at the University of Nairobi.

From left: Eng. Jacton Mwembe, Hon. Secretary – IEK; Eng. Margaret Ogai, Registrar/CEO – EBK; Eng. Maureen Auka, CEO – IEK; Dr. Eng. Damaris Oyaro, IEK Capital Branch Chairperson; Prof. Eng. Siphila Mumenya, Dean of the Faculty of Engineering at UoN; Eng. Erastus Mwongera, Chairperson – EBK; Eng. Luka Kimani, representing the Chief Guest, Principal Secretary of Roads, Eng. Joseph Mbugua; Eng. Harrison Keter, 1st Vice President – IEK; Eng. Jennifer Gache, Chairperson of the Women Engineers Committee – IEK; Eng. Barbara Adhoch, CEO – ACEK; Prof. Eng. Christopher Muriithi Maina, IEK Council Member.

Eng. Shammah Kiteme, CE, FIEK

Message from the President

This issue 21 of Engineering in Kenya magazine focuses on Biomedical Engineering. This branch of engineering deals directly with healthcare provision in terms of production of equipment that are used in supporting treatment of patients and helping in their recovery from sickness. Operations, maintenance and repair of the Biomedical equipment and other processes that are supportive of clinical operations is a very vital area in healthcare provision. For instance, a ventilator machine supports a patient who cannot breath under normal circumstances. A suction machine is necessary to facilitate various surgical operations in removing fluids.

Magnetic Resonate Imaging, X-ray and multiple other radiological and radiographical processes are very vital for diagnostics and helping clinicians identify the diseases to be treated. The Biomedical equipment used for these processes requires attention of Biomedical engineers. This also includes their calibration to ensure that the results they give are accurate.

These types of equipment generate radiation that can be harmful if not properly handled. Engineers in healthcare space must properly deploy proper radiation protection measures to safeguard people working with and around these equipment.

It is actually safe to say that once the doctor leaves the patient, the nurse and the Biomedical Engineer are in charge of the patient. Hospital beds, dialysis equipment, operating tables are examples of other equipment. Catheterisation labs, Linear Accelerators, monitors, Computerised Tomography (CT) scans, dental chairs are all equipment that normal operations in the hospital for healthcare provision would be impossible without. Biomedical engineers are responsible for their production, operations, maintenance and repair. Biomedical engineers should therefore understand mechatronics, electrical, and mechanical principles of operations of the various medical equipment.

Many hospital environments require various medical gases including medical grade oxygen, medical air, cardon dioxide, nitrous oxide among others. Some of these like oxygen gas require plants for generation and this means that engineers operating in the hospital should understand the operation of the plant and its various aspects. This includes fluid dynamics and safe handling of the generated medical gases from the plant all the way to the patient terminal in theater or hospital ward. Purity and pressure levels of the medical gases have to managed as well. Engineers must manage all these.

Hospital Engineering is very critical as it involves saving lives. A mistake can lead to loss of lives for patients. This must be avoided at all costs as the hospital exist to save life. If careless handling leads to loss of life, medico-legal issues can also ensue and paralyse healthcare provision.

Biomedical engineering is also evolving very fast. Like many other fields, Artificial Intelligence (AI) has come with big impact on the way the equipment operate. The equipment processors are now trained to be able to give results and AI is the first interpreter. This implies that reskilling of Biomedical engineers is necessary so that they can diagnose and repair all modern Biomedical equipment.

The hospital environment generally presents unique challenge to engineers. Because it deals with diseases, infection control is an aspect that is key. Unlike other working environments, infection control considerations have to be factored in the design and construction, operation and maintenance of hospital facilities. These are areas that the biomedical engineers operate in and the general understanding of the infection control protocols is very important for safe operation and maintenance of biomedical equipment.

Healthcare Engineering is a specialty area that should include not just the biomedical equipment but the entire scope of engineering required within hospital environments. This includes power, heating ventilation and air conditioning, construction and maintenance of buildings and other facilities within the hospital, provision of water and sanitation facilities including solid waste handling. Some healthcare areas require controlled humidity and temperatures and this is also the role of engineers to achieve these. All these require a special understanding of the unique requirements for the hospital environments.

Unfortunately, there is no university in Kenya offering the specialty training in Healthcare Engineering. While we have biomedical engineering training, we need universities in Kenya to develop a curriculum to offer basic and advanced degrees in Healthcare Engineering. This will facilitate acquisition of the specialty knowledge required to enable engineers to effectively operate in the healthcare engineering environment. Currently, many engineers operating in this space are either trained electrical, mechanical, civil engineers who learn on the job to be able to work in the hospital environments.

IEK appreciates this important branch of engineering and in recognition of this the council welcomes all members in this area of specialized knowledge to play an important role in influencing policy in healthcare.

The council established a taskforce on Universal Healthcare which is one of the priorities of the fifth administration. This taskforce has synthesised various issues affecting the sector and developed policy proposals that forms our contribution to the improvement of the healthcare sector. These proposals look at how the various areas of improvement in the sector and as we share them with policy makers the institution is involved in advocacy relevant to all sectors where our members are involved.

Our efforts to amend the IEK Constitution will see inclusion of more areas and classes of membership that continue to strengthen the institution. We believe in numbers we have strength required to shape policy direction for this country and especially in all the infrastructure sectors. The Institution continues to produce the infrastructure score card which focuses on our various infrastructure and examines their status. The report is a vital advocacy tool as we produce it to inform policy makers on areas of focus for improvement of our infrastructure.

As the industry continues to evolve and match technological changes, IEK has invested in training programs to future-proof the careers of our members. These include application of Internet of Things and Artificial intelligence to Engineering. Quantum Engineering, Bioinformatics, Renewable energy, Circular economy, design of resilient infrastructure and various other areas of training that the institution focuses to make sure our members are relevant in their work today and in the future.

It is therefore fitting that this issue of Engineering in Kenya focuses on Biomedical engineering because as engineers we have a lot of input to make in the healthcare sector to make sure we have a healthy nation. I now invite all our readers to interact with this rich content in this issue.

Message from the Honorary Secretary

Eng. Jacton. A. Mwembe, PE, MIEK

I welcome you dear esteem reader to the 21st edition of *Engineering in Kenya (EiK)* Magazine, dedicated to the dynamic and transformative field of **Biomedical and Healthcare Engineering**. This issue highlights the intersection of engineering and healthcare, a sector that is witnessing rapid advancements and innovations, reshaping how medical care is delivered, and how patients experience health services across the world, including in Kenya.

Biomedical engineering is not just a field of study but a movement that brings together the precision of engineering with the compassion of healthcare. This powerful convergence is revolutionizing the way we understand, diagnose, treat, and ultimately care for patients. Biomedical engineers are leveraging cutting-edge technologies such as artificial intelligence (AI), robotics, 3D printing, wearable health monitors, and telemedicine to enhance patient outcomes and improve the efficiency of healthcare systems. The role of engineers in this space is no longer peripheral but central to solving some of the world's most pressing healthcare challenges.

At the heart of these innovations lies a fundamental drive to improve the quality of life for patients. The development of advanced prosthetics and orthotics helps in the restoration of mobility to individuals with disabilities, alongside sophisticated imaging devices which provide more accurate diagnosis, biomedical engineering thus is at the forefront of revolutionizing patient care.

Robotics developments and applications in the areas of surgical operations allows for a minimally invasive surgical techniques allowing for quicker recovery times and lower risks for patients, significantly improving the overall healthcare experience.

As we celebrate the progress of biomedical engineering globally, Kenya too is experiencing a renaissance in this field. The healthcare sector in Kenya has seen exponential growth in recent years, and this is largely due to innovations powered by engineers who are passionate about improving healthcare systems. From urban centers to rural communities, Kenya's healthcare landscape is benefiting from the integration of advanced medical technologies, many of which have been spearheaded by local engineers and innovators.

For instance, the adoption of telemedicine and mobile health (mHealth) solutions in Kenya has been particularly impactful. These platforms have expanded access to healthcare, particularly in underserved areas where physical infrastructure is limited. Engineers are working closely with healthcare providers to design systems that are not only technologically advanced but also adaptable to the unique challenges posed by the country's geography and socio-economic conditions.

Furthermore, renewable energy solutions have played a crucial role in ensuring that hospitals and medical facilities, especially in remote areas, are able to function continuously. Solar-powered medical equipment and off-grid energy systems are now a common sight in Kenya, reducing dependency on unreliable power supplies and increasing the resilience of healthcare infrastructure. This move aligns with the global push toward sustainable healthcare solutions and is something that biomedical engineers in Kenya are helping to pioneer.

One of the recurring themes that runs through this issue of the Engineering in Kenya Magazine is the importance of collaboration. The integration of biomedical engineering into healthcare is not a solitary pursuit; rather, it is an endeavor that requires the joint efforts of engineers, medical professionals, government agencies, and the private sector. The multidisciplinary nature of this field demands that experts from various backgrounds work together, each contributing their knowledge and skills toward a common goal: **improving patient care and advancing healthcare systems.**

The IEK **Universal Healthcare Task Force** is one of the key initiatives that is helping to facilitate these conversations. By bringing together stakeholders from different sectors, the task force is driving discussions on policy, infrastructure, research, and innovation in healthcare engineering. These collaborations are essential for formulating strategic solutions that can address the challenges facing Kenya's healthcare system, including the need for affordable healthcare services, improved diagnostic capabilities, and equitable access to advanced medical technologies.

This edition also shades lights on IEK collaborative partnerships with various universities and research institutions in fostering the future of biomedical engineering trainings. The increasing number of young engineers entering the biomedical field is promising, and their contributions are crucial in ensuring that Kenya remains at the forefront of healthcare innovation. It is inspiring to see how students, graduate interns, and emerging professionals are making significant strides in research, development, and practical applications that have the potential to transform Kenya's healthcare landscape.

Engineers, particularly those in the biomedical field, have played a crucial role in advancing these transformative healthcare technologies, addressing critical challenges in diagnosis, treatment, and patient care. Through the development of AI-driven diagnostic tools, biomedical engineers have improved the accuracy and speed of disease detection, enabling earlier and more effective interventions. In robotic and minimally invasive surgery, their expertise in designing precision-driven robotic systems has significantly reduced surgical risks and recovery times. The innovation behind wearable health devices is largely driven by engineers who integrate advanced sensors and real-time monitoring capabilities, empowering individuals to track their health proactively. Furthermore, the application of 3D printing in prosthetics, implants, and tissue engineering showcases engineering ingenuity in making personalized and cost-effective healthcare solutions more accessible. The expansion of telemedicine and remote healthcare has also been made possible by engineers developing secure, high-speed communication platforms that bridge the gap between patients and medical professionals, ensuring healthcare access even in remote areas. These advancements underscore the indispensable role of engineers in revolutionizing the biomedical space and improving healthcare outcomes worldwide.

As we continue to witness the rapid growth of biomedical engineering and healthcare technologies, I urge all stakeholders—engineers, healthcare providers, policymakers, and community leaders—to engage in this critical discourse. Now more than ever, we must work together to create a healthcare system that is not only efficient and effective but also inclusive and equitable. By embracing innovative technologies, promoting research and development, and fostering collaborative partnerships, we can create a healthcare system that provides quality care to all Kenyans, regardless of their geographic location or socio-economic status.

The contributions featured in this edition of the EiK Magazine, ranging from interviews with thought leaders to technical articles and success stories, are a testament to the incredible work being done in this field. I invite you to read and reflect on these insights, engage with the content, and consider how you too can contribute to the ongoing transformation of healthcare engineering in Kenya.

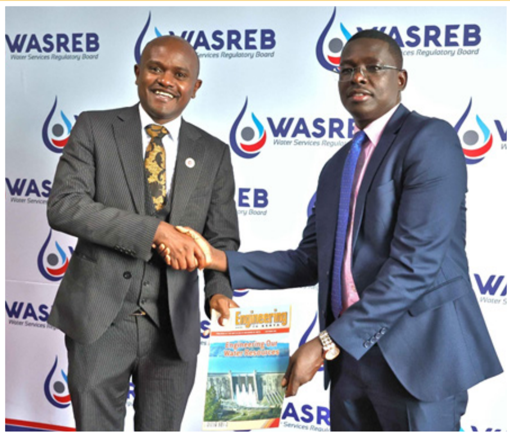
Together, let us champion engineering-driven healthcare solutions that will help create a healthier, more prosperous Kenya for all.

PICTORIAL

Eng. Harrison Keter, 1st Vice President of IEK, giving a media briefing during World Engineering Day celebrations at University of Nairobi on 4th, March, 2025.

The Institution of Engineers of Kenya (IEK) officially launched the Engineering Capability Building for Africa Program (ECBAP), a transformative 10-year initiative aimed at enhancing engineering skills and technology transfer across Africa. The launch, sponsored by SANY Group, followed a week-long training on Artificial Intelligence for Engineers. Speaking at the event, IEK President Eng. Shammah Kiteme expressed appreciation for the support of SANY Group, the Engineers Board of Kenya (EBK), and the China Association of Science and Technology (CAST) in strengthening engineering education and capacity-building in Kenya. Also in the photo are Eng. Maureen Auka, Chief Executive Officer of IEK (far right), and Eng. Harrison Keter, 1st Vice President (far left).

The IEK Council, led by President Eng. Shammah Kiteme, paid a courtesy call on the Water Services Regulatory Board (WASREB) and met with Ag. CEO Richard Cheruiyot to discuss strategic collaboration in addressing challenges in the water sector. Key discussions focused on leveraging IEK's technical expertise to reduce Non-Revenue Water (NRW), strengthen infrastructure investments, and support mentorship programs for women engineers. Both institutions explored opportunities for collaboration on policy development, capacity-building, and sustainable solutions to enhance water service delivery in Kenya.



During the courtesy visit, Ag. CEO Richard Cheruiyot of WASREB received a copy of Engineering in Kenya magazine, published by IEK. The magazine, themed Engineering Our Water Resources, highlights research initiatives by IEK aimed at addressing water sector challenges. This exchange underscored IEK's commitment to knowledge sharing and policy development to enhance sustainable water resource management in Kenya.

Engineering Related Contamination Risks in Aseptic Pharmaceutical Manufacturing: Analysis of Causes and Control Measures

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Picture Courtesy
Robotics and aseptic manufacturing in pharmaceuticals

1. Introduction

Aseptic manufacturing of pharmaceutical products is carried out in a closed system to prevent microbial ingress in product and product contact areas. Aseptic manufacturing involves production of pharmaceutical products while ensuring that there is no microbiological, particulate nor pyrogenic contamination in the process from storage, formulation, filling, and packaging (Aditi, 2023). Aseptic manufacturing is mostly applied in the production of biologics, vaccines, injectables, intravenous infusion products and eye/ear, nasal drops. Aseptic processing is very sensitive and usually tightly controlled. The most critical consequence of administration of contaminated product or non-sterility is direct patient death (Sandle, 2017).

Contaminant entry into a product or product pathway may originate from manufacturing materials; poor personnel behavior, contaminants ingress into the manufacturing area from surrounding environment; product mix-up during manufacturing due to poor design or manufacturing procedure and poorly cleaned processing equipment. According to Agalloco, J., et al., (2004), the top ten causes of microbial contamination in aseptic processing are personnel contaminants, human error, aseptic assembly, non-routine activities, mechanical failure, airborne contaminants, failure of HEPA filters, material transfer and improper sterilization. Microbial contamination even in minor quantities can cause deterioration of product safety and danger to patient health (Gupta, Bhatt, Shukla and Kumar, 2024). If found contaminated, the affected batches of product are discarded, and a thorough corrective action preventive action (CAPA) initiated. If already released to the market, a traceability and recall procedure is initiated, a process which is time consuming, expensive and might lead to withdrawal of certification by the regulator leading to loss of business continuity and public trust.

Engineers in a manufacturing facility are tasked with design, construction, installation, operation, maintenance and monitoring performance of manufacturing equipment and facility. Personnel such as engineers in the process of providing services to ensure that a manufacturing plant runs trouble free may act as agents of cross-contamination from one point to another either directly or indirectly (Sarla, 2020). Engineering related contaminants include personnel related contaminants such as dirty Personnel Protective Equipment and shared tools used from one station to another, these act as potential carriers of microbial contaminants; design flaws in facility HVAC system, poor pressure zoning which doesn't allow specified clean room categorization, HEPA filters inefficiency which may admit microbes into the facility; exposure of product pathway to external environment during maintenance and so on. Measures must be put in place to identify, analyze, monitor, and control such risks (Gupta et al, 2024),

The paper focuses on contamination risks which can be directly controlled by engineering operations and personnel. Specifically, the objectives being identification, assessment and control of contamination risks related to engineering operations and personnel. The researcher based the study on

B. Braun Pharmaceuticals Ltd which is a global manufacturer and distributer of sterile Large Volume Parenterals (LVPs) Small Volume Preparations (SVPs) and sterilized Water for Injection (SWFI). B. Braun Pharmaceuticals EPZ Ltd is among few facilities in Kenya which practice aseptic and sterile manufacturing. The company has a robust and well controlled classified manufacturing areas under ISO class C and D.

2. Methods

Identification and assessment of engineering related contamination risks was done through Failure Mode Effect and Analysis (FMEA) method by a select Cross-Functional Team (CFT). A combination of risk analysis as per FMEA model and risk control strategy is an effective method for sterility failure analysis (Boom et al, 2022).

The CFT consisted of a quality assurance officer, a mechanical technician, a process chemist, and a microbiologist. FMEA was considered best suited for the study because it applies the knowledge, skills, and experience of the CFT to identify, assess and control contamination risks. The scope involved Design FMEA (DFMEA) and Process FMEA (PFMEA). Sahayam (2023) describes DFMEA as a method of identification of potential failures in the design of a system and the effect it has on the quality, performance, and safety of a product. PFMEA on the other hand assesses the potential failure in the manufacturing stages which could lead to a non-conforming product (Pantazopoulos et al., 2005)

Contamination risks were identified the by CFT through experimental method, analysis of process data or technical and scientific knowledge. The contamination risks were then categorized as either personnel related, process related, or airborne related. Assessment was done using a 5-point scale risk matrix. Likelihood of occurrence, ease of identification and severity of the contamination were all assessed. A risk Prioritization Number (RPN) was then used to determine the risk ranking and categorization. The risk rating together with scientific knowledge and a reference of GMP guidelines were then used to determine the best control measures.

3. Results

3.1 Identification of Contamination Risks

Identification was done through interrogation of what might cause non-sterility when engineers carry out their duties. Contamination risks related to personnel hygiene were identified qualitatively using microbiological sample collection and analysis. Contamination risks related to process handling were identified from trend analysis of deviations and CAPA records. Contamination risks related to HVAC system performance were identified through the experience of the CFT and scientific knowledge. Results of the identified contamination risks identified is summarized in Table 3.1 below.

Table 3.1: Summary of Engineering related contamination risks

Category	Contamination risks	Causes	Mode of Detection
Personnel related	Contaminated PPEs	Failure to observe personnel hygiene and use clean, sterile PPEs	Microbiological analysis
	Shared maintenance tools	Failure to dedicate tools to be used in cleanzone and sanitize them	Microbiological analysis
Process related	Exposure of product pathway	Non-aseptic disassembly of pipes and fittings	Chemical and Microbiological analysis
Airborne	Mechanical damage of HEPA Filters	Improper handling during installation	Non- Viable Particle Count test
	Poorly installed HEPA Filters	Improper installation allowing air leakage into classified area	Environmental analysis test
	Poor regulation of AHU	Change of settings during cleaning, monitoring	Pressure Balancing and Pressure Differential Monitoring
	Wrong air flow patterns	Out of specifications air velocity and pressures	Air Flow Patterns Test

Source: Author (2024)

3.1.1 Contaminated PPEs and Tools

Assessment of the level of contamination of personnel PPEs was done for staff from four departments working in the classified clean manufacturing area. Personnel were assessed by collecting swabs on different parts of their bodies, incubating the samples for 48hrs, then carrying out microbiological analysis of both bacterial and fungal microbial counts as Colony Forming Units (CFUs). Results are presented in table 3.2 below.

Table 3.2: CFU contribution per department

Part of the body	Results (cfu)			
	Production	Quality Assurance	Quality Control	Engineering
Right elbow	17	7	7	19
Left elbow	24	9	3	23
Right knee	8	8	4	35
Left knee	8	4	3	8
Behind the head	8	4	3	21
TOTAL	65	32	20	106
Number of staff	14	6	4	11
Average (Counts/ person)	4.6	5.3	5.0	9.6

The results were analyzed to determine the level of contamination per department and the concentration of CFUs on different parts of the body. The result of analysis is summarized in figure 3.1 and figure 3.2 below.

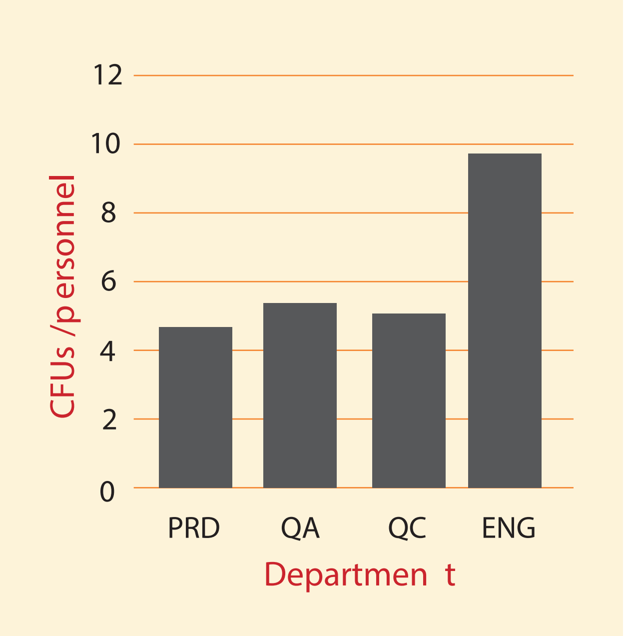

Fig 3.1: CFUs per personnel per department

The average distribution of CFUs per personnel indicated that Engineering personnel had the highest number of 9.6 CFUs per personnel compared to other departments that were in the range of 4 to 5 cfu/personnel. The high number of CFUs/personnel in engineering is attributed to the nature of work carried out by engineering personnel which is highly active work of lifting, turning, and handling of different machine parts, equipment, and tools. However, control measures should be put in place to limit cross contamination.

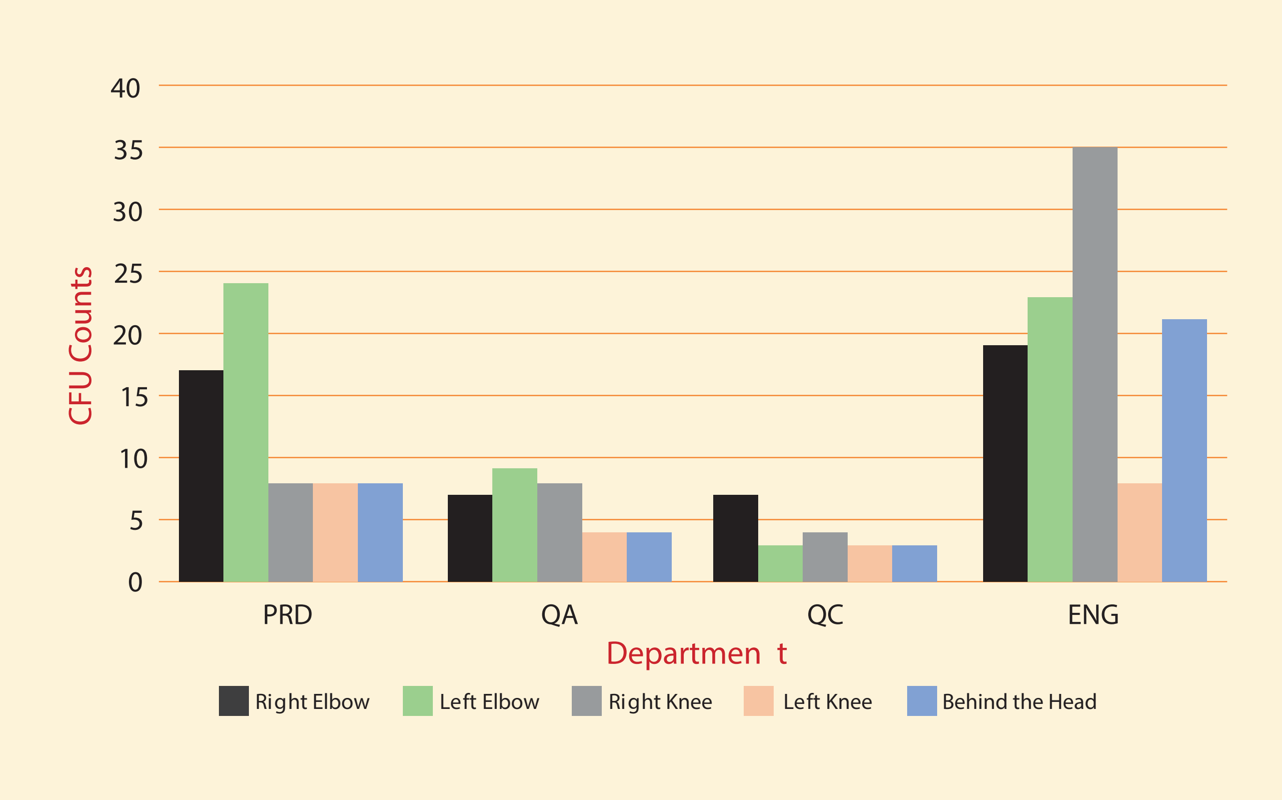

Fig. 3.2: CFUs distribution on parts of the body

The distribution of CFUs on different parts of the body indicated that engineering personnel had most contamination on their right knee, left elbow, left elbow, and left elbow respectively. This is associated to their maintenance works which involves bending and supporting their bodies on their knees and elbow while carrying out various maintenance activities.

3.1.2 Exposure of Product Pathway.

Manufacturing of sterile pharmaceutical products is carried out in a closed loop piping not exposed to external environment. This is done to ensure that the aseptic characteristic of the product is maintained. Though rare, engineering technicians during maintenance of production equipment may expose product pathway when addressing breakdowns. Some possible cases of exposure include addressing leakages in product transfer piping/equipment, opening of fittings such as clamps, replacement of faulty instruments and so on.

The CFT identified the cases as possible contamination risks as summarized in table 3.1. Contamination through exposure of product pathway may lead to sterility failure and discarding of the entire batch of product. Identification of this contamination risk through microbiological analysis of the product sterility and analysis of the chemical properties of the product. The source of contamination associated to this risk is not easy to detect and involves thorough investigation, control measures must therefore be put in place to mitigate chances of occurrence.

3.1.3 Airborne Contamination Risks.

HVAC system is used to maintain aseptic conditions of clean room manufacturing area. Characteristics of a perfect HVAC sysem includes ability to maintain the recommended Air Changes per Hour (ACPH), temperature and Non-Viable Particle Count in clean rooms. Engineers carry out HVAC systems design, maintenance, monitoring and revalidation. Cases of poor design, lack of reliable monitoring and ineffective preventive maintenance of HVAC system can lead to serious clean zone air borne contamination. The CFT identified that failure of HVAC system can occur through inadequate monitoring, wrong design, and lack of technical capability to diagnose failures of the HVAC system. The causes of environmental contamination attributed to HVAC flaws include mechanical damage of HEPA filters, poorly installed HEPA filters, poor regulation of AHU dampers, air leakage into clean manufacturing rooms and wrong air flow patterns in Laminar Air Flow (LAF).

Mechanical damage of HEPA filters was identified as a likely cause of contamination. HEPA filters are used as the final point of air filtration before entry into the clean manufacturing area. HEPA filters recommended for use in clean rooms have a porosity of 0.3 μm. Mechanical damage of the filtration module can result to penetration of non-viable particles into classified spaces and out of specification out of specification. Mechanical damage can occur due to poor handling during installation or normal wear.

Poorly controlled AHU was identified as another risk to contamination. Poor regulation may result from unintended adjustment during cleaning and maintenance. The fault is detected by out of specification pressure differentials readings on magnehelic gauges. The risk is likely to lead to out of specification ACPH, Air Velocity and room pressure.

External air leakage into classified clean manufacturing area was identified as another probable contamination risk. The risk is likely to occur through holes, cracks and crevices in the roof ceiling panels or walls; poor sealing below doors and poorly fixed fixtures such as light panels, roof panels, conduits, windows and so on. The faults can result due to poor facility maintenance and poor fitting during installation.

Wrong airflow pattern may occur between subsequent rooms or between rooms and corridor. The effect could lead to loss of Laminar Air Flow (LAF) for equipment such as sampling booth and dispensing booth. Wrong airflow pattern may be caused by wrong engineering design of HVAC system, clogged air filters, either too high or too low air velocities, poorly controlled AHU and so on. Correct air flow pattern provides confidence that there is no cross contamination from one area to another.

3.2 Assessment of Contamination Risks.

Analysis of the identified risks was done using a 5-point scale for likelihood of occurrence, ease of detection and severity of the contamination risk. The interpretation of the parameters in a scale of 1-5 is tabulated in table 3.3 and the result of risk assessment is in table 3.4 below.

Table 3.3: Risk Measurement

Likelihood of Occurrence		Ease of Detection		Severity of Contamination	
Score	Description	Score	Description	Score	Description
1	Very Low	1	Definitely detected	1	Negligible
2	Low	2	Highly detectable	2	Marginal
3	Moderate	3	Mean chance of detection	3	Moderate
4	High	4	Low chance of detection	4	Critical
5	Very High	5	Very Low chance of detection	5	Very Critical

Source: Author (2024)

The scales in table 3.3 above were used by the CFT to assess the three parameters of each risk with the results tabulated in table 3.4 below. The RPN was calculated by multiplying the likelihood of occurrence by ease of detection by severity of risk. The risks were then categorized into three bands using the RPN.

RPN <20 – Minor, a bit safe, might not affect process.

RPN ≥20 ≤40 – Major, not safe, requires monitoring.

RPN >40 - Critical, requires corrective actions and monitoring.

Table 3.4: Summary of Risk Assessment

Contamination Risk	Likelihood of Occurrence	Ease of Detection	Severity of Contamination	RPN
Exposure of Product Pathway	3	5	5	75
Poor regulation of AHU	4	3	5	60
Air leakage into classified areas	3	3	5	45
Wrong air flow patters	3	3	5	45
Mechanical damage of HEPA Filters	2	4	5	40
Poorly installed HEPA Filters	2	4	5	40
Contaminated PPEs and Tools	2	3	5	30

Fig. 3.3: Contamination Risk Ranking

4. Discussion

The objective of running an aseptic manufacturing process is to prevent microbial ingress. Engineering related contamination risks must be monitored and controlled through a contamination control strategy with focus on both control and monitoring (Sandle, 2017). Engineering design plays a key role in specifying a robust HVAC design which will fuse high efficiency performance and contamination control features.

Contamination risks due to exposure of product pathway during maintenance was found to be critically high with a RPN of 75. This is because the risk is not easy to detect and has severe effects. The contaminants introduced along the product pathway are likely raise product bioburden which might lead to sterility test failure of the finished product. Maintenance should not be done when there is a product inside manufacturing vessels or piping. Opening of pipe fittings and exchange of spares should be done aseptically followed by CIP/SIP or sanitization. Introduction of new parts and piping through welding should be followed by passivation.

Contamination risk due to poor regulation of AHU was found to be very critical with a RPN of 60. Poorly regulated AHU would likely lead to wrong ACPH, inability to control room differential pressure and temperature. This was attributed to high likelihood of occurrence and high severity. The fault is corrected by first ascertaining and adjusting air velocity to match requirement then carrying out pressure balancing by adjusting AHU dampers or air riser shutters to meet the required room/corridor pressure. A sustainable solution would involve installing a locking mechanism for damper handles to avoid unintended adjustments.

Contamination risk due to wrong airflow patterns was categorized as a major risk with a RPN of 45. The risk has a high severity of 5, low likelihood of occurrence and difficulty in detection because proper detection is only possible through a fog test. Fog is generated using poly glycol and purified water in a fog generator fitted with a filter. The pattern of fog movement from the generator nozzle to the return air riser is observed then recorded in a video to act as evidence of the air flow direction.

Contamination risk due to external air leakage was found to be a major with a RPN of 45 attributed to its high severity, low likelihood of occurrence because of scheduled facility maintenance and easier detection through Pressure Differentials and Non-Viable Particle Count. Correction is done by identifying and sealing air leakages. After correction, a non-viable particle count test and pressure differential monitoring should be carried out.

Contamination risks due to mechanical damage of HEPA filters was found to be major with a RPN of 40. This is because of its difficulty in detection and high severity. To verify the condition of the HEPA filters, a HEPA filter integrity test is done using an aerosol generator and aerosol photometer. An aerosol PAO (Poly Alpha Olefin) is introduced on the upstream at a pressure of $2Kg/cm^2$. PAO is recommended as a challenge agent because it generates aerosol size of 0.1- 1.0μm (Mondal 2022). An Aerosol Photometer is then used to detect penetration of PAO at the downstream. Max penetration of 0.01% is allowed beyond which the HEPA filter is considered unfit for use. After correction, verification of air velocity using a digital anemometer and pressure balancing of the AHU dampers should be done. A viable particle count test should then be carried out to ascertain the room conditions.

Contamination risk due to contaminated PPEs and tools was found to be major with a RPN of 30. This is based on the nature of work Engineering personnel carry out and the access they have to different stations with different processes. Engineering personnel working in classified rooms must always put on a sterile gown, gloves, and booties. To prevent cross – contamination and reduce likelihood of occurrence, engineering personnel should change into clean sterilized gowns every time they visit the clean rooms. Torn and contaminated gowns and gloves should be changed immediately. Additional measures may involve installing an air shower for personnel to pass through for decontamination when they access the clean manufacturing area or move from one room to another. Shared engineering tools should ne decontaminated by wiping with isopropyl alcohol (IPA) before transfer from one station to another.

5. Conclusion

The FMEA method provided a reliable mode of identification and analysis of contamination risks which engineering personnel can directly mitigate. All identified risks were either major or critical with severe effects. Exposure of product pathway was found to be the most critical risk followed by poor regulation of AHU, wrong airflow pattern and external air leakage respectively. Poorly installed HEPA filters, mechanical damage of HEPA filters and contaminated PPEs & tools were also observed to be major risks but of lower ranking.

Effective engineering design, maintenance and monitoring of manufacturing facilities and equipment are engineering practices which must be executed with contamination control in mind. Effective monitoring of HVAC system performance requires knowledge of the system and having requisite equipment to carry out air velocity test, pressure balancing, viable particle count, HEPA filters leak test, fog test and recovery tests.

Proper personnel hygiene and conduct coupled with a good understanding of sterile manufacturing principles are part of pharmacovigilance principles which must be practiced retain product quality and efficacy. An efficient HVAC system plays a critical part in aseptic manufacturing therefore, HVAC system is recommended for annual revalidation or when need arises. Performance monitoring using robust and modern monitoring systems such as Building Management System (BMS) and Environmental Management System (EMS) is most effective. The systems feature an alarm system, frequency drives to adjust air velocity based on need, real-time temperature and humidity measurement, generation of performance reports and so on.

The study was restricted to experimental observations and use of CFT opinions in an FMEA model for engineering related contaminants only, further research can be carried out with a broad population and other data collection methods. Other contaminants not related to engineering processes can also be analyzed. Further research can also be done on non-sterile manufacturing firms, health facilities and health related research institutions.

The study revealed that contamination is very critical and can lead to severe impact on public health if not monitored. The paper serves as a best practice guide to pharmaceutical product manufacturers to focus on quality of the products by investing in effective pharmaceutical manufacturing plants. The study also serves as a reminder to engineers on the part that engineering design, maintenance, and monitoring plays in building quality into a pharmaceutical product.

Kenya majorly depends on importation of Pharmaceutical Products. Promotion of local manufacturing of high-quality products in Kenya will address the need of provision of high quality and affordable healthcare to the public.

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Fuzzy Logic Predictive Model for Early Diagnosis and Prognosis of Breast and Prostate Cancer

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1. Introduction

Breast and prostate cancers are among the most prevalent and impactful menaces worldwide. Early diagnosis and accurate prognosis are crucial for effective treatment and improved survival rates [1]. Traditional diagnostic methods and statistical models have limitations in handling the complexity and uncertainty inherent in medical data [2]. Fuzzy logic, which allows modelling of imprecise and ambiguous information, offers a promising approach to enhance diagnostic and prognostic accuracy.

Breast cancer is the most frequently diagnosed cancer among women, with over 2.3 million new cases and 685,000 deaths reported globally in 2020 [3]. Prostate cancer in the other hand is common cancer in men, with an estimated 1.4 million new cases and 375,000 deaths in the same year [4].

Traditional methods for diagnosing breast and prostate cancer include imaging techniques, laboratory tests, and biopsies. Mammography is the primary screening tool for breast cancer, with high sensitivity but also a notable rate of false positives and negatives [5]. Prostate-specific antigen (PSA) testing and digital rectal examinations (DRE) are standard for prostate cancer screening, but they too have limitations in specificity and sensitivity [6].

Accurately predicting the prognosis of breast and prostate cancer patients involves evaluating various clinical and pathological factors. For breast cancer, factors such as tumor size, lymph node involvement and hormone receptor status are critical. Prostate cancer prognosis depends on PSA levels, Gleason score, tumor stage, and patient age [7]. Despite the availability of these factors, existing statistical models often struggle with the inherent complexity and variability of cancer progression.

Artificial intelligence (AI) techniques have shown promise in enhancing cancer diagnostics and prognostics. Methods such as logistic regression, decision trees, and neural networks have been applied to predict cancer outcomes with varying degrees of success [8]. However, these methods are limited by their "black-box" nature, which reduces interpretability and clinical acceptance.

Fuzzy logic is a mathematical framework for dealing with uncertainty and imprecision which makes it suitable for modelling complex systems [9]. Advantages of Fuzzy Logic in Oncology includes handling Uncertainty and variability inherent in medical data for accurate and reliable predictions [10]. Fuzzy logic models can incorporate clinical expertise through the creation of intuitive "if-then" rules, enhancing their interpretability and acceptance among clinicians [11]. Fuzzy systems can be easily updated as new medical knowledge and data become available, ensuring that they remain relevant and accurate over time [10].

Fuzzy logic has been applied successfully in various medical domains, including diagnostics, treatment planning, and decision support systems [12], [13], [11].

Despite advancements in medical technology, early detection and prognosis prediction of breast and prostate cancers remain challenging. There is a need for more reliable, interpretable, and adaptive models that can integrate diverse clinical parameters and expert knowledge.

Fuzzy logic models have shown potential in cancer diagnostics and prognostics. For breast cancer, fuzzy logic has been used to interpret mammographic findings, integrating parameters like mass shape, margins, and density to improve diagnostic accuracy [14]. In prostate cancer, fuzzy models have been applied to PSA levels, biopsy results, and MRI findings to enhance the prediction of cancer presence and progression [15]. These studies highlight the ability of fuzzy logic to synthesize diverse clinical inputs into a coherent diagnostic or prognostic assessment.

Integrating fuzzy logic models into clinical decision support systems (CDSS) can provide clinicians with valuable tools for early diagnosis and prognosis prediction. CDSS equipped with fuzzy logic can offer interpretable, rule-based recommendations that align with clinical reasoning, facilitating better patient management.

2. Methods and Materials.

This section outlines steps for developing and validating fuzzy logic predictive models for the early diagnosis and prognosis prediction of breast and prostate cancer. The process includes model design, development and validation.

Fuzzy logic system consists of four main components: fuzzification, rule base, inference engine and defuzzification. The general structure of the fuzzy rule-based system is illustrated in Fig.1. The fuzzification block takes specific, real-world inputs and transforms them into fuzzy sets. In this process, a single precise value is converted into a spectrum of possible values, each with varying degrees of membership in predefined fuzzy categories. The fuzzy inference engine is the heart of the system, applying logical rules to the fuzzified inputs to make decisions. Using IF-THEN rules, it processes these fuzzy inputs to generate corresponding fuzzy outputs. It contains the expert knowledge that drives the system's behavior. The database stores membership functions and other key parameters necessary for the fuzzy logic system to function. These membership functions are applied during both the fuzzification and defuzzification stages. Once the fuzzy inference engine generates fuzzy outputs, the defuzzification block converts them back into precise values. This step is essential since real-world applications require exact outputs. The input refers to the specific, real-world data that the fuzzy system processes, while the output is the final, crisp result of the process.

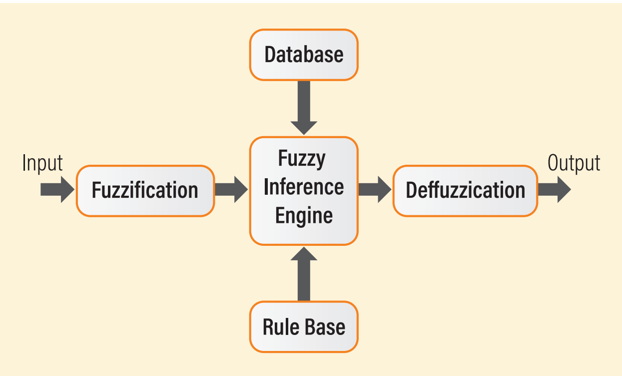

Fig. 1. General structure of fuzzy rule-based system

This approach was employed in associating inputs with relevant outputs in the context of cancer risks. The formula used in the Mamdani fuzzy inference system during the defuzzification step, is represented by the Centroid of Area (COA) that computes the crisp output from the aggregated fuzzy set:

$$y_{crisp} = \frac{\int y.\mu B_{agg}(y)dy}{\int \mu B_{agg}(y)dy}$$

where

y_{crisp} = Variable representing the output

Numerator $\int y.\mu B_{agg}(y)dy$ represents the weighted sum of the output values.

Denominator $\int \mu B_{agg}(y)dy$ represents the total area under the aggregated membership function.

The formula calculates area under aggregated fuzzy set, providing a crisp, single-valued output that reflects the overall inference of the fuzzy system. Clinical experts were used to developed set of if-then 15 rules for prostate and 36 rules for breast cancer. Sample rules are given next:

"IF Tumor Size is T2 AND Lymph Node is Level 2 AND Hormone Receptor is PR Positive THEN Cancer Risk is **High**".

"IF PSA is High AND Gleason is Grade 4-5 AND Tumor Stage is Stage 3 AND Age is Middle-Aged THEN Cancer Risk is **High".**

Using Kaggle datasets, specifically the Breast Cancer Wisconsin Dataset that Includes features such as tumor size, shape, and other clinical measurements and Prostate Cancer Data with patient-specific details like PSA levels, Gleason scores, and other relevant features for predicting prostate cancer. Quantitative analysis was performed to evaluate the model's accuracy and determine the impact of individual features on cancer risk using a sample dataset of 1000 patients.

Figure 2 shows the fuzzy logic model used to predict cancer risk based on several important health indicators. Mamdani fuzzy inference engine was used because of its ability to handle complex, multi-dimensional problems with interpretability and transparency essential in the medical field. Its capacity to provide fuzzy outputs also better aligns with the uncertainty inherent in predicting diseases like cancer.

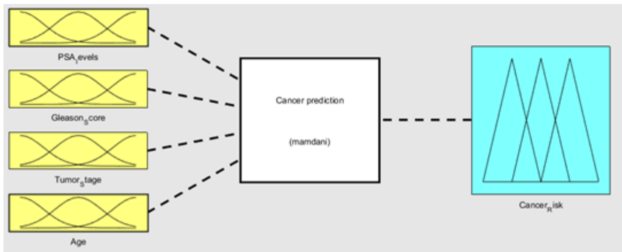

Fig.2. Mamdani fuzzy inference engine.

Input/output Variables and Membership Functions for prostate cancer are shown in Table 1 and Table 2 shows Membership functions and linguistic terms for prostate cancer.

Table 1. Membership functions and linguistic terms for prostate cancer

Variables	Categories	Parameters
PSA levels (ng/mL)	Low :0-2.5	[-5.4 -0.6 1.896 2.5]
	Moderate 2.5-4.0	[1.279 2.409 4.242 4.0]
	High 4.0-10.0	[2.66 4.92 8.054 10]
	Very high >10	[6.962 9.89 12.3 16]
Gleason Score	Grade 1: cells look similar to normal cells	[-2 0 2]
	Grade 2-4: cells look less like normal cells	[0.7 1.579 3.37 4.54]
	Grade 5: cells look very abnormal.	[3.019 5.019 7.019]
Tumor Stage	Stage 0: precancerous change	[-1.992 0.01303 1.208]
	Stage 1: small tumor hasn't spread	[0.118 1.007 2.33]
	Stage 2-3: tumor grown outside the original organ	[1.425 1.92 2.85 3.29]
	Stage 4: metastatic	[2.761 3.952 4.972 7.632]
Age	Young: <40 years	[-36 -4 28.6 40.0]
	Middle aged: 40-69 years	[14 39.4 68.8 91.44]
	Older: > 70 years	[64.2 80.66 104 136]

Variables	Categories	Parameters
Cancer Risk	Low risk	[-0.348 0.00347 0.0783 0.27]
	Moderate risk	[0.1 0.321 0.496]
	High risk	[0.371 0.537 0.7783]
	Very high risk	[0.68 0.769 1.01 1.19]

Table 2. Membership functions and linguistic terms for breast cancer

Variables	Categories	Parameters
Tumor size	T1-less than 2cm	[-5.4 -0.6 1.896 2.5]
	T2-2-4 cm	[1.279 2.409 4.242 4.0]
	T3- greater than 5cm	[2.66 4.92 8.054 10]
	T4-spread into the chest wall or skin	[6.962 9.89 12.3 16]
Lymph node involvement	Level 1 lateral to the pectoralis major	[-2 0 2]
	Level 2 – Posterior to the pectoralis major.	[0.7 1.579 3.37 4.54]
	Level 3- Medial to the pectoralis	[3.019 5.019 7.019]
Hormone receptor status	ER positive: Estrogen receptor positive	[-1.992 0.01303 1.208]
	PR positive: progesterone receptor positive	[0.118 1.007 2.33]
	HER2 positive: Human epidermal growth factor receptor 2-positive	[0.6 1 1.4]

Variables	Categories	Parameters
Cancer risk	Low risk	[-0.348 0.00347 0.0783 0.27]
	Moderate risk	[0.1 0.321 0.496]
	High risk	[0.371 0.537 0.7783]
	Cancer Risk	[0.68 0.769 1.01 1.19]

3. Results

In this section, we present the outcomes of applying the proposed fuzzy logic model for cancer prediction. The model was developed to handle the inherent uncertainty and imprecision in medical data, providing a robust framework for early cancer diagnosis. Through the integration of clinical parameters and fuzzy inference systems, the model demonstrated its ability to predict cancer risk with high accuracy. The results are assessed in terms of key performance metrics, including sensitivity, specificity, and overall prediction accuracy. Additionally, we compare the model's predictions with actual clinical diagnoses to evaluate its effectiveness in real-world scenarios. The Rule Viewer in fuzzy logic was used to visually examine the system and interact with the fuzzy inference system (FIS) by showing how the inputs, rules, and outputs are related. It helps in understanding the effect of different input variables on the output and how the fuzzy rules are applied.

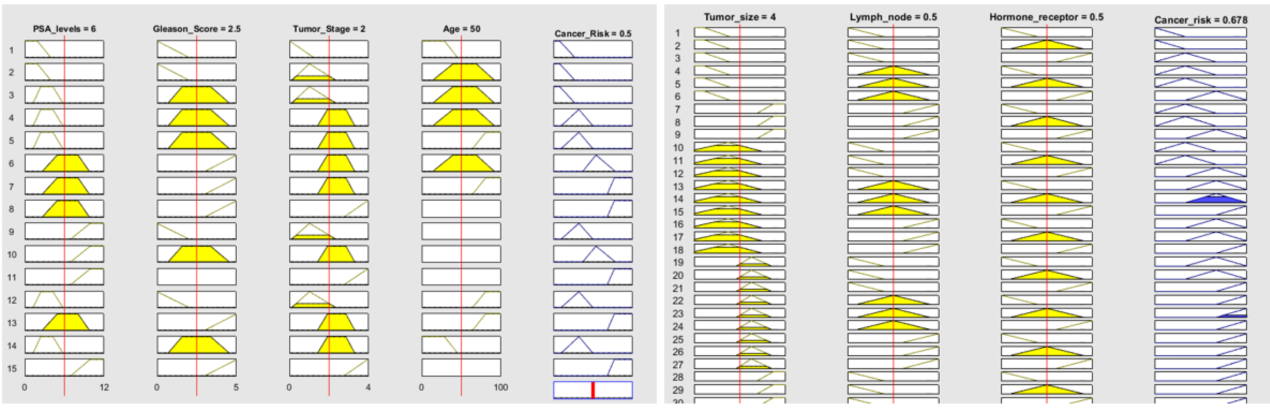

Fig. 3. MATLAB Rule viewer for prostate and breast cancer

The Rule Viewer shown in figure 3 was used in MATLAB for cancer prediction to interpret, visualize, and tune fuzzy logic rules that handle the inherent uncertainty in medical data. It aided in making the predictive model more transparent and understandable, which is crucial for clinical applications for trust and decision-making.

Confusion matrix displayed in table 3 was used to compute Accuracy, precision, sensitivity, specificity, and the F1 score using a dataset of 1000 patients.

Table 3. Confusion matrix.

	Predicted positive	Predicted negative
Actual Positive	True positive (TP)- 450	False Negative (FN)-80
Actual negative	False positive (FP)-70	True Negative (TN)-400

The 3D surface plots provided insights into how different clinical variables interacted to impact cancer risk. Figure 4 shows a sample analysis based on interactions between key variables:

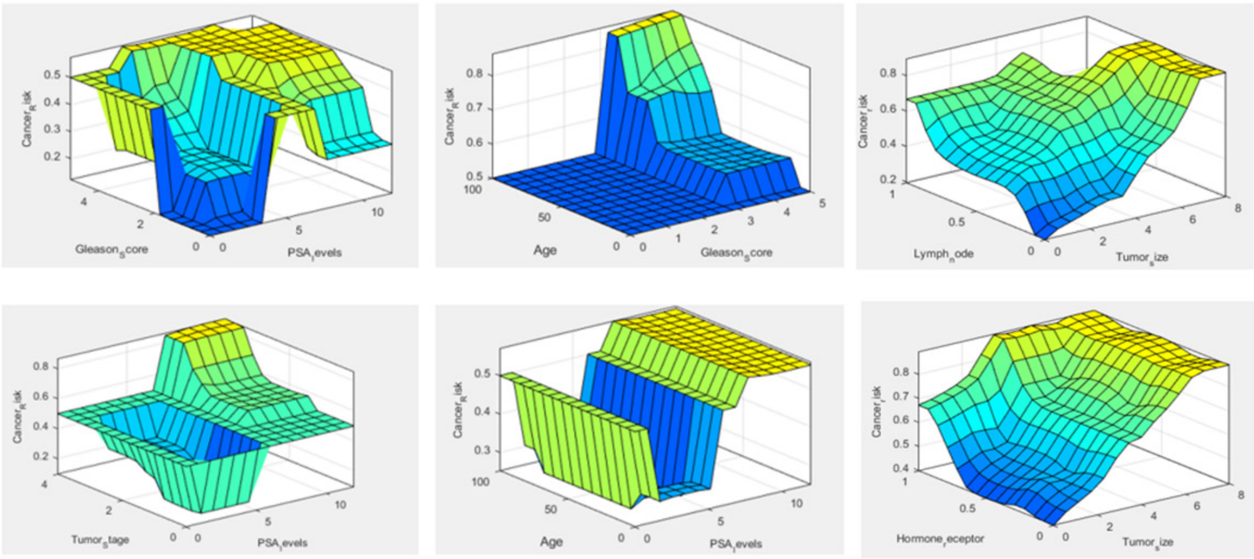

Fig. 4. Surface view of cancer predictions

It can be concluded that Patients with a Gleason score greater than 4 and PSA levels above 5 ng/mL had a cancer risk, significantly higher than those with lower Gleason scores and PSA levels. Patients aged above 65, a PSA level above 6 ng/mL result in a higher cancer risk, compared to patients under 50, where the cancer risk was approximately less for the same PSA level. The model indicated a sharp increase in cancer risk after age 60, with a rise in risk for patients with elevated PSA.

Tumor larger than 5 cm in size combined with lymph node involvement were associated with a cancer risk. For tumor smaller than 2 cm, the risk was significantly lower, regardless of lymph node involvement. Hormone receptor-positive tumor larger than 4 cm had a cancer risk probability of 65%. In hormone receptor-negative cases, the risk was lower for the same tumor size.

The Model was compared with Baseline Algorithms to validate the robustness of the developed cancer prediction model using the same dataset.

Table 4 Model comparison

Algorithm	Accuracy	F1-Score
Fuzzy Logic	85%	85.6%
Logistic Regression	81.3%	83.5%
Support Vector Machine (SVM)	82.7%	84.1%
K-Nearest Neighbors (KNN)	80.5%	81.2%

The analysis of Table 4 indicates that Fuzzy Logic model outperforms the other algorithms in both accuracy and F1-Score, making it the best-suited model for cancer prediction in this scenario. Its ability to handle uncertainty and imprecision in the data makes it particularly valuable in medical applications. While SVM and Logistic Regression also offer competitive performance, KNN appears to be the least effective for this task, likely due to its sensitivity to data variability. To ensure model's generalizability, 10-fold cross-validation was performed and the model maintained consistent performance across all folds: Average Accuracy: 84.5%, Standard Deviation: 1.2%, Cross-Validation F1-Score: 85.1%. This shows that the model is stable and less likely to overfit to the training data.

4. Discussion

In this study, we developed a machine learning model to predict cancer risk using Breast Cancer Wisconsin Dataset and Prostate Cancer Data from Kaggle, achieving an accuracy of 85%. Key features such as PSA levels, Gleason score, and tumor size were identified as significant predictors of cancer risk, aligning with established clinical knowledge. However, the study's limitations include the relatively small and homogeneous dataset of 1000 patients, which may not generalize well to broader populations.

5. Conclusions

The cancer prediction model demonstrates strong performance in assessing cancer risk using clinical and demographic data. Having a precision of 86.5% and recall of 84.9%, the model effectively identifies true cancer cases while minimizing false positives and negatives. However, deploying this model in clinical environments requires thorough validation, continuous refinement, and strict adherence to ethical guidelines to ensure reliability. Although the initial results are promising, larger and more diverse datasets are needed to improve its generalizability across various populations. Incorporating additional data types, such as genomic and imaging data, would further enhance the model's clinical relevance. Through these improvements and comprehensive validation, the model could significantly enhance early cancer detection and provide more accurate risk assessments in healthcare. Future developments should focus on integrating fuzzy logic with machine learning techniques to boost accuracy and expanding its application to other medical domains, such as cardiovascular and neurological diseases, where early diagnosis faces similar uncertainties.

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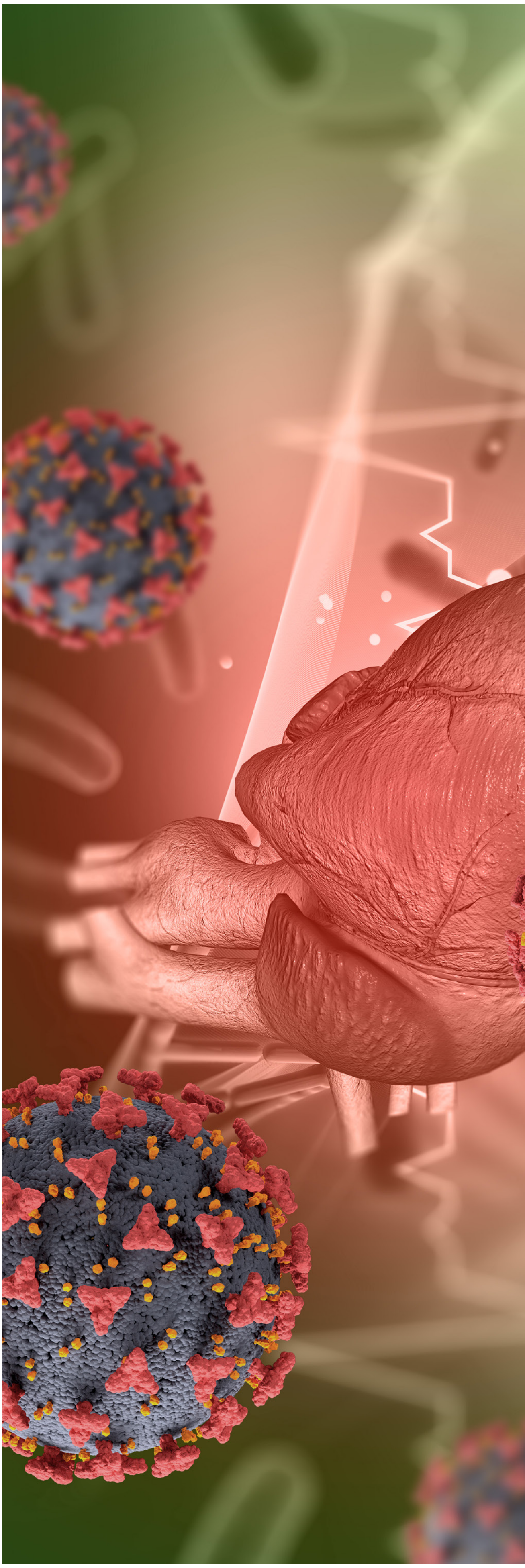

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IEK Stakeholders dinner
[From left: Eng. John Nyaguti, IEK Council Member; Eng. Erick Ohaga, Immediate Past President, IEK; Eng. Shammah Kiteme, President, IEK; H.E. Dr. Irungu Kang'ata, Governor, Murang'a County; Eng. Christine Ogut, 2nd Vice President, IEK; Eng. Jacton Mwembe, Hon. Secretary, IEK; Eng. Harrison Keter, 1st Vice President, IEK; Eng. Florah Kamanja, IEK Council Member; Eng. Albrian Maondu, IEK Council Member; Eng. Jennifer Korir, Hon. Treasurer, IEK; Eng. Lilian Kilatya, IEK Council Member; and Eng. Cedric Obonyo, IEK Council Member.]

IEK Stakeholders dinner
The IEK & the Institution of Civil Engineers (ICE) sign an MoU to strengthen global engineering collaborations, a major step forward for capacity building and knowledge exchange. Guillaume Patricot, ICE Representative in Kenya, and IEK President Eng. Shammah Kiteme signed the agreement.

International Women's Day Dinner
From Left: Eng. Dr. Damaris Oyaro - IEK Capital Branch Chair; Eng. Jennifer Gache - Chair of Women Engineers Committee; Eng. Margaret Ogai - Registrar/CEO EBK; Eng. Christine Ogut - 2nd VP of IEK; Hon. Martha Karua EGH SC - PLP Party, Eng. Annette Ingaiza - Chair of the Future Leaders Committee, Eng. Harrison Keter - 1st VP of IEK and Eng. Jane Mutulili - Chair of ACEK

Nairobi City County Engagement with various professional bodies in the built environment sector

Artificial Intelligence (AI) Training for Engineers Programme in Action

Artificial Intelligence (AI) Training for Engineers Programme

IEK signs MoU with the Chartered Institute of Arbitrators (CIArb) Kenya Branch

Evaluation of Effluent Quality Trend Before and After Filtration Through the Composite Filter from Shirere Waste-Water Treatment Plant upto River Isiukhu, in Kakamega County, Kenya

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I. INTRODUCTION

Water quality is essential for social economic development, environmental sustainability and human health. Due to the high population density, particularly in Africa, pollution exposure projected in low and middle-income nations has increased (Boretti, & Rosa, 2019). A number of parameters such as , temperature, electrical conductivity, total dissolved solids (TDS), anions fluorides, sulfates, phosphates, nitrates, chlorides, carbonates, and bicarbonates in river waters, are used in evaluating water quality, (Chebet et al., 2020). Athi River, for example, supports millions of people along the 390-kilometer channel and it is polluted by high levels of cyanobacterial (Takawira, 2021). These effluents come from Nairobi River which is a tributary of Athi river.

During the rainy season, the water in the latter often turns brown in color due to surface run off. It later becomes greenish over a period of time as a result of cyanobacteria algae formation on the water surface. According to the World Health Organization (WHO, 2005), some cyanobacteria species produce toxins that harm both animals and humans. In a similar scenario, the sources of water in Kakamega Town and its vicinity are River Isiukhu and River Yala. Its' old water intake was built in 1956 while the current intake in 1992. These collect water from River Isiukhu at Savona while River Yala waters is abstracted at Tindinyo as reflected in Nzoia Cluster Two Assessment (WHO, 2005). The average production of water from these sources' accounts for 44% of the total demand and estimated to be 8696 m3/day against an average daily consumption of 12,796 m^3/day. To bridge the short fall, most business owners have sunk shallow wells. However, majority of people in slum dwellings within Kakamega collect water from unguarded springs polluted by pit latrines and some utilize ' roof catchment and tanks to collect rainwater from their rooftops for domestic use.

Water quality in Kakamega Town, like in other urban areas, is affected by poor municipal solid waste disposal management systems. Other than stand-alone septic tanks for domestic wastes in residential areas, the rest of the town is served by Kakamega County sewerage network. Wastes from the sewerage end up into the Shirere Waste Water Treatment Plant and eventually into River Isiukhu. Other treatment plants in the town include Kambi Somali Treatment Works and MMUST Treatment Works. The study site was Shirere Waste Water Treatment Plant (WWTP) which was identified with poor filtration efficiency. Various techniques have been examined for wastewater treatment. Examples include electro chemical processes, aerobic biodegradation, flocculation, adsorption, and froth floatation. However, majority of these have had to be combined so as to overcome shortcomings, and others include photo-electro-Fenton, electro-Fenton and electrooxidation (Natarajan et al., 2018). Even then, the desire for identifying potentially efficient, low-cost and locally available filter media as an adsorbent has been considered critical for sustainable environmental management (Aregu et al., 2018). Thus, a number of naturally occurring adsorbents like pumice, sand scoria and different biochar materials, vermin-filtration methods have been adopted.

The 2019 population census of Kenya, indicated that 31% of the population live in urban areas, (KNBS, 2020). Increasing number of populations into towns without equivalent planned urban infrastructure has resulted into allot of environmental problems which are increased by the inability of urban authorities to manage large quantities of generated wastewater (Ogara, 2019). These Urban areas have faced challenges emanating from inadequate resources, poor infrastructure and defective cleanup technologies (Koop, & Leeuwe., 2017). Other challenges included lack of effluent quality monitoring procedures at wastewater treatment plants. Residents of Kakamega town, like their counterparts in other urban areas, face the risk of contracting diseases as a result of inefficient sewerage systems

(Okari, 2019). Current practices such as onsite treatment, offsite treatment, conventional treatment and stabilization ponds for water and wastewater treatment in urban areas are insufficient (Wang et al., 2014).Septic tank and soak pit waste management are examples of onsite wastewater treatments (Judith. ,et al.,2010).

The simplicity and low cost of stabilization ponds have made them an attractive proposition in both developed and developing countries. However, some of the problems of stabilization ponds are poor design, poor maintenance and overloading of ponds hence producing poor quality of effluents. Poor design emanates from either omission of an aerobic pond or non-alignment of facultative, aerobic or maturation ponds in series. The omission of aerobic ponds result into release of BOD and COD. Poor maintenance includes non-replacement of concrete side and bed slabs, removal of sludge from embankments and screen repairs that often leads to side and underground seepage. Hydraulic overloading caused by excess flow from the sewer piping system due to over population and open manholes. (Duncan,1987). Additionally, they all lack affordable infrastructure that can be adopted to effectively lower concentrations of effluent discharged from the treatment ponds into water bodies.

Efforts have been made to improve the quality of wastewater discharged into water bodies. Examples include a study by Aregu et al., (2018), in which a vertical filtration infrastructure was adopted. The orientation was such that the effluent flowed into two reactors from top to bottom. One reactor had pumice granules and the other with scoria granules. They found that pumice removal of BOD was more efficient than scoria and vice versa to COD. However, this was not a field-based activity. In another laboratory-based study by Hannandeh et al., (2017) a vertical composite filter comprising of biochar and sand in a column of 150mm high as filter media was adopted. The removal efficiency ranged between 50.6% to 87.5% depending on the experimental parameter under investigation. The flow of effluent was from top to bottom with high hydraulic transient. Philiphi et al., (2021) also used a vertical column of filters composed of sand and pumice for removal of phosphates under top to bottom flow by gravity. However, both natural flow of wastewater discharges and the infrastructural orientation of wastewater course-way into streams hamper the adoption of vertical filtration technologies.

The current study adopted and incorporated a horizontal flow-based reactor of pumice and sand composite filter in the exit of the maturation pond at Shirere Wastewater Treatment Plant. This was to mitigate on the inadequate removal of waste from effluents. The filter materials consisted of granular sand and pumice stone at depths of 200 mm, 400 mm and 600 mm. These depths were identified using a scientific criterion (French, 2012 formula). These depths were using granular filter media bed depth (L) to grain size (D) ratio, optimum range of 1000-1200 (French, 2012). The effluent entered in a lateral manner by gravity through perforations in the front screen. It was controlled by the principle of differentials in hydraulic heads of effluents before and after filtration. Naturally, waste materials get adsorbed onto the composite materials as it passed through the filter.

II. LITERATURE REVIEW

The world is facing wastewater management issues as a result of increasing industrialization and increased population density. The United States Environmental Protection Agency (EPA) estimated that over 850 gallons of untreated waste go into aquatic bodies each year, (Biswas et al., 2013). These untreated or inadequately treated wastewater effluent contains a number of compounds that are hazardous to plants and animals. These compounds are classified as chemicals of emerging concerns (CECs), persistent organic pollutants (POPS), and polyaromatic hydrocarbons (PAHs) among others. Since the inception of the Stockholm Convention in 2004 the assessment of risks associated with brominated diphenyl ethers and perfluorinated alkyl acids and associated compounds in waste waters has been intensified.

Previous researchers such as Mwamburi, (2018) and Gawlik et al., (2009), carried research on pollution of natural water bodies and found high levels of contaminants. Common persistent organic pollutants (POPs) found in Africa include aldrin, chlordane, chlordecone, DDT, dieldrin, endrin, endosulfan, HBCDD, HCB, HCHs, heptachlor, hexabromobiphenyl, mirex, PBDEs, PCBs, PCDDs, PCDFs, PeCB, PFOA, and PFOS. Their distribution is shown in Figure 1 below.

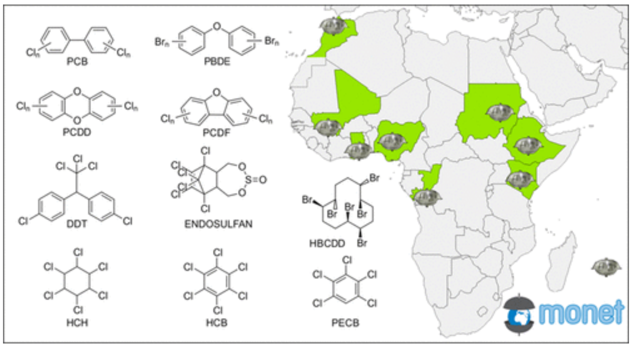

Figure 1: Persistent organic pollutants commonly found in Africa

Source; Adopted from, (Weichen Liao et. al., 2021).

These compounds which include pesticides, pharmaceuticals and personal care products (PPCPs) amongst other industrial and domestic wastes have the ability to bio accumulate and biomagnifies in the different trophic levels, thus causing both acute and chronic toxicity in the different organisms.

Heavy metal contamination in sediments has been noted to affect the quality of water bodies (Khan et al., 2022). Other inorganic pollutants of similar nature include nitrates, phosphates amongst others (Moazzem, et al., 2018). These inorganic pollutants may affect the body by affecting hemoglobin levels, damage both kidney and liver, nerve system and can cause cancer (Verma, & Dweivedi, 2013). Consequently, discharge of poorly treated effluent into rivers like River Isiukhu could result in contamination of its waters.

Filters for wastewater vary from system to system. This is due to variety of reasons, including conditions of the water entering the system and desired purity of the filtered water. Amongst these, there are; particle and membrane forms of filtration used in wastewater treatment plants (WWTPs) of which, particle filtration is mostly used. Membrane technology used for removing solids in wastewater treatment is usually based on ultra-filtration or microfiltration. The membranes can be introduced into the biological wastewater treatment process either as separate unit operation downstream of the biological step, or integrated into a biological process, (Judd Water, 2019). If the membranes are added as a separate unit operation, they are often referred to as polishing step and are usually based on the hollow fibre membrane configuration. According to Blšťáková et al., (2009), domestic wastewater treatment plant monitoring was performed at the municipal wastewater treatment plant and the Parallel operation of flat sheet and hollow fiber membrane modules showed effective removal of organic matter in effluent water quality.

Zahid and Saber, (2011), evaluated three different textile materials (Acrylate, Polyester, and Nylon) as filter media for Membrane Bioreactor (MBR) treating municipal wastewater. The actual hydraulic retention times were 8.6, 8.9 and 8.0 h in R1, R2 and R3. At 5.3–5.5 g/l mixed liquor suspended (MLSS) and 26.3 days solid retention time (SRT) the membrane bioreactors were effective in removing 93–95% of COD, 99% of total suspended solids (TSS) and turbidity, 89–94% of total kjeldahl nitrogen (TKN) and 90–96% of total ammonia nitrogen. Phosphorous removal was limited to 51–55% while faecal coliform was reduced by four logs.

Membrane bioreactors (MBR) is one of an emerging treatment technology applied to various types of wastewaters including municipal solid waste leachate, (Chiemchiasri et al., 2023). Solid waste leachate usually contains high organic matter, nutrients, inorganic salts, and toxic compounds with its characteristics highly varied. A combination of biological treatment and membrane filtration in membrane bioreactor makes this technology unique for the removals of organics, nutrients, and organic micro-pollutants containing in solid waste leachate.

Particle filtration is a system that uses physical or mechanical ways to separate particulates from liquids. Small scale wastewater treatment that produces less amount of solid wastes compared often employ bag filters. In this case, solid particles larger than one micron are retained in the bag while allowing water to pass through (Svarovsky, 2000). Filtration of particles smaller than micron is better achieved using cartridge in which solid particles, and microorganisms like bacteria and viruses are trapped within the particles as water flows out at the outlet end. Particle filtration has also seen the development of sand filters as natural materials for the treatment of wastewater (Racha et al., 2020). The efficiency of these processes depends among others on filter porosity, size and shape of filtration grains and fluid characteristics that often that often affect hydrodynamics and fixation rates of wastes on the granular materials used. Attempts have also been made to improve the granular filtration properties of sand by augmenting it with activated carbon, biochar and membranes.

Composites filters are blend of two or more different constituents that impart unique filtration characteristics that enable quality water to be improved. The desire to have cost-effective technologies for wastewater treatment has seen the development of a number of particles based natural composite filter materials. Examples include sand and pumice stone used as filtration media for rapid removal of turbidity. Variables investigated included component of filtration rate, bed depth, and particle size, (Farizoglu et al., 2013). Similarly, volcanic rocks of pumice and scoria have been used in lowering concentrations of BOD, COD, TSS, nitrates, phosphates, ammonia, sulphates and chromium, (Aregu et al., 2018). Furthermore, Hannadeh et al., (2017), using a vertical composite filter comprising biochar and at a depth of 150 mm was used in the removal of effluents and of BOD, COD, TSS, nitrates, phosphates filtrate quantities determined. Similarly, residual phosphates in filtrates were determined by Philiphi et al., (2021), using a vertical column filter of sand and pumice at 550mm depth.

There are three important design elements considered while designing wastewater granular filters. These filter elements were: Temporal loading, Hydraulic loading rate and the direction or method of delivery. The temporal loading, has three varieties which includes the intermittent, pulsed and continuous, while hydraulic loading rate contains, high rate, rapid rate, and slow rate. The direction or method of delivery includes two varieties of flow, trickling or downward flow, and pressure which is upward flow (Starke media, 2020). Filter media may consist of different grades of filter medium ranging from gravel to sand. Finer particles in a granular filter are more effective at filtration of wastewater and give better results (Starke media, 2020). According to Eliasson, (2002) the granular media must be coarse enough to permit a sufficient flow rate yet fine enough to provide adequate treatment. Media that is too coarse lowers the wastewater retention time to a point where treatment becomes inadequate. Media with small grain size slow the water movement and increase the chance of clogging.

Wastewater granular filters have a filtering medium consisting of silica, pumice, scoria, anthrocites, and gravel. Sand filters are commonly used everywhere as sand is easily available around the world. Fine sand of the lower layer requires very fine opening in the strainer and clogging problems might result. Design factors affecting performance or filters are; type of material, size of granular, depth of filter, flow rate and material combination. Number of suspended solids in the flow also affects the filter performance (Cleasby, 1974). Dual media filter has more advantage in improving filtrate quality. Dual media filter is known as composite filter.

Based on granular type design, Hamoda, Ghusian & Jasem (2004), conducted a study where laboratory experiments were carried out at room temperature (20–25 C) using four identical filter columns made of Plexiglas, each of 1 m height and 15 cm internal diameter, packed with granular media of 70 cm depth. Each filter was operated at a constant filtration rate; thus, four rates were tested in the range of 2–15 m3 m 2 d 1. Mono-media (sand) and dual-media (sand and anthracite) were tested and three types of municipal wastewaters, namely raw, primary and secondary-treated effluents were applied. The results obtained indicate that considerable improvements in effluent quality could be attained by tertiary sand filtration. The highest removal efficiency was obtained at low filtration rate of 2 m3 m 2 d 1, but higher filtration rates achieved acceptable removal efficiencies and provided effluents of good quality to satisfy the irrigation water quality standards.

According to Eliasson, (2002) the granular media must be coarse enough to permit a sufficient flow rate yet fine enough to provide adequate treatment. Media that is too coarse lowers the wastewater retention time to a point where treatment becomes inadequate. Media with small grain size slow the water movement and increase the chance of clogging. The effective size (D10) and uniformity coefficient (Uc) are the principal characteristics of granular media treatment systems. The ideal sand media for intermittent sand filters is a coarse sand with an effective size between 0.3 mm and 0.5 mm.

Sheikh et al., (2007) studied the impact of hydraulic loading rate on tertiary filtration of wastewater using a pilot-scale, dual-media, rapid depth filtration system of latex particles and spherical glass bead collectors. In their study, loading rates of 12.2, 15.3, 18.3, 21.4, and 24.4 m/h were tested on parallel filter columns treating the same coagulated secondary wastewater to determine the impact on removal of turbidity, particles (2–15 µm), total coliform bacteria, Escherichia coli, and MS2 bacteriophage, as well as on the particle deposition profile in the filter bed. The result revealed that Increasing the loading rate from 12.2 to 24.4 m/h decreased the removal efficiencies for all metrics.

Additionally, Sheikh et al., (2007), revealed that the impact of loading rate on particle removal was similar to the one predicted by a clean-bed filtration model, although the model significantly under estimated the removal efficiencies of the smaller particles. The results of their research indicated that loading rates higher than those typically used in tertiary filtration can produce acceptable effluent quality, and support a regulatory approach based on filter effluent turbidity.

Using different granular type design Grasset, (2011) evaluated granular media *filtration for the removal of a suite of chemical contaminants which are found in wastewater. Laboratory and pilot-scale sand and granular activated carbon (GAC) filters were trialed for their ability to remove atrazine, estrone (E1), 17*-ethynylestradiol (EE2), N-nitroso dimethylamine (NDMA), N-nitroso morpholine (NMOR) and N-nitrosodiethylamine (NDEA). Generally, sand filtration was ineffective in removing the contaminants from a tertiary treated wastewater, with the exception of E1 and EE2, where efficient removals were observed after approximately 150 d. Batch degradation experiments confirmed that the removal of E1 was through biological activity, with a pseudo-first-order degradation rate constant of 7.4 × 10−3 h−1. GAC filtration was initially able to effectively remove all contaminants; although removals decreased over time due to competition with other organics present in the water. The only exception was atrazine where removal remained consistently high throughout the experiment.

2.1 Methodologies in effluent parameters analysis

2.1.1 Biochemical Oxygen Demand (BOD)

BOD is currently measured using a standardized method known as the closed bottle, developed by (Jouanneau et al., 2014). International standards explain this (ISO 5815-1-2003). The test is based on microbiological samples collected from the environment in general, unknown microbial diversity, 105 cells/ml.) Allylthiourea Addition dilution and seeding technique (Kim et al., 2003). This takes 5 days to complete. The biggest downside of this strategy is the amount of time it takes to achieve (5 days), (Gram et al., 2002). Due to unpredictability, the approach does not perform well for most acceptable equipment for real-time environmental monitoring. Alternatives have been developed primarily to do a classified BOD analysis.

2.1.2 Chemical Oxygen Demand (COD)

Most COD tests currently employ potassium dichromate as an oxidant. Digestion is carried out on materials containing a predetermined amount of oxidants, sulfuric acid, and heat (150°C). Metals and salts are commonly used to decrease interference and catalyze digestion which takes two hours. The two most prevalent titration and colorimetric methods, (Han et al., 2021).

2.1.3 Total Suspended Solids (TSS)

The total solids portion is collected on a filter for TSS analysis. For the analysis, a man934-AH glass micro-fiber or its equivalent with a nominal pore size of 1.5 mm is often employed, and a pre-determined amount, typically 0.1 liter, is passed through the filter. Before the sample is filtered, the filter is weighed, and then it is dried at 103-1050 degrees Fahrenheit. The filtration process is best for samples containing roughly 200mg/L of clay-size particles. Evaporation as well as wet-sieving filtration are the other two ways (Kagey, 2019).

2.1.4 Nitrates

Methods used in nitrate analysis are four namely; Diphenylamine spot plate method (SPOT), Spectrophotometric plate method (SPEC), Nitrate-selective electrode method. (NSE) and High-performance liquid chromatographic method (Cathyl et al.,1995).

2.1.5 Phosphorous

Phosphorous is found in low absorptions in nature and is necessary for all life forms. It results from natural methods such as organic matter breakdown and rock weathering. Phosphorous levels indicate nutrient quality, organic enrichment, and the water body's overall health. Erosion, sewage or detergent discharge, urban runoff, including rural runoff comprising fertilizers, plants and animals' debris can all cause higher amounts. Problems including as algal blossoms, loss of species variety and increased weed growth can occur when concentrations are too high. Increased pH and turbidity are caused by abundant plant growth, such as algal blooms, as well as the generation of toxins and odor: growth of algal in streams can range from 0.01 to 0.1 mg/l (Total Phosphorous), 0.006 mg/l (Dissolved Reactive Phosphorous), and 0.001 mg/l (Aquatic Ecosystem Balance) (Dissolved Reactive Phosphorous).

2.6 Previous Studies on Wastewater Treatment Improvement

Pollution of river water by wastewater has the potential to have a severe negative impact on aquatic sustainability (Wang et al., 2021). Njunguna et al., (2017) conducted research on the quality of water in the Nairobi River, focusing on the presence of metals. They discovered that the amounts of lead, copper, zinc, and manganese in the water exceeded WHO and NEEMA guidelines. They also found that harmful levels of bacteria and E. coli use incredibly high. Pollution impacts on health of those who rely on Nairobi River for agriculture and consumption. Sample at Thwake River where Nairobi River flows found four of these metals and the water had concentration of sewage at 120 times higher than what is recommended. Dark green color in wastewater effluent indicates algae scum with high level of cyanobacteria. They further proposed Waste Water Treatment Plant to handle the waste produced in the county must be upgraded and expanded.

In previous literature, Geem et al., (2018) applied improved optimization through the use of analytic differentiation to find the crucial shortfall position of evolved oxygen gas for sewage treatment as well as reuse systems utilizing computational intelligence. The study developed an improved sewage water treatment as well as reuse optimization model that includes three options: filtration, nitrification, and redirected irrigation. The model developed could be compared to the current research in terms of prediction of several parameters.

Recent advances in water and wastewater treatment with a focus on membrane treatment Zoubouilis, & Katsoyiannis, (2018) classified published papers in major categories. That is, (a) Those that investigate the application of membrane treatment processes. (b) studies that investigate application of adsorptive processes for the removal contaminants from water or wastewater. (c) studies that include novel aspects of oxidative treatment such as bubbleless ozonation. Using vacuum membrane distillation and hollow fiber modules Suga et al., (2022) investigated the efficiency of a modified membrane method. Vacuum membrane distillation is a revolutionary membrane distillation technique that has the potential to be used for a variety of separations, including water desalination and bioethanol recovery.

III. RESEARCH METHODOLOGY

Sampling was done at Shirere WWTP, Shikoye stream and river Isiukhu. Shikoye stream receives wastewater discharged from Shirere WWTP. The research used a multiple design of experimental and socio-economic approaches. Scientific analysis involved sample collection, preparation and laboratory analysis to determine among others concentration of COD, BOD, phosphates, total suspended solids (TSS) and nitrates.

Control sample conditions included triplicates collected at sites S1-S7 using labeled 500 milliliters sampling bottles and kept in ice boxes. Briefly, samples were collected at the outlet of the maturation pond before filtration (S1) and along the streams and rivers labeled S3-S7. The above was repeated with experimental sample conditions collected after the introduction of sand-pumice composite filter within S1 that created a three section of S1 namely $S1_2$, Composite Filtering Unit (CFU) and S2. New Samples were therefore collected in $S1_2$, S2-S7. All samples were transported to the laboratory for further analysis. This was done during the dry season, wet season and short rain season.

3.1 Installed Composite granular filter in the reactor

The reactor was filled with composite granular filter made of heterogenous mixture of sand and pumice stone at levels 200 mm, 400 mm and 600 mm. The composite filtration unit (CFU) or reactor was installed at the exit manhole of maturation pond for filtration process where effluent entered through front screen plate by gravity, through the filter onto outlet notch as shown in figure 3.5 below. In related study (Aregu, 2018) schematic diagram showed a vertical orientation of effluent flow into the reactors from the top.

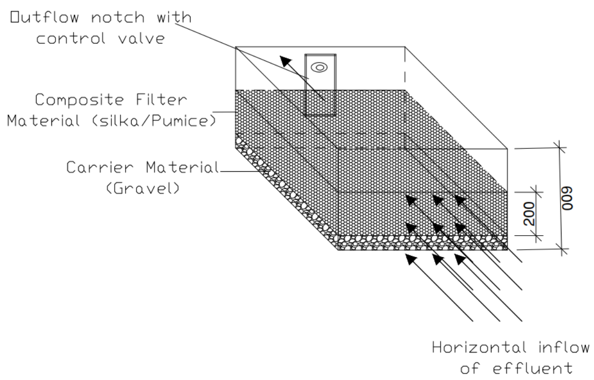

Figure 2: Installed Composite granular filter in the reactor with horizontal inflow and outflow of the effluent.

3.2 Effect of filter depth variation on the concentration of five parameters

The comparison of plots of depths against the concentrations of

BOD, COD, NO_3, PO_3, and TSS were carried out for the seasons namely March - May, June – August, and September – November 2021.

IV RESULTS AND DISCUSSIONS

The effect of the composite filter in reducing levels of wastes discharged from Shirere WWTP upto River Isiukhu via the Shikoye stream was evaluated. Concentration of COD, BOD, TSS, PO_3 and NO_3 was measured before and after installation of the composite filter at all sampling sites in all seasons at varying filter depths.

4.1 Evaluation of Chemical Oxygen Demand quality

Szabolcs (2014), proposed that the biodegradable COD in the influent wastewater consisted of two fractions which were readily (Ss) and slowly biodegradable COD (Xs). Figure 4.19 shows variation of the concentration of the COD with distance from the composite filter to River Isiukhu.

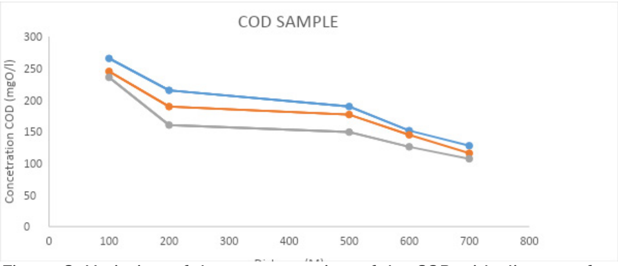

Figure 3: Variation of the concentration of the COD with distance from the composite filter to River Isiukhu at filter depths of 200 mm, 400 mm.600 mm and before filtration.

As shown in the figure above, chemical oxygen level before filter installation was 347.8 mgO/l at the outlet of the maturation pond to 172.5 mgO/l downstream of river Isiukhu. When the filter was installed at depth of 200 mm, the COD at outlet after filtration was 265.47 mgO/l up to 137.64mgO/l downstream. At 400 mm depth of the filter at the outlet was 244.97 mgO/l up to 115.4 mgO/l and 235.57 mgO/l at the outlet at 600 mm depth of the filter up to 107.16 mgO/l downstream. The filter at 600 mm depth reduced the COD level to almost NEMA standard of 100mgO/l. Thus, the study revealed that the filter had significant effect on COD reduction. Thus, this confirms that the composite filter installation had significant effect at 5% level on the trend of quality of the effluent discharged from Shirere WWTP into river Isiukhu. These results also confirmed that the discharge of effluent into Shikoye stream being well above the recommended level by NEMA (100 mgO/l) which possess a very high risk of 267.47 mgO/l to the community, animals and plants around the river. This implies that when high COD and BOD levels are dumped into a river, it accelerates bacterial growth and depletes oxygen levels in the river. Most fish and many aquatic insects perish if oxygen levels drop to dangerous levels.

4.2 Evaluation of Biochemical Oxygen Demand quality

BOD was measured to determine the rate at which a biochemical reaction would occur in a stream where a contaminant effluent had been released, (Spiro and Stigliani, 2003).

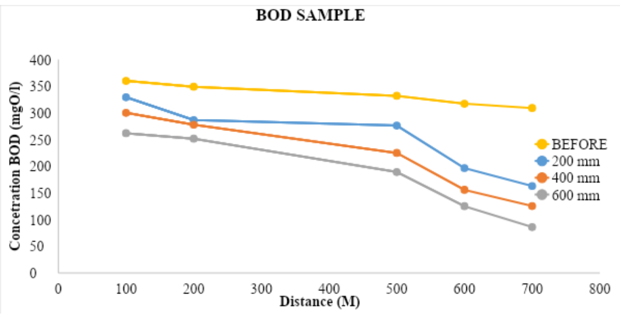

Figure 4: Variation of the concentration of the BOD with distance from the composite filter to River Isiukhu at filter depths of 200 mm, 400 mm.600 mm and before filtration.

As shown in figure 4 biochemical oxygen demand before the filter was installed was 360.5 MgO/l at the outlet up to 289.3 MgO/l downstream at river Isiukhu. When the filter was installed at 200 mm depth, the outlet level was 329.52 MgO/l up to 183.16 MgO/l downstream. At 400 mm depth 300.27 MgO/l to 125.46 MgO/l downstream and 262.1 MgO/l at the outlet to 82.98mgO/l downstream at 600 mm depth. These results show that wastewater depth influenced treatment efficiency of the pond because of two factors, namely increase of: volume of wastewater in contact with the composite filter with depth; and microbial activities with depth as their population increased with wastewater volume.

The reduction in BOD levels by 43 mgO_2/l is a major achievement in this study. It demonstrates the filter has over 57% capabilities of reducing contaminants associated with BOD. Furthermore, reduction of BOD with the depth of filter into filter chamber demonstrates capability of filter response to varying depths. Nonetheless, it is unclear whether these results are due only to the higher hydraulic retention time (HRT) of the deeper system or increase in microbial population as the volume of wastewater increased. Even then, the downstream levels of BOD after installation were close to NEMA standards recommendation of 100mgO/l, especially at 600 mm filter depth determined as 82.98 MgO/l.

4.3 Evaluation of Total Suspended Solids

The mass loadings per capita of BOD-5 and TSS are likely to remain stable when water efficiency increases, except in specific cases of grey water reuse that include on site treatment, and when regulations limit the use of garbage disposals to save water, (Lauren, et al., 2017).

The trend of quality of TSS was presented.

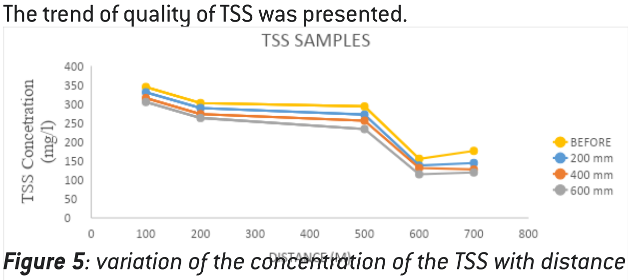

***Figure 5**: variation of the concentration of the TSS with distance from the composite filter to River Isiukhu at filter depths of 200 mm, 400 mm.600 mm and before filtration.*

At 200 mm the total suspended solids (TSS) for effluent at the outlet after filtration was 350.33 mgO/l and reduced gradually to 160.36 mgO/l downstream while at confluence the concentration was 270.8 mgO/l. At 400 mm, effluent at outlet after filtration was 315.566 mgO/l and reduced gradually to 127.36 mgO/l at the confluence and reduced to 133 mgO/l downstream. At 600 mm depth, effluent at outlet after filtration was 304.75 mgO/l and reduced gradually at the confluence to 127.36 mgO/l and reduced to 119.667 mgO/l downstream. Ali, (2018) found that removal of turbidity was relatively high in higher depths than in shallow depth. Percentage of turbidity was in the range 59 to 90%.

4.4 Evaluation of Phosphates

The trend of quality of Phosphates was presented.

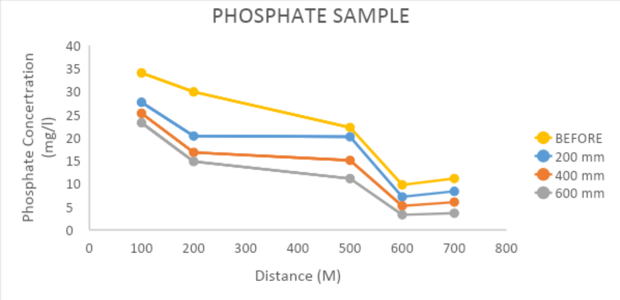

Figure 6: variation of the concentration of the phosphate with distance from the composite filter to River Isiukhu at filter depths of 200 mm, 400 mm.600 mm and before filtration.

As shown in figure 6 above, the phosphate reduced at the outlet before installation of the filter was 34.27 mg/l up to 13.20 mg/l downstream. After installation of the filter at a depth of 200 mm, the level of phosphate was 27.64 mg/l at the outlet and down to 8.34 mg/l downstream to the river. At depth of 400 mm it was 25.24 mg/l down to 5.991mg/l downstream. At 600 mm depth, the level was 23.19 mg/l at the outlet down to 3.59 mg/l downstream a river Isiukhu. The installation of the filter had high impact of phosphate reduction in effluent discharged into river Isiukhu. Thus, it was confirmed that composite filter installation had significant effect at 5% level on the trend of quality of the effluent discharged from Shirere WWTP into river Isiukhu. This also confirmed that Shirere wastewater plant is discharging highly concentrated effluents into River Isiukhu, which is too risky to aquatic life and population downstream.

4.5 Evaluation of Nitrates

The trend of quality of Nitrates was presented

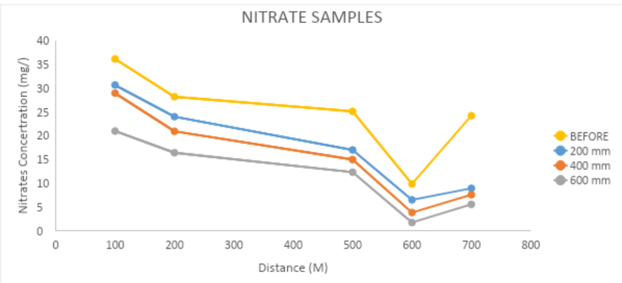

Figure 7: variation of the concentration of the Nitrates with distance from the composite filter to River Isiukhu at filter depths of 200 mm, 400 mm.600 mm and before filtration.

As shown in figure 7, the concentration of nitrate before installation of the filter was 36.13 mg/l at the out let to 24.2 mg/l downstream in river Isiukhu. When the filter was installed at 200 mm depth the level of Nitrate was 32.35 mg/l outlet up to 8.93 mg/l downstream at river Isiukhu. At 400 mm 28.93mg/l at outlet to 7.54 mg/l downstream river Isiukhu. At depth of 600 mm filter depth the level of Nitrate was 22.52 mg/l at the outlet and 5.36 mg/l downstream.

Overall, the concentration of Nitrates was lower than NEMA approved levels of 50 mg/l and proved that the filter had reduced concentration of Nitrates by 76.4 %. Comparatively George et al., (2019), in simultaneous Nitrification and denitrification in slow sand filters with rates of filtration in the range of 0.15 to 0.38 m^3/hr., filter depth of 0.5 to 1.5m^3 of sand size 0.3 to 06 mm found nitrogen concentration to be inversely proportional to the square root of the filter depths. Ali (2018), found that the cause of high removal efficiency of nitrates was due to higher biomass density supported by higher specific surface area and concluded nitrogen removal was less dependent on the sand depth. Therefore, this revealed that at 5% level, the composite filter installation had significant effect on the trend of quality of the effluent discharged from Shirere WWTP into river Isiukhu.

V. CONCLUSIONS & RECOMMENDATIONS

5.1 Conclusion

The quality of effluent was measured from the Sampling Site one to Sampling Site seven (S1 to S7) to establish the trend of COD, BOD, TSS, phosphates and nitrates concentration and compare to the standard laid by national environmental management authority (NEMA). The reference standards, risks of different usage of effluent are taken into consideration.

5.1.1 Chemical Oxygen Demand (COD)

The quality of COD measured from the data was found to be between 270 mg02/l to 12 mg02/l as shown by the trend. The NEMA standard recommended concentration is 100 mg02/l. For all the sampling sites from S1 to S7 the COD concentration is reducing. The sample discharged by the Shirere WWTP without filtration is above 100 mg02/l. The composite filter reduced concentration significantly but the required standard was realized at S3. This confirms the discharge of effluent that is highly concentrated is being released by Shirere WWTP into River Isiukhu. It is therefore important to incorporate composite filter to the waste water discharged into the environment from the plant in order to remove associated health risks.

5.1.2 Biochemical Oxygen Demand (BOD)

BOD data was originally intended to be used to assess the rate at which a biochemical reaction would occur in a stream into which contaminating effluent had been discharged (Spiro and Stiglain, 2003). From the date measured the BOD concentrations from the treatment plant is very high at 240 mg02/l and reduces continuously until is released to River Isiukhu. The effluent discharge is way above the NEMA recommended concentration of 100mg02/l but the filter reduces the concentration.

5.1.3. Total Suspended Solids (TSS)

High concentration of TSS effluent water affects high penetration thus interferes with aquatic life. The ranges from 178mg/l to 10mg/l. the standard recommended is 1,200mg/l, therefore the filtration reduces the TSS but also as the effluent moves downstream, the quantity of TSS increases as at S5 up to S6 where there is confluence of Shikoye River and River Isiukhu. But later the TSS reduced moderately up to 20mg/l. As per the

NEMA standards, the TSS in all seasons and different varying depths of the filter was within the recommended range, hence low risk.

5.1.4 Phosphates

Excessive algal development is likely when phosphates are present in natural waterways in high concentrations. The mechanism of phosphate removal happens in the water stabilization pond system. The phosphates data measured shows a reduction from 100mg/l to 2mg/l from the plant all the way to River Isiukhu. Phosphates released poses minimum risk to the water users for the maximum expected standard is 100mg/l of which the ones released were below it.

5.1.5 Nitrates

Nitrates build up due to farming activities. Nitrates are rarely found in wastewater due to hydrolyzation of nitrates to ammonia which is very volatile. The principal channel for nitrogen removal appears to be ammonia volatization, which occurred at extremely low rates in aerobic ponds, (Soares et al., 1969). This is embraced by the data acquired which shows the highest quality to be 58mg/l and reduced systematically up to River Isiukhu at 1.03mg/l. Nitrates posed minimum risk to the water users for the maximum expected standard is 100mg/l of which the ones released were below it.

Study Recommendation

The composite filter performance was evidenced by big variations in the concentrations of COD, BOD, TSS, Phosphates and Nitrates at Shirere WWTP after filtrations. The effective filtering capacity of the composite filter that had been installed showed a positive impact on the effluent filtration. Therefore, the study recommended that, the composite filter reduced concentrations of all the parameters (COD, BOD, TSS, PO_3, NO_3) significantly from Shirere WWTP along Shikoye stream upto the confluence of river Isiukhu. Most of the parameters after filtration were ranging within the required standards of NEMA. The requisite measure of adopting new technology of composite filtration should be sustained.

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Compact 3D Video Call Projector

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Introduction

As technology has continued to grow over the years the need to bridge existing gaps present between the physical and virtual world has grown especially in the communication space. Holography is an ideal technology that is used for the three-dimensional display of objects. Holography can either be recorded or in real-time. Holography uses the principle of interface and diffraction of light. Holograms can also be computer generated in that objects are reconstructed through the display of images through a spatial light modulator such as a liquid crystal display. This project brings the promise of a more lifelike solution to communication. This also allows the users to mitigate the challenges that come with the current communication which are power inefficiency, suboptimal image resolution, and bulkiness [1]. This project involves a step-by-step process in the design, development, and implementation of the 3D video call project optimization. This project leverages electrical and electronics engineering principles for optimization and design. These systems include the principle of light, wave propagation, and machine learning projects that seek to deliver an efficient and user-friendly 3D video call experience through the generation of holograms from IP images in real time.

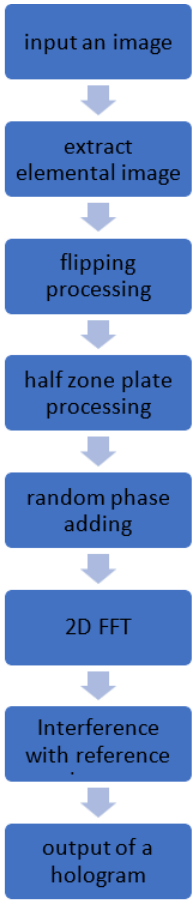
Methodology

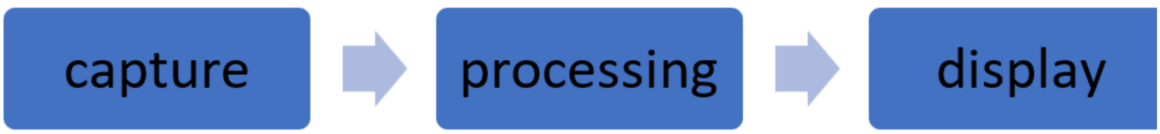
Materials

4K camera, 4 LED screen, Lens Array, Machine learning, Photographic plate, Source of light

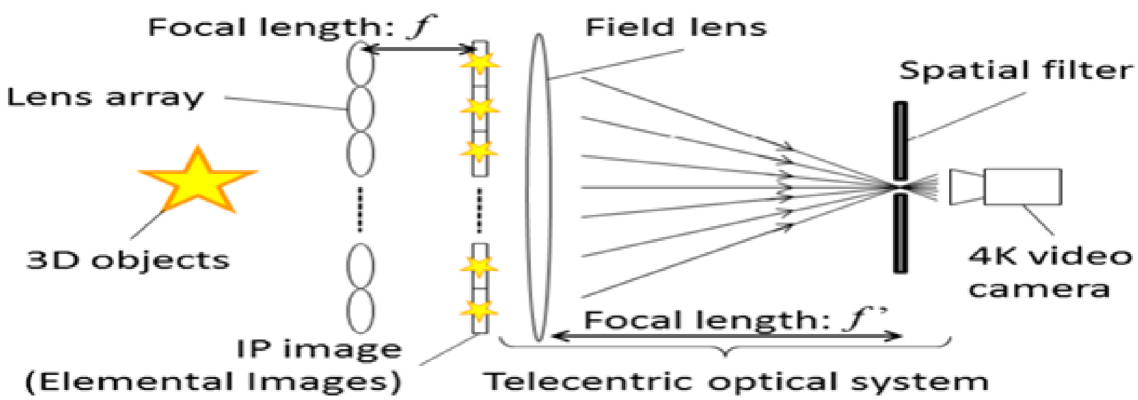
System design

Block diagram





CAPTURE



The lens array is used to help capture the image. A field lens is placed followed by a spatial filter and then a video camera. the resolution of 4K video camera is 3840(W)x2160(H) pixels. The number of pixels for each lens in the lens array is 16(W)x16(H) pixels. As a result, the lens array is constructed by 240(W)x135(H) convex elemental lenses, and the captured IP image is also constructed by 240(W)x135(H). The focal length of the elemental lens is designed to be able to capture the whole viewing area that the display block can cover.

PROCESSING

Holograms for captured IP images are calculated. the IP image is placed at a location separated from the lens array by a distance equal to the focal length. f is the focal length of the lens array constituted by elemental lenses and d is the distance from the lens array to the hologram. D is the diameter of an elemental image and DH is the diameter of an elemental hologram. The hologram images are evaluated using the following equation [4];

Equation 1 $$g_1(x_1, y_1) = \frac{1}{j\lambda f} e^{-jkf} \iint_{-\infty}^{\infty} g_0(x_0, y_0) e^{-jk\frac{(x_1-x_0)^2}{2f}} dx_0 dy_0$$

Equation 2 $$g2(x2, y2) = g2(x1, y1) = g1(x1, y1) e^{jk\frac{x_1^2+y_1^2}{2f}}$$

Equation 3 $$g_3(x_3, y_3) = \frac{1}{j\lambda d} e^{-jkd} \iint_{-\infty}^{\infty} g_2(x_2, y_2) e^{-jk\frac{(x_3-x_2)^2+(y_3-y_2)^2}{2f}} dx_2 dy_2$$

g0(x0, y0) is the light intensity distribution of the elemental image, g1(x1, y1) is the light intensity distribution before transmitting object light through the lens array, g2(x2, y2) is the light intensity distribution after transmitting object light through the lens array, and g3(x3, y3) is the light intensity distribution of the elemental hologram. k is the wave number of the object light and λ is the wavelength of the object light. Equations (1) and (3) are Fresnel diffraction integrals. Equation (2) is the phase variation of the object light caused by transmitting the object light through the lens array. If we assume that f is equal to d, then by substituting Eq. (1) and Eq. (2) into Eq. (3), we obtain the following Fourier transform

$$g_3(x_3 - y_3) = -\frac{e^{-2jkf}}{\lambda f} \iint_{-\infty}^{\infty} g_0(x_0, y_0)\, e^{j2\pi(\frac{x_0 x_3 + y_0 y_3}{\lambda f})} dx_0 dy_0$$

$$g_3(x_3 \Delta p_m, y_3 \Delta p_n) = \sum_{Y_0=1}^{N} \sum_{X_0=1}^{M} g_0(x_0 \Delta p_m, y_0 \Delta p_n) e^{j2\pi}(x_0 x_3 \frac{\Delta p_m^2}{\lambda f} + y_0 y_3 \frac{\Delta p_n^2}{\lambda f})$$

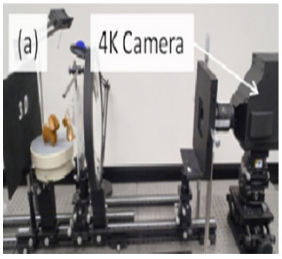
M and N are the numbers of pixels in the horizontal and vertical directions, respectively, in the elemental hologram. Δpm and Δpn are the horizontal and vertical pixel pitch of the elemental image.

ENLARGEMENT OF IP IMAGES

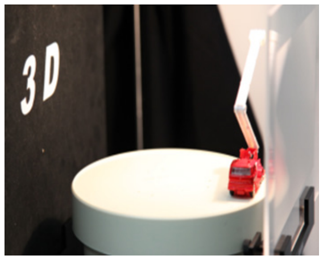
An image differs from a typical image in that each elemental image of the IP image has different object beam information. Ideally, the more elemental images there are, the higher the resolution of the 3D image that can be captured on the IP image [3].On the other hand, the larger the elemental images are, the deeper the 3D image that can be captured on the IP. For enlargement and reconstruction, we adopted machine learning to ensure a perfect reconstruction of the original image. The software was also a more realistic approach to ensure live 3D imaging.

Results

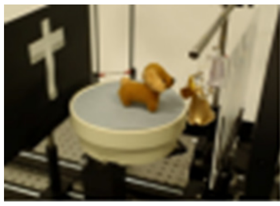
This section describes the performance of our system. The lens array consists of 240 × 135 elemental lenses. The diameter of one elemental lens is 0.8 mm and the focal length is 8.6 mm. Therefore, we can capture 3D objects with a horizontal size of 192 mm and a vertical size of 108 mm. The number of pixels in the elemental image is 16 × 16 because the number of pixels in the capture device is 4K. The number of elemental images is 480 × 270, the size of each elemental image is 16 × 16 pixels, the focal length of an elemental lens is 0.693 mm for the wavelength of green, and the diameter of each elemental lens is 0.0768 mm. The experimental results are shown in the figures below. reconstruction of color 3-D objects took place in real-time. This was implemented by software that enlarges and reorganizes these images to ensure 3D imaging.



The camera setup



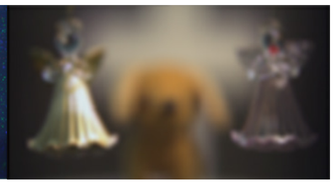
Live image of truck and 3D sign



Images captured live

Hologram of truck

Hologram of 3D sign



Holographic image of the teddy bear

Image	Time taken for hologram display in seconds
Truck	10
3D Sign	12
Teddy Bear	9

Discussion

The performance metrics of our compact 3D video call projector system demonstrate significant advancements in the field of real-time 3D imaging. The lens array, consisting of 240 × 135 elemental lenses, enables the system to capture 3D objects with a horizontal size of 192 mm and a vertical size of 108 mm. The use of elemental lenses with a diameter of 0.8 mm and a focal length of 8.6 mm allows for precise image capture, ensuring that the 3D objects are rendered with high accuracy. A key strength of the system lies in its ability to manage a large number of elemental images. This granular level of detail is critical for achieving high-resolution 3D reconstruction, particularly when using a 4K capture device. Experimental results demonstrate the system's efficiency in reconstructing various 3D objects. For instance, the time taken to display a hologram of a truck was 10 seconds, a 3D sign took 12 seconds, and a teddy bear took 9 seconds. These times reflect the system's capability to handle different levels of complexity in 3D objects while maintaining real-time performance. The relatively fast reconstruction times indicate that the system is well-suited for dynamic video call scenarios, where different objects may need to be displayed quickly and seamlessly. However, challenges remain in optimizing the balance between the number of elemental images and the computational load required for real-time processing. As the resolution of the capture device increases, the demand for more powerful image processing algorithms and hardware also rises.

Conclusion

In conclusion, our compact 3D video call projector system represents a significant step forward in the development of immersive communication technologies. The combination of advanced lens arrays and real-time image processing software has enabled the creation of a device that can capture and reconstruct 3D images with remarkable precision. Ongoing optimization and testing will be essential to further enhance the system's performance and ensure its successful integration into everyday communication tools.

Acknowledgment

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WFEO ECBAP Launch -17th March 2025
From left: Eng. Harrison Keter – 1st Vice President of the IEK; Dr. Peggy Oti-Boateng – Executive Director of the African Academy of Sciences; Prof. Gong Ke – WFEO ECBAP Task Force Chair; Eng. Joseph Mbugua – Principal Secretary, State Department for Roads; Eng. Shammah Kiteme – President, IEK; Dr. Zhou Gaya - Executive Deputy Secretary General of Chinese Society of Engineers; Eng. Margaret Ogai Registrar/CEO, Engineers Board of Kenya; Eng. Mustapha Shehu – President, WFEO; H.E. Mr. Junke He – Executive President and Chief Executive Secretary of CAST; Eng. Erastus Mwongera – Chair, Engineers Board of Kenya; Eng. Martin Manuhwa – Chair, Engineering Capacity Building (CECB), WFEO

IEK Council Pays Courtesy Visit to H.E. Mutula Kilonzo Jnr, CBS – Governor of Makueni County

IEK signs Mou with Nation Media Group (NMG) to support Newspapers in Education program

Police Band performs during World Engineering Day celebrations at the University of Nairobi

ACCELERATION OF STRUCTURAL TRANSFORMATION OF ECONOMIES OF EAC REGION: CASE OF EAC INDUSTRIALIZATION ACTION PLAN

Eng. Jennifer Atieno Gache
Regional Expert, GFA Consulting Group support to EAC commissioned by GIZ
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1. Introduction

The manufacturing sector in East Africa is a major pillar for economic development in the region contribution to at least 9 percent of the GDP. The Manufactured Value Added (MVA) growth and remains a key policy concern in the region. MVA growth has slowed down in recent years, from 5.3 % between 2005 and 2010, to 4.6 % between 2010 and 2015, falling short of the 10% annual growth rate envisaged in the EAC Industrialization Policy and Strategy. Due to the slow pace of MVA growth relative to GDP, the share of manufacturing in GDP has been contracting, from previously more than 10% a decade ago to less than 8% raising doubts about structural transformation-through industrialization- which is key to sustained economic development in the long-run. The share of manufactured exports as a share to total exports shares are below 50 percent for all East African Countries except Rwanda implying a greater need for faster growth of manufactured exports in the total exports baskets. An encouraging development however is that the case of manufactured exports, the destination is mainly to EAC or Sub-Sahara Africa signifying attractiveness of regional integration for manufacturers. This contrasts with commodity and agricultural exports, which mainly target the rest of the World. An important implication of the lack of structural transformation in East Africa is that the economies are not creating significant employment opportunities to match the needs of labour market leading to general unemployment particularly in the category of the youth. The policy makers have to strive to pursue proactive policies that can bring about rapid structural change by tapping into sectors that are strategic to the region.

2. Binding Constraints to Industrialization

The following are some identified binding constriants need to be overcome for real progress to be made towards industrializing the region:

(i) Addressing gaps in the Institutional Coordination and governance frameworks: These are manifested by the lack of implementation of viable strategies, policies and systems of coherent laws and regulations to guide the industrialisation efforts. There are further inadequacies in institutional capabilities to chart a viable visons, coordinate and backstop the process of industrialisation;

(ii) Reducing shortages of essential industrial skills: due to the underdevelopment of human capital, there are shortages of industrial sector skills similarly; industry is also challenged by weak work ethics, relatively low level of labour force regulation, poor skills mix and productivity. In addition, critical masses of technological capacities, which are needed to catalyse sustainable development, are lacking. Lastly, a demand driven education system tailored to meet the region's industrial needs is lacking.

(iii) Building quality infrastructure: Infrastructure challenges have significantly constrained accelerated development in all EAC Partner States, although the impact of these constraints has varied across the Partner States. The region's railway network is antiquated and unable to meet the demands of a 21st century economy. While the state of the region's roads can be described as fair, specific road infrastructure constraints relate to inadequate investment in capacity and maintenance of existing roads and inadequate but improving regional legal and regulatory frameworks to enable coordination of roads development initiatives. The cost of power remains a challenge.

(iv) Finacing for Industrialization progrmmes and access to affordable finance:The public debt burden experienced by EAC Partner States implies that less-and-less resources will be made available for productive activities including industrialization interventions. This is likely worsen an alreday bad situation where industry both at regional and national level often get minimal budgetary allocation.

(v) Access to finance remains one of the major factors constraining Micro, Small and Medium Enterprises (MSME) growth and

(vi) Fragmented Markets: The region has small, fragmented, and underdeveloped markets among others.

3. EAC Industrialization Strategy, 2012-2032

The EAC has developed a regional Industrialization Policy and Strategy (2012-2032) to enhance production and productivity, and accelerate the structural transformation of its economies. The results of the Strategy are to be achieved through, inter alia, diversifying the manufacturing base and raising local value-added content of exports to at least 40% by 2032; strengthening institutional frameworks; expanding trade in manufacturing; and transforming MSMEs into viable and sustainable business entities.

3.1. Determination of the EAC Priority Regional Sectors

In the development of the Strategy the region set out to identify industries that are competitive in local, regional and selected international markets. These industries dubbed, “”Strategic Regional Industries”. These were defined as innovative industries to be promoted based on comparative and competitive advantages of the region and which contribute to attainment of at least four of the following

a. Fostering of complementarities or enhancing collaborative production in the region,

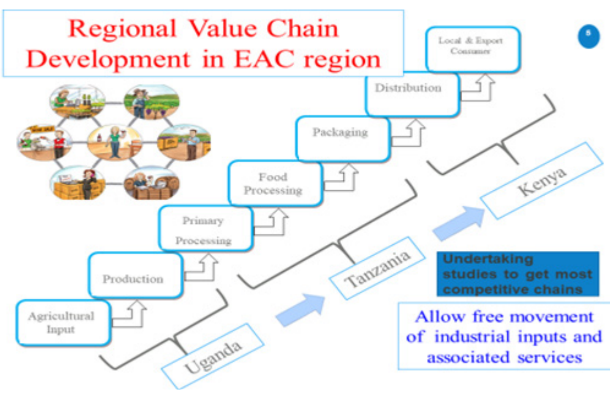
b. Large investments which may require pooling of resources to ensure that economies of scale are achieved,

c. Contributing to realisation of backward and forward linkages in the value chains with regional dimensions,

d. Contributing to employment generation in the region; and

e. Having presence in at least more than one Partner State.

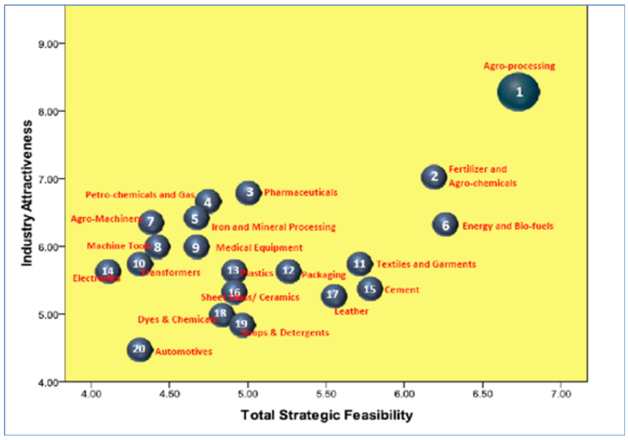
Fig 1: Regional Agro Value Chain in the EAC



3.2. Identification of the Regional Industries

The region used framework developed by UNIDO (Fig. 2) for identifying industrial development priorities. The framework that has been used in selecting target regional industries is based on two dimensions: attractiveness and feasibility.

Fig 2: Graphical Illustration on the Attractiveness and Strategic Feasibility of a Targeted Industry



From Fig. 2 above, it is clear that agro-processing, fertilisers and agro chemicals, iron/steel and metals, energy projects (ethanol) and textiles registered the highest scores on attractiveness and strategic feasibility, and therefore have the greatest potential for growth within the region.

3.3. Identified Strategic Regional Industries Basing on the above analysis and broad consultation with stakeholders, the six industries below have been selected as the ones with potential comparative advantage within the region;

a. Agro-processing

b. Fertilisers and agrochemicals;

c. Pharmaceuticals;

d. Iron-ore and other mineral processing;

e. Petro-chemicals and gas processing;; and

f. Energy and bio-fuels.

3.4. Proposals to Accelerate Structural Transformation of Industrialization in the region

a) Exploit the opportunities in the dynamic EAC market: All EAC Partner States present a very high concentration of export markets. On the other hand, the EAC is a very dynamic market where demand for manufactured goods is growing annually at 16%, and at double digits for all the 20 most demanded manufactured products of the region. At the same time, the EAC Partner States are together losing market share on the vast majority of these. The region is an important market for medium and high tech products, where EAC firms have been more successful. Firms should continue to take advantage of this.

b) Shift, in the medium and long term, from resource-based and low-tech sectors, to a larger share of medium and eventually high-tech sectors: Three of the six priority sectors are classified as medium and high tech (fertilisers and agrochemicals, pharmaceuticals, and energy and bio-fuels).

c) Upgrade smartly within sectors/value chains: The short term should focus more on upgrading within sectors/value chains, that is, undertaking processing activities to add value to agricultural products or goods with currently low prices.

d) Strengthen forward and backward linkages to boost industrial and overall economic growth: The very low levels of forward and backward linkages of the manufacturing sectors of EAC Partner States should be boosted by a) increasing the capacities of MSMEs to provide the products required by larger (exporting) firms in terms of product type, quality, quantity, price and reliability; and b) increasing local content by putting in place local content policies/preferential procurement schemes.

e) Develop and promote post-primary education programmes (TVET and university programmes) catered to supplying the manufacturing sector with a range of Selected policy recommendations highly-skilled workers. This may require starting new skills training programmes or reforming existing ones to minimise the skills gap. In order to ensure skills mismatches are mitigated to the extent possible, strong involvement of the private sector is encouraged, not only in the initial design/restructuring of such programmes is required, but through continuous collaboration and dialogue.

f) Attract foreign and domestic investments into the manufacturing sector to ensure EAC firms can exploit the emerging regional market for manufactured goods.

g) Direct limited public resources to applied research and various forms of specialised extension services in order to support the development of technology and innovation.

h) Strategically ease access to a selected set of capital goods and inputs required for production, without hampering the growth of national/regional producers of the same.

i) Introduce dedicated policies for long-term financing, matching grants, ex-post rewarding schemes and other to encourage private investors.

3.5. The key strategic thrusts to drive growth should focus on:

(i) Spatial developent of key economic corridors (regional approaches)

(ii) Cities and Urban centers as new sources of growth for industrialization and rural transformation (mainly national)

(iii) Harnessing the opportunities of the Fourth Industrial revolution (4IR)(re-skiling of workforce and skilling of youth to adapt to technological frontier

(iv) Regional approach to Global Value Chain Integration (GVC)- regional coordination for targeted FDIs, coherent policy & investment incentives, making regional value chains work

4. Conclusions and Recommendations

To enable the growth of the Industrial Sector the region has adopted an Action Plan for 2021-2027 whose theme is "Recovery and Binding Resilience for sustainable Industrial Growth". The broad Programmatic Intervention Areas to guide generation of specific action and activities to be implemented in the period 2021-2027 include:

a) Improving the competitiveness of priority regional value chains to boster intra-EAC trade

b) Developing a regionally coherent and harmonized policy framework for Local Content for regional value creation and supply chains development

c) Supporting the private sector and SMEs resilience for accelerated growth and recovery of the Industrial Sector

d) Leveraging the AfCFTA and GVCs for export growth and rapid Industrial Sector Tranformation

e) Shifting to Green Industrialization Pathways and anchoring sustainability to achieve SDGs

f) Improving Policy Coordination and Building Capacity for Industrial Policy Management

g) Optimizing Infrastructure & Logistics Networks for Spatial Industrial growth and Agglomeration

h) Stregnthening colloboration in R&D, Technology Tranfer and adotion of Fourth Industrial Revelotion (4IR) technologies

Elaboration of Strategic Actions

4.1. Improving the competitiveness of priority regional value chains to bolster intra-EAC trade

What is required here is to develop and implement the Regional Value Chains Action Plans for specific sectors. Explore the scope for establishment of a regional or national investment and financing facility (special purpose vehciels) to support the development and production of essential industrial inputs and intermediate goods industries focusing on the strategic regional value chains of priority to EAC. Industrial inputs and intermediate goods industries are by their nature capital intentisive and require scale economies to become competitive and efficient. Undertake market opportunity assessment study for the essential industrial inputs and intermediate products currently being imported into the region including existing production capacities to gauge the products and activities with greatest feasibilities and identify arange of policy intruments to be deployed to promote such industries. Organize value chain specific round tables/forum to create a platform for continuous policy dialogue and monitoring the competitiveness challenges in the sectors and prepare Investment Roadmaps for the priority regional targeting attraction of FDIs and profiling of investment opprtunities

4.2. Developing a regionally coherent and harmonized policy framework for Local Content for regional value creation and supply chains development

Conduct a mapping study on the scope and opportunities for value addition (value creation) through local content policy tool, identify the sectors with most promising potential and prepare a local content policy framework to support leveraging of such opportunities (demand side of the equation) and Develop a regional wide suppier development and linkage programme focusing on training of suppliers on requirements from multi-national compnaies, financing, exporting, quality, costing, and strategies for integrataio into regional and global supply chains.

4.3. Supporting the private sector and SMEs resilience for accelerated growth and recovery of the Industrial Sector

Mapping of information requirements for small and medium enterprises. Cluster approach to be used to gather relevant information for SMEs and a register of potential service providers prepared. Develop a regional SME Information Portal linking similar nation information sources to enhace access to comprehensive regional information on trade, investment, partnerships, procurement opprtunties etc. Provide tailored techhical assiatnce towards upgrading of production and business processess and acess to approproate technology and organize Regional SME Investment symposium creating opportunity to expore business partnerships within the region, market their products, and promote policy dialogue.

4.4. Leveraging the AfCFTA and GVCs for export growth and rapid Industrial Sector Transformation

The African Continental Free Trade Area (AfCFTA) agreement will create the largest free trade area in the world measured by the number of countries participating. The pact connects 1.3 billion people across 55 countries with a combined gross domestic product (GDP) valued at US$3.4 trillion. The actions include: Develop EAC sector specific roadmaps for participation in the AfCFTA in colloboration with private sector . The roadmaps will lay out the sectors that can harness opportunities in the continental market, comparative strengths, pecularities of targeted markets , capacity gaps to participate, policy challenges and draw a detailed action plans. Others include to devclop capacities of enterprises in the targeted value chains to comply with AfCFTA rules of origin applicable including their capacities to meet the continental standards and Support the promotion of linkages of SMEs to regional (continental) multinational corporation through activities such as SME-FDI linkage forum, buyer-seller platforms, private-private investmnet parnerships agreements etc among others.

4.5. Shifting to Green Industrialization Pathways and anchoring sustainability to achieve SDGs

In many countries, industrial production and consumption patterns outpace the renewal capacity of natural resources and governments' capacity to manage waste products. These trends in resource use and energy consumption indicate that current forms of industrial production are not sustainable in the long run, and risk undermining the social and economic development benefits achieved thus far. This calls for a shift toward green and more sustainable approaches needed to satisfy the needs of the present – without comprising the needs of future generations. The greening of industries by governments is a proactive way to decouple environmental pressures from economic growth.

4.6. Improving Policy Coordination and Building Capacity for Industrial Policy Management

In the EAC Region, the capacity and performance of the public sector that deals with industry related matters is generally low, and as a result, implementation of industry related policies and strategies has in some cases been inadequate, constrained by several factors, including poor governance and ineffective monitoring and evaluation frameworks. In addition Partner States often do not have up-to-date and reliable data of industral establishmnets and real time information of production. The situation not only curtails the prospects for an evidence based policy making but also seriosly limits the design of a credible investment proposal that can be developed and marketed to potential investors.

4.7. Optimizing Infrastructure & Logistics Networks for Spatial Industrial growth and Agglomeration

Economic corridor development is an integrative strategy and effective tool that enables industrial spread, creates jobs, upgrades infrastructure, aligns infrastructure development with urban and social agglomerations, unifies domestic markets, and links production centers with global value chains. Likewise, economci corrodors can serve as a tool to foster decentralized development away from the country's city and creates markets in the lagging regions. As EAC Partner State begin the transition to middle income status, it it critical that the countries, exploit the full potential of their various regions and finding new sources of growth that can sustain a higher growth trajectory. Corridir development ensures a holistic development and can become new drivers for structural transformation and regionally balanced development

4.8. Strengthening collaboration in R&D, Technology Transfer and adoption of Fourth Industrial Revolution (4IR) technologies

The impact of Industry 4.0—the next phase in the digitization of the manufacturing sector driven by computing power, connectivity, and new forms of human-machine interaction—will be wide and profound. It offers exciting opportunities for African manufacturers and small and medium enterprises to create new business models and integrate into global value chains. Key areas of policy focus to enbale the region harness opportunities under Fourth Industrial Revolution include: Develop national strategies for integration of 4IR technologies into the national economy. Conduct situatioal assessment of EAC readiness for fourth industrial revolution technologies (4IR technologies)-which sectors can integrate, what gaps exists, what support is needed by business, and an action plan for integrating 4IR in manufacturing, SMEs, education, Agriculture etc. The region is to forge and foster regional, and global collaboration for access, adoption, adaption and deployment and tranfer of 4IR capacities and technologies. Conduct training and skilling of workforce and youth to effectively deploy and harness the emerging opportunties under 4IR with focus on priority regional value chains and build necessary infrastructure to support wide application of 4IR technologies including digital infrastructure among others.

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Enhancing Kenya's Manufacturing Sector: The Role of Government, Regulatory Bodies and Industry

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IEK's 2024-2026 Engineering Standards and Bottom-up Transformation Agenda (BeTA) Taskforce on Manufacturing

1. Introduction

Kenya's Vision 2030 is a long-term development blueprint aimed at transforming Kenya into a newly industrializing, middle-income country providing a high quality of life to all its citizens by 2030. Manufacturing is identified as a critical component for achieving this vision through several strategic measures. On the economic pillar, it places a strong emphasis on industrialization as a key driver of economic growth. The aim being to increase the contribution of manufacturing to GDP and create more employment opportunities. The strategy focuses on expanding the export base of manufactured goods, enhancing value addition to agricultural and mineral products and creating more job opportunities. Consequently, several key flagship projects were identified:

a) Establishing SEZs to attract investment, increase productivity, and enhance competitiveness in manufacturing. Development of industrial parks to provide infrastructure and facilities conducive to manufacturing activities.

b) Revitalizing the textile and apparel industry to exploit the potential of the AGOA (African Growth and Opportunity Act) and other trade agreements. Establishing a robust iron and steel industry to support construction and manufacturing sectors.

c) Improvement of transportation infrastructure, including roads, railways, ports, and airports, to reduce the cost of logistics and enhance the movement of goods and raw materials.

d) Expanding and modernizing the energy sector to ensure reliable and affordable power supply for manufacturing industries.

e) Enhancing information and communication technology infrastructure to support manufacturing processes and facilitate e-commerce.

f) Enhancing technical and vocational education and training (TVET) to equip the workforce with the necessary skills for modern manufacturing.

g) Promoting research and development (R&D) to foster innovation and the development of new manufacturing technologies.

h) Improving the business environment by streamlining regulations, reducing bureaucratic hurdles, and enhancing transparency to attract both local and foreign investors.

i) Encouraging PPPs to leverage private sector expertise and resources in the development of manufacturing infrastructure and projects.

j) Implementing favorable trade policies to protect local industries while promoting competitiveness in the global market.

k) Ensuring that manufacturing practices are environmentally sustainable, with a focus on reducing carbon footprints and promoting green technologies.

l) Promoting inclusive growth by ensuring that the benefits of industrialization are widely shared across different regions and populations, including marginalized communities.

m) Targeted focus to promote MSMEs through economic incentives by the government to special groups such as youth and women and provision of subsidized access to government services.

Despite its potential, the manufacturing sector faces several challenges, including inadequate infrastructure, high production costs, and regulatory hurdles. This paper explores the strategic roles of the government and industry in overcoming these challenges and enhancing the sector.

2. Current State of the Manufacturing Sector

The manufacturing sector in Kenya contributes about 10% to the GDP and employs over 300,000 people directly (KAM2018). On average, however, manufacturing has been growing at a slower rate than the economy.

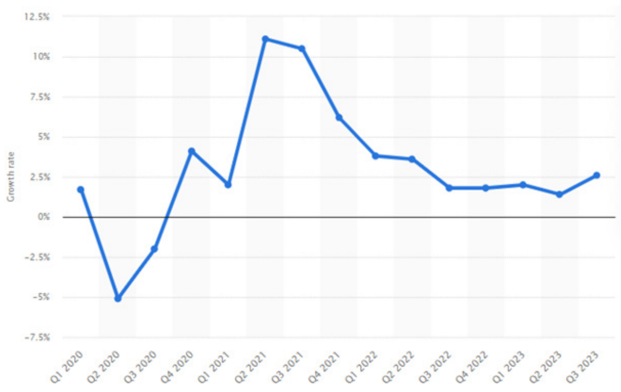
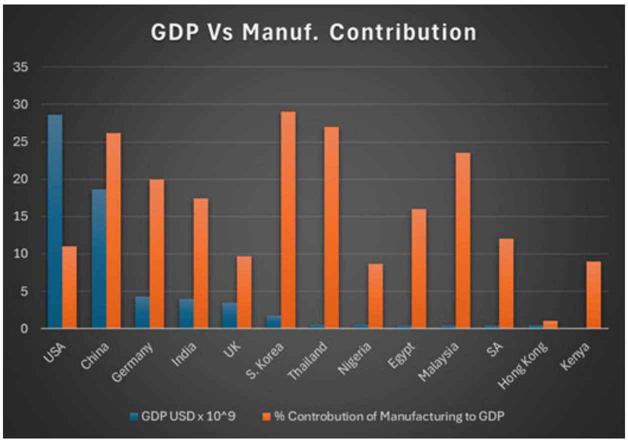


Fig 1: Gross Domestic Product (GDP) growth of the manufacturing sector in Kenya between Q1 2020 and Q3 2023 (Source: https://www.statista.com/statistics/1168103/gdp-growth-of-the-manufacturing-sector-in-kenya/)

This implies that the share of manufacturing in GDP has been reducing over time. As a result, it can be argued that Kenya is going through premature de-industrialization in a context where manufacturing and industry are still relatively under-developed and Kenya seems to have 'peaked' at a point much lower than in much of Asia.

Fig figures illustrates the varying importance of the manufacturing sector across different economies. Generally, there exists a correlation between a country's GDP and its manufacturing contribution, but the strength of this correlation may vary depending on the country's level of economic development, industrialization, and economic structure.



Fig……. Comparison of Country's GDP & % Contribution by the Manufacturing Sector (World Bank)

In many developed countries, the contribution of manufacturing to GDP tends to be lower compared to services. However, the sector is often highly advanced, capital-intensive, and a key driver of exports. Examples shown in figure …… include the United States, Germany, and Japan. Middle income economies often experience a significant correlation between GDP and manufacturing as they are typically in the process of industrializing. Manufacturing therefore plays a crucial role in driving economic growth. Countries like Mexico and Brazil fall into this category. In the low-income economies, manufacturing's contribution to GDP is limited by a lack of infrastructure, capital, and technology, with agriculture dominating the economy. However, as these economies develop, the contribution of manufacturing will tend to increase, leading to a stronger correlation over time. Examples include many Sub-Saharan African countries.

Presently, agriculture, remains the backbone of Kenya's economy, contributing 22.4% to the country's GDP and creating 40% of jobs. Despite the above, Kenya still imports food worth Kes 200 billion annually. Suffice to say that the Agri-based manufacturing sector contributes approximately 48% of the total manufacturing contribution to the GDP. This demonstrates the opportunities that lie in agriculture alone. Subsidy on fertilizer can increase the total productivity in the agricultural sector.

In the non-food Agri-based value chains, leather and leather products are among the most traded commodities in the world, with their current value estimated at USD129.3 billion (Kenya Leather Development Council 2020). Africa owns 20% of the global livestock population but accounts for only 4% of the leather produced. The country has the third largest herd of livestock in Africa, behind Ethiopia and Botswana. Currently, most of the leather is exported in raw hides and skins, and a huge percentage is in the form of wet blue and crust, with an export value of about Kes 14 billion. By restructuring the leather industry, reducing production costs, minimizing waste and improving animal husbandry, the sector can generate approximately $ 106 million by 2030 from both the domestic and export market. According to the Kenya Association of Manufacturers (KAM), this will create jobs from 17,000 to 100,000, of which 70% will be in the informal Micro & Small Businesses.

Growth in the manufacturing sector has been stymied by various impediments such as inefficient logistics, limited access to finance, and skills gaps.

3. Government's Role in Enhancing the Manufacturing Sector

3.1 Policy and Regulatory Framework

George Stigler (George J. 1971), an economist and Nobel Laureate examined the necessity of government regulation and acknowledged that state regulations can pose either an opportunity or a challenge to every industry. This implies that regulations can bring advantages to society or be viewed as a hindrance. The primary goal of economic regulation should be to promote competition, improve resource allocation efficiency, and allow enterprises to grow their product offerings. According to Product Market Regulation Index, Kenya has some of the most substantial hurdles to entrepreneurship. According to the report, these barriers are the result of burdensome entry rules that are less common globally, as well as an unmanaged system of licensing and permit requirements at the national and county levels (World Bank, 2020). KAM regulatory audit in 2020 showed that some licenses are renewed manually.

This inefficient process increases costs of doing business and creates opportunities for corruption and fraud. The other problem captured from the audit is the long, cumbersome and expensive process of starting a business in Kenya due to tax and licensing requirements. There is thus a need to have regulations that simplify business registration, reduce bureaucratic hurdles, and provide clear guidelines for operations to encourage investment in manufacturing. For instance, Rwanda's streamlined regulatory framework has made it easier for businesses to start and operate, attracting significant foreign direct investment (FDI) into its manufacturing sector (USDS-Rwanda,2023.). In the recent past, Kenya has been renewing its Finance bill annually, affecting different manufacturing sectors with inconsistent tax policies and regulations. This has led to so many multinational companies like GlaxoSmithKline and Procter & Gamble to shut down operations in the country. A stable and predictable regulatory environment is therefore crucial for long-term investments in manufacturing. Frequent changes in regulations or sudden policy shifts can create uncertainty, discouraging investment and innovation in the sector.

Providing industry targeted tax incentives, subsidies for energy, and grants for technological upgrades can lower production costs and encourage investment in the manufacturing sector (World Bank, 2024). Kenya could develop targeted industrial policies that focus on sectors with high potential for growth, such as textiles, agro-processing, and pharmaceuticals (OECD, 2024). For example, South Korea's focus on electronics and automotive industries in its early stages of industrialization led to significant economic growth. Malaysia on the other hand provided significant tax incentives to attract investment in electronics, which became a cornerstone of its economy. South Africa has offered subsidies for energy efficiency improvements, benefiting its industrial sector. Implementing policies that encourage recycling, resource efficiency, and waste reduction can drive sustainable manufacturing. The European Union has been at the forefront of adopting circular economy policies, which have fostered innovation and new business models in manufacturing. Offering incentives for green manufacturing practices can also attract environmentally-conscious investors and markets. Germany's Energiewende (Energy Transition) has promoted green manufacturing, particularly in energy-intensive industries.

Implementing favorable trade policies, export incentives and negotiating trade agreements can open new markets for Kenyan manufactured goods and protect local industries from unfair competition (UNIDO, 2024), (IMF, 2024). Vietnam, through export subsidies and tax rebates has become a global hub for electronics and textiles. Mexico's involvement in North America Free Trade Agreement NAFTA (now USMCA) significantly boosted its manufacturing sector, particularly in automotive and electronics. Kenya could strengthen regional integration by developing regional value chains with neighboring countries. The European Union has been successful in creating integrated value chains across member states, boosting manufacturing in less developed regions.

Effective policy and regulation are foundational to the development and success of a manufacturing sector (WEF,2016). They create a conducive environment for investment, ensure access to necessary resources, protect workers and the environment, and promote innovation and global competitiveness.

3.2 Infrastructure Development (Veronicah)

Kenya has made significant progress in infrastructure development through the mid-2000s and its peak notable in the last past three years after the implementation of the Public Private Partnership act of 2021 to overcome budgetary constraints.

1. Transport and Logistics: Investing in infrastructure, such as roads, railways, and ports, is crucial for reducing logistical costs and improving supply chain efficiency.

a. The Railway infrastructure - The Standard Gauge Railway (SGR) project completed in 2017 has revolutionized transport efficiency and enhanced trade within its corridor and to the larger Eastern Africa Region through its commercial freight operations. The extension to the Naivasha Inland deport and further to plan to extend the SGR network to Kisumu and onward to the Malaba border with Uganda, provide an ambitious catalyst to trade in the area.

b. The Road transport infrastructure - the development of the Nairobi Southern bypass, Eastern Bypass, Nothern bypass and Western bypass roads have led to the opening up of the road network within Nairobi and increasing ease with which commodities are transported with minimal delays. Industrial set ups have increased along the major roads where land is affordable in the outskirts of major urban centers. For example, the extension of the Kenol Marua rd has led to opening up of export processing companies to easily acess farm produce from farmers located around Mount Kenya zone.

c. The Airport Infrastructure - The expansion of the Jomo Kenyatta International Airport through the upgrade of the airport infrastructure and additional runway has brought about increase in passenger traffic and spurred economic growth for Kenya and the East African hub. Tourism industry has been boosted greatly due to the effective service delivery, increased number of airline services and improved security.

d. The PORT infrastructure - Mombasa is fully functioning as the gateway of East Africa and the starting point of logistics along the Northern Economic Corridor leading to the landlocked countries, Uganda, Rwanda, Burundi and South Sudan. The Government of Kenya is keen on increasing profitablity and efficiency in port operations in Mombasa and Lamu. The Port of Mombasa recently completed Phase 1 of the Mombasa Port Development Project (MPDP), which included construction of a second container terminal, three additional berths and installation of two ship-to-shore cranes and four rubber-tire gantry cranes. The infrastructure aims to add capacity to serve over 1 million units. The expansion of Port of Lamu in northern Kenya, under the Lamu Port-South Sudan-Ethiopia-Transport (LAPSSET) Corridor, is East Africa's largest and most ambitious infrastructure project, consisting of a 32-berth port in Lamu and other supporting infrastructure. The first 3 berths, were completed in 2021 with berth 1 having handled 50 ships so far. The government is financing construction of roads and airports that link Lamu Port to Northern Kenya to help realize its full potential and provide better access to Ethiopia and South Sudan. Kenya intends to develop the remaining 29 berths using a PPP model financed by the private sector. In general, though the port expansion projects, Kenya is placing itself on the global map as a preferred choice of trading center and backbone to trading operations to the land locked countries in Africa.

2. Energy Supply: Ensuring a reliable and affordable energy supply is vital. Investing in renewable energy sources and upgrading the national grid can mitigate frequent power outages and reduce energy costs. Kenya's greatest infrastructure challenge lies in the power sector. Kenya's energy mix predominantly consists of green energy with geothermal, hydro, wind, and solar accounting for 87% generation in 2023. Renewable sources are expected to replace existing thermal plants as Kenya moves towards a fully green grid by 2030.

The GoK is focused on developing the geothermal power potential in Kenya with a plan for drilling additional wells in the Rift Valley. KenGen plans to add 560MW of geothermal power to the grid through joint ventures, in addition to 1000MW of wind, and various solar installations at existing hydro sites. GDC plans to develop 2000MW. In addition, KETRACO plans to construct over 10,000 kilometers of high voltage transmission to allow power generated get to intended load centers.The additional generation aims to ensure ready supply for upcoming demand largely from heavy consumers in industries.

However, the increase in the cost of electricity has been cited as a major factor to the high cost of production passed down to consumers. Therefore, the Government of Kenya must provide incentives for industrial consumers through cost friendly tariffs to produce and pass down cost benefits to the customers. The Net metering regulations by Epra are in their final stages to allow prosumers enjoy benefits of generating power back to the utility in an effort to encourage the journey to a fully Green Grid.

3.3 Skills Development

Skills development is crucial to Kenya's manufacturing sector, as it enhances productivity, innovation, and competitiveness. Technical and Vocational Education and Training (TVET) and apprenticeship programs play an essential role in equipping the workforce with practical skills and knowledge that meet industry demands. TVET institutions provide hands-on training in various technical fields, such as mechanics, engineering, and technology. These institutions bridge the gap between theoretical education and practical industrial skills. As Kenya industrializes, the need for a skilled labor force to operate advanced machinery and apply innovative techniques is paramount. TVET ensures that workers can adapt to the changing technological landscape, thereby reducing reliance on foreign expertise and boosting local employment. Apprenticeship programs on the other hand integrate learning with work, allowing trainees to acquire industry-specific skills while on the job. These programs foster real-time problem-solving and innovation, preparing individuals to meet the dynamic needs of the manufacturing sector. By aligning skills training with the needs of industries, apprenticeship programs reduce skills mismatches and ensure a steady flow of competent workers.

Investing in skills development, will enhance Kenya's industrial capacity and lead to increased efficiency, higher quality products, and greater economic growth. Moreover, a skilled workforce can attract more foreign direct investment, particularly in sectors such as agro-processing, textiles, and automotive industries, thus driving industrialization and creating sustainable employment opportunities.

3.4 Financial Support (Paul)

The phrase that Kenya and the Asians giants Singapore and South Korea were economically at per during her independence is the most overused by successful government especially in the last 2 decades. The question begs what have we learnt and implemented from the two case studies. Singapore and South Korea have both implemented extensive government support and policies to spur the growth of their manufacturing sectors.

By drawing parallels from the Asian benchmarks the power that be must embark on the following financial and policy support to the manufacturing sector:

1. Tax Incentives and Grants:

Such programs should provide corporate tax exemptions or reduced tax rates to companies in high-value manufacturing sectors.

Productivity and Innovation Credit (PIC): Aimed at encouraging companies to invest in productivity improvements and innovation, offering tax deductions, allowances, and cash payouts.

Research and Development (R&D) Tax Incentives: Companies conducting R&D activities can benefit from tax deductions and allowances.The government should offers significant tax credits and direct funding for companies engaged in R&D, particularly industries fostering innovation in manufacturing technologies.

2. Infrastructure Support:

Special-Purpose Corporation: The government should dedicate an agency responsible for developing industrial infrastructure. The agency will provide specialized industrial estates and facilities to support the needs of manufacturing companies.

3. Funding and Financing:

Enterprise Financing Schemes (EFS): these should provide loans and financial support to SMEs in manufacturing for various needs, including working capital, equipment purchase, and trade financing.

Grants for Innovation and Productivity (GIP): these are to offer funding for companies to innovate, automate, and adopt new technologies in their manufacturing processes.

4. Workforce & Skills Development:

Skills Future: is national movement that offers Singaporeans grants and credits to individuals and companies to upskill workers, with a focus on the manufacturing sector's needs; this offers them with opportunities to develop their fullest potential throughout life, regardless of their starting point.

Professional Conversion Programmes (PCP): This is a program in Singapore targeted at Professionals,Managers,Executives and Technicians (PMETs) mid-career switchers to unergo skills conversion and move into new occupations or sector that have good prospects and opportunities for progression. The program provides training and salary support for workers transitioning into manufacturing-related roles.

Human Resources Development Programs: The government to invest in education and vocational training specifically tailored for the manufacturing sector, including initiatives for up-skilling workers in new technologies.

5. Industrial Policy and Financial Support:

Strategic Industries Promotion: The government to designate key industries (like semiconductors, automobiles) and provided direct subsidies, low-interest loans, and tax incentives.

Credit Guarantee Fund and Finance Corporation: Such institutions should provide financial guarantees and loans to manufacturing companies, particularly SMEs.

6. Industrial Clusters and Special Economic Zones (SEZs):

Industrial Complexes and Technoparks: The government should develop industrial complexes where manufacturers benefit from shared infrastructure, reduced land costs, and other subsidies.

Free Economic Zones (FEZs): Special zones offering tax breaks, reduced tariffs, and streamlined regulatory processes to attract foreign and domestic manufacturing investments.

The two Asian economic giants have transformed their manufacturing sectors into globally competitive industries through these measures and by focusing on creating a business-friendly environment with a strong emphasis on innovation and direct support to key industries and fostering a skilled workforce. These efforts have resulted in sustained growth, high levels of productivity, and significant contributions to each country's GDP.

Kenyan government by creating subsidized loan schemes and credit facilities for SMEs in the manufacturing sector can alleviate financial constraints. Development of financial institutions can play a crucial role in this regard.

Government-led initiatives in Investment Promotion will attract foreign direct investment (FDI) in manufacturing in turn bringing in capital, technology, and expertise.

4. Industry's Role in Enhancing the Manufacturing Sector (Eng. Sang)

4.1 Adoption of Technology and Innovation

Modernization of Production Processes: Industries must invest in modern machinery and technology to enhance productivity and competitiveness. Adoption of Industry 4.0 technologies, such as automation and the Internet of Things (IoT), can revolutionize manufacturing processes.

Research and Development (R&D): Investment in R&D is essential for innovation and the development of new products. Collaborative R&D efforts between industry and academia can yield significant advancements.

4.2 Market Development

Export Promotion: Industries should actively participate in international trade fairs and expos to showcase Kenyan products. Forming strategic alliances with international partners can also enhance market access.

Quality Standards: Adhering to international quality standards can make Kenyan products more competitive in the global market. Certification and compliance with these standards should be a priority.

4.3 Sustainable Practices

Environmental Sustainability: Adopting environmentally sustainable practices, such as waste reduction and energy-efficient processes, is crucial. Green manufacturing not only meets regulatory requirements but also appeals to environmentally conscious consumers.

Corporate Social Responsibility (CSR): Industry players should engage in CSR activities that benefit local communities and contribute to socio-economic development.

5. Collaborative Efforts (Mathope)

5.1 Public-Private Partnerships (PPPs)

Public-Private Partnerships (PPPs) are collaborative engagement between government entities and private sector partners designed to deliver public infrastructure projects leveraging the strengths of both sectors while such partnerships aim to achieve shared goals, balancing the responsibilities and risks involved. PPPs provide a robust framework that involves the private sector in a way that ensures the government meets its socio-economic obligations, successfully implements sector reforms, and achieves public investments. By optimizing the allocation of tasks, responsibilities, and risks among public and private partners, PPPs foster an environment conducive to industrial growth and development (Asian development Bank).

PPPs can be instrumental in driving growth across various economic sectors and enhancing a country's productive value chains. The government and private sector can collaboratively mobilize resources to promote sustainability in the manufacturing sector, particularly by supporting less profitable and under-incentivized value addition supply chains. This is achieved through risk-sharing, cooperative, and collaborative agreements, often formalized through contracts with flexible ownership structures between public and private entities, typically over the long term (Rai et al., 2017).

With the enactment of the Public-Private Partnerships Act, 2021, and the establishment of the PPP Directorate under the National Treasury, Kenya has reached an advanced level of preparedness with a solid legal and regulatory framework. This framework is expected to attract private investors to collaborate with the government in delivering turnkey projects. The Act aims to address institutional and governance challenges that have hindered the successful implementation of PPPs in Kenya. Transportation and infrastructure, health solutions, agricultural and blue economies, water and sanitation, housing, industrial parks and manufacturing, and ICT infrastructure are among the sectors targeted for investment (Cytonn.com, 2021).

In a lower-middle-income country like Kenya, the success of the manufacturing industry and its role in supporting a diverse and dynamic economy cannot be overstated. Over the years, targeted investments in expanding infrastructure, such as transport and health services, have led to the rise of PPP projects in the country. Some of these mega-projects, delivered through PPP engagements, were intended to bolster the country's efforts to stimulate the manufacturing industry. These investments are projected to positively impact the movement of people and goods while reducing production costs.

Developments in the transport sector, such as the expansion of trunk and access roads, are key areas expected to spur growth in sectors like agriculture and the blue economy, with a ripple effect on the manufacturing industry. The government has also developed Special Economic Zones (SEZs) and County Aggregation and Industrial Parks (CAIPs) to attract private sector investors and stimulate the manufacturing industry in the country. Private sector involvement in the development and operation of these parks can enhance services and lead to successful outcomes for both MSMEs and other investors by providing investment-ready infrastructure.

Public-Private Partnerships (PPPs) play a crucial role in facilitating technology transfer, skills development, and human capital support. Private investors have significantly contributed to the education sector by partnering with the government to establish educational institutions, techno-parks, and incubation centres. (Stiglitz & Wallsten, 1999), in their analysis of the impact of PPPs in technology, emphasized that government-industry collaboration in research and development (R&D) can bridge the gap between private and social outcomes, yielding substantial benefits for both sectors. The incentivization of skills development, the active involvement of academia in PPP-driven R&D projects, and rigorous government oversight to ensure that knowledge transfer aligns with specific goals and effective commercialization of skills are essential for fostering the growth and sustainability of Micro, Small, and Medium Enterprises (MSMEs) in the manufacturing industry.

5.2 Industry Associations and Advocacy

Manufacturing industry, like many other sectors, plays a significant role in the economic growth of a country. There are numerous challenges posed to this sector that require collective and coordinated approach to address them. Industry associations and advocacy is such an important tool that provides these mechanisms. This provides a platform for businesses to collaborate on common issues, share knowledge and best practices, and advocate for policies that support their growth and development. These groups are also key drivers of policy changes that create a more conducive environment for industrial development.

Industry associations engaging with government agencies, regulatory bodies, and other stakeholders to ensure that the interests of their members are effectively represented. Through lobbying for favourable regulations, tax incentives, and trade policies, these organizations help establish a framework that encourages expansion, innovation, and competitiveness. They play also a critical role in facilitating dialogue between the private sector, government, and other key players, fostering a business environment that supports sustainable industrial growth in Kenya.

There are several industrial associations and advocacy groups in Kenya, representing different players in the manufacturing industry along with other industries. The Kenya Association of Manufacturers is a key player as the premier representative of manufacturing and value-add industries in Kenya. The organizations key services include:

i. Policy advocacy where it makes policy and regulatory interventions, represents member interests at different levels of government and participates in legislative and budgetary processes,

ii. Business facilitation by supporting members easily comply with regulatory and statutory requirements, market linkage, sensitization, productivity improvement and MSME support,

iii. Information and training by conducting and supporting industry research, access to trade and market, dissemination industry related information ad release of industry report.

iv. Networking and linkages by conducting interactive forums such as gala nights, sectoral and regional forums, industrial visits, seminars and other engagement activities. (KAM, 2023)

There are other advocacy groups in the country include Federation of Kenyan Employers (FKE), Kenya Private Sector Alliance (KEPSA), Fresh Produce Exporters Association of Kenya (FPEAK), Fresh Produce Exporters Association of Kenya (FPEAK), Kenya Flower Council (KFC), The Eastern Africa Association among others. These organization serve similar purposes in supporting their members.

To support a vibrant sustainable manufacturing industry, advocacy groups and institutions can enhance the following interventions strategically targeted to support the manufacturing industry:

a) Policy Advocacy, Standard Setting and Compliance:

Kenya is known to have one of the most progressive constitutions in the Sub-Saharan Africa which puts public participation at the centre of legislative and policy formulation process. Advocacy groups can capitalize on this by ensuring that their members' interest in the introduction of policies and procedures do not disadvantage their member.

Certain policies and legal procedures introduced by the government can inadvertently work to the disbenefit of key players in the manufacturing sector. Recent years, we have witnessed a lot of such regulations. Government may sometimes need to be reminded of the effects of such regulation at the point of public participation.

It's the work of such groups to lobby for favourable tax policies, trade regulations, and incentives that support industrial growth. The need for infrastructure improvements, such as reliable energy and transportation networks, essential for manufacturing is also key point of focus for this groups.

Recent years, active participation and advocacy was witnessed around the finance bills that were used to undertake raft of tax law reforms, county legislations, illicit trade prevention efforts, energy legislation including the introduction of net metering regulations 2024, participation in standards development technical committees among others.

It is also expected that advocacy groups help their members ensure compliance with regulatory and statutory requirements, collaborate with regulatory bodies to establish industry standards that ensure quality, safety, and sustainability and promote adherence to these standards.

b) Capacity Building and Collaborations:

Capacity building is a very important endeavour that can help achieve sustainability in the manufacturing industry. With rapid growth in technology, the need for short and quick product development cycles, continuous innovation and upgrading human capital is very important. Industry groups such as KAM have invested in Industrial hub where knowledge good manufacturing practices, quality management and other skills needed are provided.

Research and Development (R&D) initiatives that are sector focused can be promoted through advocacy groups be established collaboration forums between members where R&D is conducted and finance jointly by members of similar interests. Academia-Industry-Government collaboration to enhance R&D culture is very important both for the growth of local industry and capacity building for workforce development. This collaboration can only be fostered more successfully with the involvement of industry membership organizations. Also of importance is the collaboration between peers in the industry and exchange of knowledge, technology transfer from international players.

c) Facilitating Access to Finance:

Advocacy for favourable financial policies, availability and access to affordable credit is very essential pillar that can spur and sustain growth in the manufacturing sector. This also build confidence in the reliability and resilience of the industry thus attracting more investment to the country.

Advocacy can partner with government and financial institutions to create tailor-made financial products for the manufacturing sector. This will go along way by ensuring that their an increased interest among Kenyans to venture into manufacturing.

d) Market Access and Expansion:

Government of Kenya has over the years invested in export promotion, trade facilitation and provide a seamless market access to Kenyan manufacturers. However, many Kenya manufactures have not utilized these opportunities to their fullest. Advocacy groups need to enhance their effort in creating awareness among members about these initiatives, conduct trade fairs and missions where Kenyan industry can participate and be connected to market more easily.

These groups should also help members to navigate through export regulations, benefit from market access opportunities presented by regional integration, single market agreements and other fora.

e) Promoting Sustainable Practices:

Climate and environmental sustainability is of paramount importance in todays industry. Over the years, sustainable practices have become an integral part of the growth of any industry. Industry membership groups can play a leading role in the adoption of these practices, help members transition to green practices and adopt sustainable manufacturing practices. The recently gazetted net-metering regulations 2024 provide a paradigm shift in the adoption of renewable energy. However, it is now very important that industry players are informed of the opportunities presented by such regulations.

f) Data Collection and Analysis:

Data driven advocacy strategic decision making is an important facet of smart and effective way to influence legislative and regulatory developments that are aimed at supporting in the industry. It is the responsibility of membership and advocacy groups that this information is collected analysed and presented to policymakers in a organized manner to inform the direction take by the country. This information can also prove to be critical in guiding investment in R&D by government and other financial institutions partners. Media and information sector also need the insights and trends obtained from such data to inform how they engage and inform the public in civic education and upraise them of changing trends in the country regarding this sector.

g) Enhancing Industry Reputation:

Finally, public perception is very important and can help harness a wider support for players in the industry both by the government and their electorate. Industry advocacy groups will need to educate their members on this and promote ethical practices and corporate social responsibility among members to build trust with consumers and stakeholders. A good reputation is also good for brand equity, where manufacturers can leverage on their good brand awareness to push theor products into the market and even harness access and market shares in the region because the good image at home. Safaricom and equity bank have capitalized in this and ventured into neighbouring countries in the region.

6. Role of Regulatory Bodies

Regulatory bodies are fundamental in shaping a conducive environment for the manufacturing sector by ensuring adherence to standards, promoting fair competition, and safeguarding consumer and environmental interests. Regulation is key in eliminating technical barriers to trade, fight against illicit trade and ensure compliance with standards and other regulatory requirements. The key functions of industry regulators encompass the formulation and enforcement of regulations, the provision of certifications, the facilitation of industry development and the dissemination of information. By establishing clear guidelines and monitoring compliance, these bodies not only uphold quality and safety but also drive innovation and efficiency within the sector, ultimately contributing to sustainable economic growth.

6.1 Quality Infrastructure and Trade Facilitation

Kenya Ministry of Investment, Trade and Industry has in the recent passed released the draft national quality policy which is expected to promote economic prosperity through quality products and services in line with government policies and objectives including Vision 2030. The policy brings together organizations (public and private) together with the policies, relevant legal and regulatory framework, and practices needed to support and enhance the quality, safety and environmental soundness of goods, services, and processes. The key players in the quality infrastructure in Kenya that are very pivotal in the sustainable growth of the manufacturing industry are explained below.

a) Kenya Bureau of Standards (KEBS)

Kenya Bureau of Standards (KEBS) is the government agency mandated to provide standardization, metrology and conformity assessments (SMCA) services in the country. KEBS is responsible for developing and enforcing standards to ensure that Kenyan manufactured goods meet both local and international quality requirements. By maintaining high standards, KEBS helps improve the competitiveness of Kenyan products in global markets.

KEBS play an essential role in enhancing the competitiveness of Kenyan Made products both the regional, continental and global stage and ensure smooth market access for the same.

i. Standardization: As the organization mandated to facilitate standardization of goods and services, KEBS should focus on developing market-oriented standards that are dynamic and responsive to the need of Kenyan market while ensuring that such standards are attainable by Kenyan manufacturers. In collaboration with industry advocacy groups, manufacturers and academia, KEBS can play a pivotal role by ensure sustained growth of the manufacturing industry by adopting a responsive approach to market needs and expectations in terms of standardization.

ii. Promotion of fair trade and production of safe and quality products: KEBS operates a product certification scheme that covers and certifies all products made in the country after a stringent product and process evaluation. The organisation also conducts surveillance both the factory and market levels to ensure compliance and enforcement is conducted. Through these activities, KEBS is expected to maintain fair trade policy to ensure Kenyan manufacturers are protected from illicit trade by unscrupulous traders. Through Imports inspection, the organization has the weapon to ensure that substandard products do not flood the Kenya market to ensure sustainability of locally manufactured products.

iii. Adoption and harmonization of Kenyan standards with regional, continental and international standards: This will ensure market access of products made locally to countries in the continent and the global stage. To build a competitive export-oriented industry, the bureau should build capacity among Kenyan producers and ensure Kenya takes a leadership role in the regional and continental market integration.

iv. Focus on MSME and capacity building: The Kenyan MSME needs both capacity building and support to help them access market for the products. KEBS can formulate a MSME friendly certification scheme that makes it easy for the cottage industry to comply with and ensure continuous support is provided to this segment through continuous capacity building to improve their competitiveness.

v. Close collaboration and coordination with industry membership and advocacy groups to support seamless uptake of standards and enhance compliance with requirements for locally manufactured products.

6.2 Environmental Regulation

Section 7 of the Environment Management and Coordination Act, EMCA, CAP 387 of the laws of Kenya establish an authority that is tasked to undertake all actions needed to ensure clean, health and sustainable environment in Kenya through supervision and coordination of all matters elating to the environment. This authority is called National Environment Management Authority (NEMA).

In its draft 2023-2027 strategic plan, the organization lays out its contribution to the UN SDGs 6, 7, 11,12 and 13 which are also deemed very essential in supporting the sustainable growth of a resilient manufacturing industry in the country. The organization has also committed to support the African Union Agenda 2063 and East Africa Community Vision 2050 to promote an inclusive and sustainable socio-economical growth, transformation and development. (NEMA, 20204). The organization identifies Climate change, Ecological integrity of ecosystems, Environmental Pollution, and Green and Circular Economy as four of its five strategic goals for the five year period of 2023-2027.

The successful achievement of the Key Result Areas (KRAs) tied to these goals ideal for realization of transformative, resilient and sustainable manufacturing systems. However, from analysis of the available literation, the involvement of the authority in promoting the development of the manufacturing sector through collaboration, capacity building and other targeted support was seen to be minimal if not non-existent.

The manufacturing industry is a big contributor (both positively and negatively) to environmental sustainability. The authority can build capacity for this sector to promote investment in circular-economy-oriented manufacturing, adoption of green energy and sustainable practices. A nearly non-existent waste recycling is a field NEMA is encouraged to support and incubate MSME investment in the same. Kenyan industry is not very keen on carbon trading and attracting financial support that comes with the emerging market. Creation of awareness among Kenyan manufacturers specially in the agricultural value addition segment of the industry will go a long way in promoting the government's goal to support the global effort to achieve net-zero carbon emission while at the same time attracting the much-needed credit facility that comes with such initiatives.

6.3 Consumer Protection and Fair Competition

The Competition Authority of Kenya was established under Section 7 of the Competition Act No. 12 of 2010 and is responsible for, among other things, promoting and ensuring compliance with the Act. One key objective of the Act is to safeguard consumers from unfair and deceptive market practices. To strengthen this mandate, the Act was amended in 2016 to include Section 70(A), granting the Authority the power to independently initiate investigations into consumer violations and impose administrative remedies.

Legal framework for consumer protection in Kenya prior to the 2010 constitution was majorly fragmented with different aspects covered by varied acts of parliament and other legislative pieces including the standards act Cap 496, Weights and Measures Act Cap 513, the Foods, Drugs and Chemical Substances Act Cap 254, the Pharmacy and Poisons Act Cap 244, the Public Health Act Cap 242 among other laws. Since 1963, there were no express provisions in law that directly regulated the protection of Kenya consumer or even define their rights.

This has over time created gaps that benefitted profiteers and fostered unscrupulous practices where consumers were exposed to misleading advertisement and misinformation. Following the enactment of the 2010 constitution and the consumer protection act 2012, this gap was sealed, and legal redress was provided for unfair trade practices and consumer rights.

Article 46 of the 2010 constitution of Kenya provides the rights of a consumer which include the rights:

i. to goods and services of reasonable quality.

ii. to the information necessary for them to gain full benefit from goods and services.

iii. to the protection of their health, safety, and economic interests.

iv. to compensation for loss or injury arising from defects in goods or services.

The United Nations has developed the guidelines for consumer protection in 2016 which were intended to provide a valuable set of principles that set out the main characteristics of effective consumer protection legislation, enforcement institutions and redress systems. The guidelines are widely accepted as the benchmark for international framework for promoting consumer protection and encourages its adoption and implementation by member states.

Countries that have achieved reasonable success in consumer protection have used risk-based approaches to ensure compliance where high sectors and products that are more susceptible to consumer fraud and counterfeiting are closely monitored. Risk profiling is done for different kinds of businesses forming the bases for the risk-based monitoring. (Fadi Adra, 2017)

Consumer protection and fair-trade policies foster innovation which leads to better-quality products and services being offered at a competitive price, thus increasing both consumer and producer welfare. Competition law was deemed the most appropriate and least intrusive way of regulating markets. It also encourages smooth entrants by reducing barriers for manufacturers to access market and protects them from unfair competition and monopolistic tendencies of established market players.

6.4 Industrial Development Facilitation

Sessional Paper No. 9 Of 2012 on The National Industrialization Policy Framework For Kenya 2012 – 2030 provided a policy framework and strategies to revitalise the industrial sector for effective contribution to national growth, employment and wealth creation. The national industrialization policy was intended to provide guiding framework to help the nation achieve the vision 2030 that intends to build a newly industrialized middle-income nation.

A situational analysis conducted through this policy framework has how the government of Kenya over the years has tried to prope up the manufacturing industry. Through sessional papers and policies, the government has tried to build an export oriented industry which was aimed to improve efficiency in the entire economy, stimulate private investment and increase the sector's foreign exchange earnings. These attempts include Sessional paper No.1 of 1986 on renewed economic growth, Sessional Paper No.2 of 1996 on Industrial Transformation to the Year 2020, Master Plan for Kenya Industrial Development 2008 and the Kenya vision 2030.

While strong industrialization policies and support for export promotion has was believed to the magic trigger that could drive a country in to the league of newly industrialized countries, this has not be the reality for Kenya. Despite the long list of strongly worded policies, there has been a constant decline of the contribution of the manufacturing sector to the national GDP from over 10% in 2006 to roughly about 7% in 2024 despite the increased output.

This is policies have not led much success in the country's manufacturing sector. This majorly resulted from lack of coordinated effort to implement these policies from time to time or lack of inter-ministerial approach where when one part of government was working on the promotion of industry, the other side was busy pushing policies that made the business environment very unsuitable for investment. This is evident from the tax regimes that were introduced every other year that made setting up shop in the country very hard and unprofitable.

To promote industrial development, there is a need for a whole government approach where apart from providing financial support for Kenyan investors, the government needs to encourage foreign direct investment, attract investments in the high skill/high technology industries that will integrate informal MSMEs in the form value chain.

Through investment facilitation efforts for Kenya provided by the government through agencies like Kenya Development Corporation (KDC), there is a need to target investment in manufacturing industries by supporting MSMEs in the cottage and informal sector to take up government funds and invest in value addition.

Promotion of PPP in investment, research and development to support the manufacturing industry is another approach that has not been much explored in Kenya. There investors out there who, when guaranteed government and return on investment, can invest in targeted value chains to spur growth and development for the manufacturing industry.

7. Conclusion

The enhancement of Kenya's manufacturing sector requires a concerted effort from both the government and industry. By implementing strategic policies, investing in infrastructure, promoting skills development, and fostering innovation, Kenya can unlock the full potential of its manufacturing sector. Collaborative efforts and partnerships will be key to achieving sustainable growth and making Kenya a competitive manufacturing hub in the region.

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Reducing Household Air Pollution: The Crucial Role of Kenyan Engineers in the Clean Cooking Transition

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Introduction

Cooking is a fundamental human activity, and access to clean cooking fuels is a key indicator of the United Nations Sustainable Development Goal (SDG) 7. According to the World Health Organization (WHO), clean cooking involves using low-to-zero emission fuels and technologies, such as clean cookstoves, liquefied petroleum gas (LPG), natural gas, ethanol, electricity, or solar energy. In contrast, biomass (wood, charcoal, crop waste, and animal dung), coal, and kerosene are classified as pollutant fuels due to their high emissions. This classification is primarily based on the concentration of fine particulate matter (PM2.5) and carbon monoxide (CO) emissions, with soot and smoke being the most recognizable forms of these pollutants. To qualify as a clean cooking solution, PM2.5 and CO emissions must not exceed 62 mg/MJ and 3.0 g/MJ, respectively[1].

Health Effects of Pollutant Cooking Fuels and Technologies

Pollutant cooking fuels pose significant health risks, particularly for low-income households that rely on them. Women, children, and the elderly are disproportionately affected due to gender roles, prolonged indoor exposure, and weaker immune systems. While all cooking fuels emit some level of PM2.5, pollutant fuels produce significantly higher concentrations, leading to increased household air pollution (HAP). HAP is a major contributor to premature deaths and respiratory illnesses such as asthma, pneumonia, heart disease, stroke, chronic obstructive pulmonary disease (COPD), and lung cancer[2]. Traditional cooking technologies using pollutant fuels also heighten the risk of severe burns. Additionally, studies link solid fuel use to headaches and eye disorders[3], including nuclear cataracts, conjunctivitis, and conditions affecting the sclera, cornea, iris, and ciliary body (DSCIC). For expectant mothers, exposure to these fuels is associated with low birth weight and stillbirths[4].

Cooking in Kenya: Key Statistics

According to the 2022 Demographic and Health Survey (DHS) by the Kenya National Bureau of Statistics (KNBS), fuel stacking is common in Kenyan households, with the primary fuel sources shown in Figure 1. Approximately 68.5% of the population relies primarily on non-clean fuels for cooking, with 81% of these users residing in rural areas—highlighting the urban-rural disparity in clean cooking access[5]. The widespread use of pollutant fuels has led to emission levels exceeding WHO guidelines, contributing to significant health burden. In 2021, HAP was linked to approximately 26,300 premature deaths, accounting for 8.6% of total deaths that year.Under-five child mortality, largely due to respiratory complications from HAP, was reported at 31 per 1,000 births[6]. While the overall death rate from HAP has declined from 142 per 100,000 people in 1990 to 129 per 100,000 in 2021—primarily due to increased adoption of LPG and improved cookstoves—factors such as population growth and the reliability of the data collection methods must be considered when interpreting these trends.

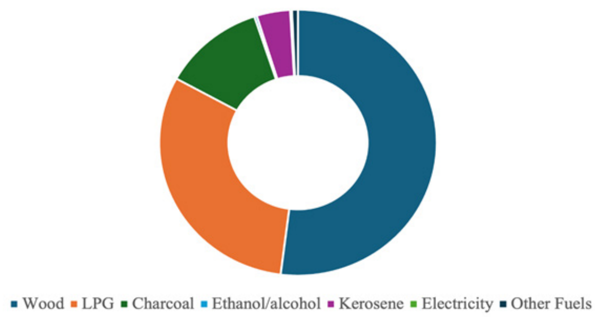

Figure 2: Cooking fuel mix in Kenya (2021).

Government Policies and Initiatives Towards Clean Cooking Transition

Clean cooking transition is a key priority in Kenya's policy framework, highlighted in documents such as *Kenya Vision 2030[7]*, the *National Climate Change Action Plan (NCCAP) III (2023–2027)[8]*, and Kenya's Nationally Determined Contribution (NDC) under the UNFCCC Paris Agreement. Since 2010, the Government of Kenya and its partners have demonstrated strong commitment to this transition, doubling clean cooking access from 15% to 31%[5]. However, under a business-as-usual scenario, approximately 60% households will still rely on solid fuels by 2030—despite the goal of achieving universal clean cooking access by then.

To address this, the Kenya National Cooking Transition Strategy (KNCTS)[5] was launched in 2022 as a data-driven, inclusive, and transparent framework to accelerate sustainable and profitable clean cooking access by 2028. The strategy provides a comprehensive baseline assessment of Kenya's clean cooking sector, analysing the current energy mix, gender dimensions, barriers, opportunities, and enabling factors for adoption. Using modelling techniques, it proposes an optimal cooking energy mix and outlines a roadmap to achieving universal access, as illustrated in Figure 2.

To increase electric cooking adoption from the current paltry 0.2% to the projected 10%, the *Kenya Off-Grid Solar Access Programme[7]* is enhancing electricity access and clean energy transitions in 14 underserved counties. Additionally, Kenya Power & Lighting Company Plc (KPLC) and its partners are running live electric cooking demonstrations under the Pika Na Power initiative[9]. This program educates the public on energy-efficient electric cooking appliances, their benefits, and how to prepare local meals using electricity—aiming to dispel common myths, such as the belief that electric cooking is costly or that it compromises food taste.

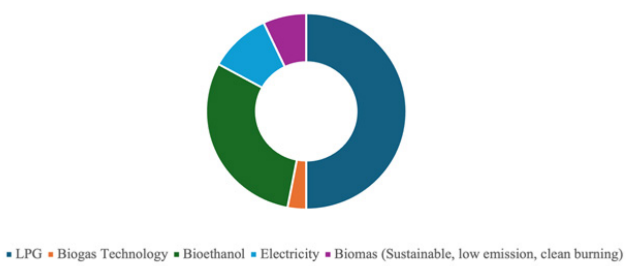

Figure 3: Modelled cooking fuel mix in Kenya (2028).

The Role of Engineers in Reducing HAP

Engineers play a crucial role in mitigating household air pollution (HAP) by designing and implementing clean cooking systems, improving infrastructure, and advocating for sustainable solutions. Their contributions span multiple areas, including:

a) Ventilation and Air Quality Monitoring - Engineers involved in housing construction should ensure proper natural ventilation and incorporate air purification systems such as chimneys and hoods. Additionally, integrating real-time air quality monitoring devices can help track household air pollution levels and support data-driven interventions.

b) Renewable Energy-Powered Cooking Solutions - Engineers can design and implement cost-effective, renewable energy-based cooking solutions such as solar cookers, biogas systems, and electric stoves. In off-grid rural areas, where electrification efforts rely on mini-grids and Solar Home Systems (SHS), integrating energy or thermal storage solutions can enable reliable clean cooking on power-limited solar photovoltaic (PV) systems. Among refugees and pastoral communities, engineers can advocate for communal clean cooking facilities in partnership with governments and development organizations.

c) Clean Cooking Technology Development - Optimizing cookstove designs to enhance combustion efficiency and minimize emissions is a key engineering challenge. Engineers can develop energy-efficient cookers that leverage induction and pressure-cooking principles, which are particularly viable given Kenya's predominantly renewable electricity supply. Integrating sensor-based monitoring systems can further enhance efficiency, track emissions, verify carbon footprints, and enable seamless payment system integration.

d) Research and Development (R&D) - Engineers can advance clean cooking technologies by improving affordability, usability, and performance. Research and innovations in low-cost insulation, catalytic materials, thermal batteries, and phase change materials can enhance energy efficiency while reducing emissions. Collaboration with health professionals and development stakeholders can help ensure that these technologies are culturally appropriate, effectively support local cooking needs, and utilize sustainable fuel sources.

e) Capacity Building and Training - As part of local communities, engineers should facilitate training programs for technicians and end-users to ensure the safe installation, operation, and maintenance of clean cooking technologies. Additionally, they should collaborate with stakeholders to raise public awareness of the benefits of clean cooking and proper technology use.

f) Clean Cooking Standards and Policy Development - Engineers, in collaboration with policymakers and experts, play a key role in establishing national standards for clean cooking technologies to ensure safety and emission compliance. They should also provide technical advisory support to governmental and non-governmental organizations in developing policies and programs that promote clean cooking adoption. For example, engineers and economists can work together to design special electricity tariffs for affordable electric cooking and efficient grid load management[10].

Conclusion

The widespread reliance on biomass for cooking remains the leading contributor to HAP in Kenya, resulting in severe health consequences which strains the healthcare system and overall low standard of living. While significant efforts have been made to promote the clean cooking transition, progress has slowed down in recent years, meaning many households will still depend on pollutant fuels by 2030. Engineers, in collaboration with other stakeholders, must act by designing, developing, and implementing affordable, context-appropriate clean cooking solutions. Beyond technology development, their role extends to infrastructure planning, policy advocacy, capacity building, and research—ensuring a sustainable transition that reduces HAP and improves public health.

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Impact of Engineers in Digital Transformation and Innovation: Focus on Biomedical Engineering, Biotechnology and Telemedicine to Improve Healthcare

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1.0 Introduction

Digital transformation is rapidly changing public services, bringing new benefits, innovation, and accessibility. Engineers in Healthcare are at the forefront of this change, driving progress and improving the quality of healthcare services. Biomedical engineering, biotechnology and telemedicine are the key areas where engineering innovation is changing the healthcare landscape. This article explores the important role of professionals in the digital transformation of healthcare and how their involvement in these areas can improve patient outcomes, efficiency and overall Healthcare.

2.0 Literature review

Digital Transformation in Healthcare

Digital transformation in healthcare provides solutions to boost health systems, such as bringing health services directly to people's homes and underserved communities, assisting in the mapping of disease epidemics, and using digital tools that make health care more responsive and productive.

The global health system is rapidly adapting to the impact of digital transformation and innovation, which is reaching the world of health. The role of engineers is important, directing their training to achieve off-site assistance, improve patient management, provide comfortable treatments, make early diagnoses, assist the healthcare staff, and provide reliable e-health information and communication methods, as well as protection. Also, take into consideration the issues concerning consent, privacy, and solvency. The engineers will participate in optimization and cost reduction. Digital transformation is easy to understand for e-consultation, e-treatments, e-monitoring, and e-prevention and is the most relevant need in terms of health innovation (Marques & Ferreira, 2020). It will also simplify clinical processes, provide real-time data, and streamline consultation management, thanks to telemedicine; facilitate real-time care thanks to big data and artificial intelligence; and improve clinical efficiency (Hermes et al.2020). Telemedicine can reduce inappropriate emissions, admissions, and consultations. Some remote healthcare solutions can also assist doctors and administrators in managing emergencies, disasters, and outbreaks quickly, saving time and resources. Moreover, the engineers in the field of digital transformation have increased their ability to create real solutions (Kraus et al.2021)

Although the phrase "digital health" may evoke visions of cutting-edge, futuristic technology, it can actually refer to a variety of interventions, including:

- Biomedical engineering;
- Bio technology;
- Telemedicine;
- Electronic health records and standards underpinning the exchange of data;
- Public health portals that provide transparent access to an individual's personal health records and contacts with the health system;
- Clinical decision-making support tools in primary care;
- Nanotechnologies; and
- Artificial intelligence.

Biomedical Engineering: Revolutionizing Healthcare Technology

Biomedical engineering (BME) is an interdisciplinary field that combines principles of engineering, biology, and medicine to improve healthcare outcomes. Its impact on the health sector is profound, revolutionizing medical diagnosis, treatment and patient care.

Biomedical engineers are responsible for many medical devices, including:

1. Prosthetics: Artificial limbs that replicate the functionality of natural limbs, often incorporating advanced materials and technologies like robotics for better movement and control.

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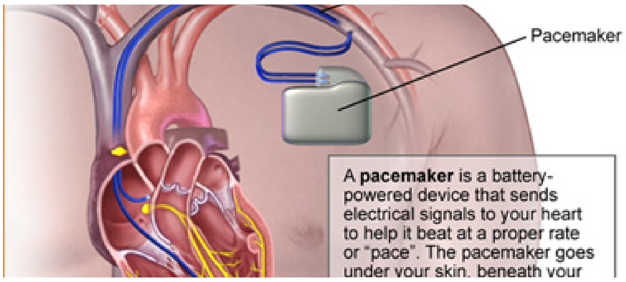
2. Implants: Devices implanted in the body, such as pacemakers, artificial joints, and dental implants, designed to restore function or support biological structures.



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3. Diagnostic Equipment: Tools such as MRI machines, CT scanners, and ultrasound devices. They provide physicians with detailed images of the human body, enabling earlier diagnosis and more precise treatments. These non-invasive technologies have drastically improved healthcare by allowing doctors to detect conditions like tumors, cardiovascular diseases, and neurological disorders without invasive procedures.

https://kenya.unfpa.org/sites/default/files/dsc_1151_1.jpeg

4. Therapeutic Devices: Equipment like infusion pumps, nebulizers, and laser surgery tools that deliver treatment to patients effectively and safely. Laser surgery is minimally invasive (no scalpels and cutting involved), allows extremely precise targeting of specific tissues hence very appropriate for delicate surgeries, is less painful, ensures minimal blood loss and reduced recovery time.

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5. Wearable Health Technology: Devices such as fitness trackers and smartwatches that monitor health metrics like heart rate and activity levels. These devices allow patients to actively engage in managing their health while enabling healthcare providers to track and analyse this data remotely, leading to early interventions when health problems are detected.

6. Robotics in Surgery: Robotic surgical systems, such as the da Vinci Surgical System, allow for minimally invasive procedures with greater precision.

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7. Biomaterials: Development of materials that interact with biological systems, used in various applications from sutures to scaffolds for tissue engineering. They are used to replace or repair damaged tissues, support the growth of new tissues, or function as part of a medical device or drug delivery systems.

8. Rehabilitation Devices: Tools like exoskeletons and physiotherapy equipment designed to assist in patient recovery and mobility improvement.

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Biotechnology

Biotechnology involves the use of biological systems and living organisms to develop medical innovations. Biotechnology's impact on the health sector is profound, driving innovations that enhance disease prevention, diagnosis, and treatment.

1. Development of Biopharmaceuticals: (Chung et al., 2020).

2. Genetic Engineering and Gene Therapy: (Nabel, 2018).

3. Diagnostics and Personalized Medicine: Advanced biotechnological techniques, such as PCR (Polymerase Chain Reaction) and next-generation sequencing, have significantly improved diagnostic capabilities. These methods allow for rapid detection of pathogens and genetic conditions, facilitating timely interventions. Moreover, biotechnology underpins personalized medicine, where treatments are tailored based on an individual's genetic profile, leading to more effective and targeted therapies (Collins & Varmus, 2015).

4. Vaccine Development: The rapid development of vaccines. Techniques like mRNA technology have revolutionized vaccine design, allowing for quick responses to emerging infectious diseases (Kahn et al., 2021).

5. Biomanufacturing: (Jiang et al., 2020).

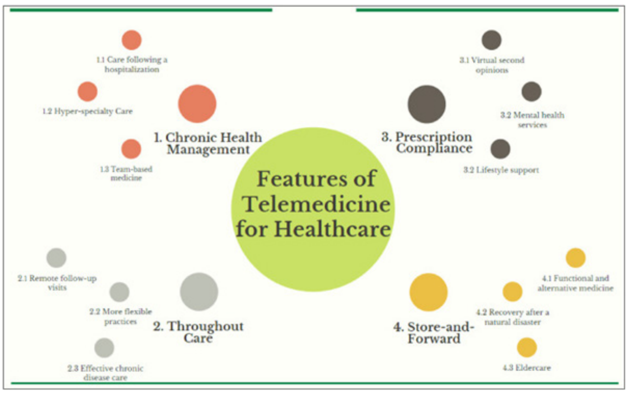
6. Regenerative Medicine: The field of regenerative medicine leverages biotechnological advancements to repair or replace damaged tissues and organs. Stem cell therapy, tissue engineering, and the use of biomaterials are key areas where biotechnology contributes to healing and recovery (Lanza et al., 2019).

Telemedicine

Regular hospital visits can be expensive due to travel expenses. During Covid-19 Pandemic, when physical interaction became risky, people turned to telemedicine.

Engineers in telecommunication, software development, and medical IT play a key role in creating the infrastructure that makes telemedicine possible.

In addition to increased access, telemedicine has also proven to be highly effective in managing chronic diseases. Engineers have developed remote monitoring systems that can track patients' vital signs, such as blood pressure, blood sugar, and heart rate, and quickly send the information to a doctor. This allows doctors to regularly monitor patients, intervene quickly, and adjust treatment plans as needed, improving the management of chronic conditions such as diabetes, hypertension, and heart disease.



Telemedicine for healthcare: Capabilities, features, barriers, and applications. *Sensors international,* 2, 100117. https://doi.org/10.1016/j.sintl.2021.100117

Electronic Health Records and Standards

Engineers have been instrumental in the development and implementation of electronic health records (EHRs), which streamline patient information management and increase access to healthcare providers. These digital systems are built on standard systems and facilitate the exchange of health information across multiple platforms and institutions. Standards such as Health Level Seven (HL7) and Fast Healthcare Interoperability Resources (FHIR) allow information to be shared securely and efficiently, better facilitating continuity of care and reducing the risk of medical errors. By enabling seamless data transfer, engineers support a more integrated healthcare system where patient information is readily available, enhancing clinical outcomes. If a person seeks medical care from another hospital, there is no need to repeat the test performed at the other hospital. Doctors also have access to all medical records, ensuring the best care is provided.

Public Health Portals

Public health portals are another significant innovation driven by engineers, providing transparent access to personal health records and interactions with the health system (Fischer et al., 2018).

Clinical Decision-Making Support Tools

In primary care, engineers develop clinical decision-making support tools that help physicians make decisions based on data and evidence. These tool uses algorithms and data analysis to provide patient-specific recommendations, alerts, and reminders. For example, engineers develop systems that can analyze patient history and identify drug interactions or recommend screening tests based on clinical guidelines. These tools help reduce errors and improve patient care by improving decision making processes.

Nanotechnologies

Nanotechnology is at the forefront of medical innovation, and engineers are at the forefront of its application. By manipulating nanoscale data, engineers create drug delivery plans, advanced imaging techniques, and diagnostic tools that can detect diseases at earlier stages. For example, nanoparticles can be designed to deliver chemotherapy drugs directly to cancer cells, minimizing damage to healthy tissues and improving treatment outcomes. This systematic review has the potential to improve treatment options and patient outcomes.

Artificial Intelligence

Artificial Intelligence (AI) is perhaps the latest revolution in healthcare today, with engineers developing complex algorithms that can analyze large amounts of data to uncover insights and patterns. Applications of AI range from predictive analytics to machine learning algorithms that help predict disease outbreaks and diagnose illnesses based on medical images. Engineers are designing these systems to support clinical decision-making, automate administrative tasks, and enhance patient engagement through chatbots and virtual assistants. Integrating AI into healthcare not only increases efficiency, but also enables personalized treatment plans based on individual patient needs.

Challenges and the Future of Engineering in Healthcare

Engineers are instrumental in the digital transformation of Healthcare, but there are still challenges to overcome.

Data privacy and cybersecurity are becoming major concerns, especially as more medical information is stored and transmitted digitally. Keeping patient data safe and healthcare systems secure from cyberattacks requires engineers to be innovative and vigilant.

The digital divide is another major challenge. Not all patients, especially in low-income and rural areas, have access to the internet or digital devices. Engineers must focus on creating solutions that will bridge this gap and ensure that telemedicine and other digital health innovations are accessible to everyone.

3.0 Conclusion

Engineers are at the forefront of the digital transformation in healthcare, innovating to improve patient care and operational efficiency. Their work in biomedical engineering, biotechnology, telemedicine, and AI is not only improving the quality of healthcare, but also making it accessible to many people. As the healthcare industry continues to use technology, the collaboration between engineering and medicine is vital to solving current issues such as data security and the digital divide. Moving forward, engineers will play a key role in using new technologies to improve healthcare in ways that benefit everyone, regardless of socioeconomic status. The future of healthcare will depend on the integration of engineering and medicine, leading to more efficient, responsive, and patient-centered healthcare system.

4.0 Recommendation

Engineers will have to innovate ways of ensuring that patient data is kept confidential despite it's accessibility for the purpose of tele-treatment and ensure healthcare systems are secure from cyberattacks.

Not all patients, especially in low-income and rural areas, have access to the internet or digital devices. Field research need to be conducted to assess the access level and alternatives be devised to support provision of telemedicine and other digital health innovations to everyone.

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Kenyatta University's Role in Advancing Medical Engineering Education and Research in Kenya

Kenyatta University (KU) strives to advance medical engineering education and research in Kenya in a time when technological developments hold the key to transform healthcare. Through Invention Education (IvE), program in partnership with Rice University, the Biodesign fellowship with Stanford University, the founding of a design studio with TiKA/Cezeri lab, and the scheduled Masters in Medical Devices Innovation launch, KU is reshining the future of healthcare with a strong focus on innovation, collaboration, and education.

Through the partnership on the Invention Education (IvE) program, Kenyatta University and Rice University have provided fresh paths for students to participate in innovative medical research and invention. This program presents a once-in-a-lifetime chance for students to work on practical medical difficulties, create creative ideas, and see them realized in close industry cooperation. By means of this cooperation, KU students expose themselves to the industry's best practices, research techniques, and modern medical technologies.

Through encouraging a creative and problem-solving attitude, the IvE program helps students to tackle urgent healthcare challenges. On the other hand, using Rice University's resources and experience, KU is giving its students the tools and knowledge required to lead in the field of medical engineering.

Fellow in Biodesign with Stanford University

The Biodesign fellowship with Stanford University marks another key milestone in KU's efforts to advance Healthcare Technology Innovations. This fellowship program is intended to provide fellows with the skills and experience necessary to identify unmet medical needs, conceptualize novel solutions, and turn them into commercial products.

Design Studio for TiKA/Cezeri Lab

Innovation thrives in a culture that values experimentation and collaboration. Our construction of a design studio in collaboration with the TiKa/Cezeri lab demonstrates the university's dedication to promoting creativity and innovation. This design studio serves as a gathering place for students, educators, and researchers to collaborate on groundbreaking initiatives that solve crucial healthcare issues.

With cutting-edge technology and resources, the design studio creates an ideal setting for brainstorming, prototyping, and testing. By bringing together varied ideas and viewpoints, KU is fostering a collaborative ecosystem that fosters the creation of innovative medical equipment and solutions. The relationship with the TiKA/Cezeri lab strengthens the university's ability to foster creativity and bring transformational ideas to reality.

Launch of Masters in Medical Devices Innovation

Kenyatta University intends to develop a Masters in Medical Devices Innovation to meet the growing demand for qualified people in medical engineering. This program seeks to equip students with superior education and training, preparing them to flourish in the rapidly expanding field of medical technology.

The Masters program will address a variety of topics, such as medical device design, regulatory affairs, clinical trials, and commercialization methods. KU ensures that its graduates have the knowledge and skills required to manage the complexity of the medical device industry by delivering specialized courses and hands-on training. This program will be essential in developing the next generation of medical engineering innovators and leaders.

Conclusion

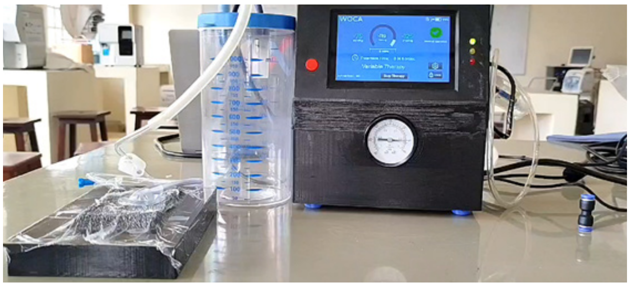
Kenyatta University's commitment to medical engineering teaching and research is seen in its strategic alliances, innovative programs, and emphasis on encouraging creativity. Collaborating with famous institutions such as Rice University and Stanford University, as well as creating cutting-edge facilities in conjunction with TiKa/Cezeri lab go a long way in defining the future of healthcare in Kenya and beyond.

As KU continues to push the boundaries of medical engineering, it is well positioned to make important contributions to the global healthcare scene. KU's activities empower students to become pioneers in medical innovation, eventually boosting healthcare quality and community well-being.

Picture 1

Picture 2

(Pictures 1 and 2): Hands-on prototyping of medical device innovation



Picture 3

Picture 4

Sample Innovations include : Picture 3: Wound healing device and Picture 4: Laparoscopic device

(Picture 5): IvE Makerspace Workshop held in January 2025 with facilitators from RiceUniversity, and attended by partners from the IvE network in Nigeria, Tanzania and Malawi

Picture 6: Invention Education Program showcase during Kenya Innovation Week 2024

Picture 7

Picture 8

(Pictures 4 and 5: East Africa Biodesign 2025 Cohort Fellows during the training bootcamp)

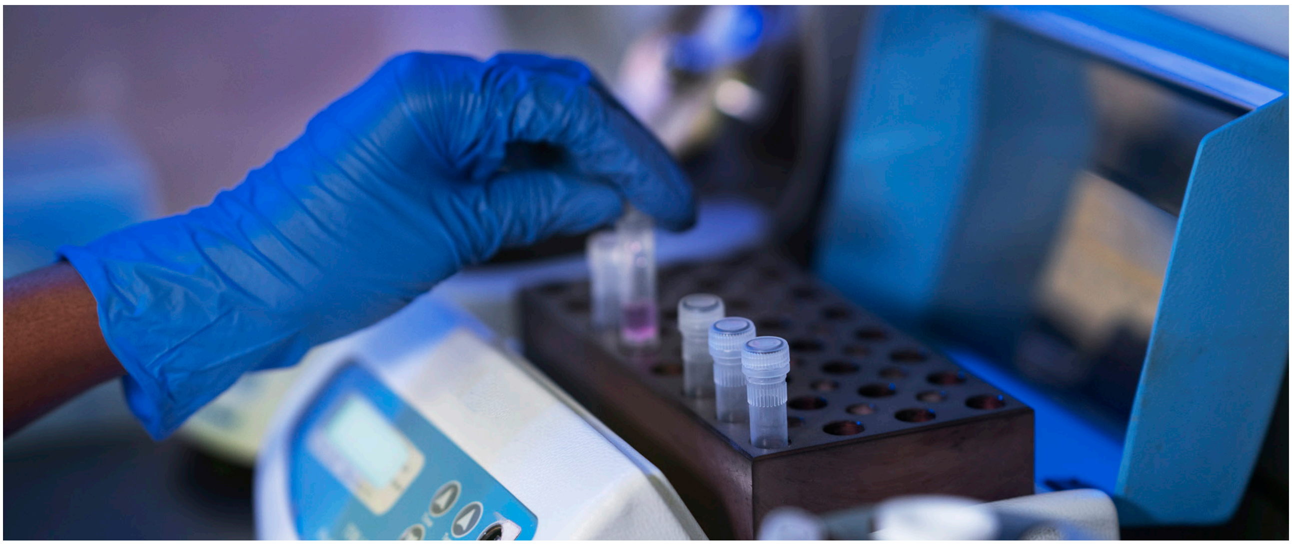
Picture 9

Picture 10

(Pictures 6 and 7: Trainings on training and production in advanced technology at the Cezeri Lab Digital Design and Production Laboratory)

Picture 11: Launch of the partnership between Kenyatta University and Rice University, on 8th January 2025

Picture 12:Casey Howard (L) and Professor Matthew Wettergreen (R) with the Ag. Vice Chancellor Prof. Waceke Wanyoro during the launch of the partnership between Kenyatta University and Rice University



Innovations in Prototyping Medical Devices

Dr. Kamau Gachigi
Founder and Executive Director
Gearbox Kenya Limited

What informed the decision to start up Gearbox Kenya Ltd?

I have been in academia, teaching, since 2000. What happened in Kenya in the early 2000s in our economic landscape in technology was the advent of MPesa, which changed everything. From our point of view, in academia, it opened up alot of opportunities, and we started to see a lot of startup companies coming out of the university community especially computer science students developing successful apps. We had always suffered from the absorbability of our graduates in engineering into career space. Consider the Big Four Agenda, you need a certain number of engineers to achieve those plans. If you benchmark with what's happening in the Far East, or what has happened in the Far East in terms of development, we need many, many more engineers per capita to grow in the manner that they have.

Ironically, we have too few engineers when measured from the point of view of our national development plans, and yet even the few we have cannot find jobs.

So, any way in which engineers can graduate and then find themselves useful to the economy is important, and business is a very big opportunity for that. We always hear people say, 'Don't go to be employed.' Of course, that's not really accurate, but it's a nice thing to say, to put a focus on being able to create jobs. We asked the question, 'How do we do this for engineers? How do we provide opportunities for engineering graduates that we saw happening for computer science graduates?' For engineering, it is not as easy as it is for computer scientists. You need to do a lot of design and prototyping, and the process is iterative. Basically, it's a lot more difficult to create a product that will be manufactured than it is to make an app that will be used in the society. We determined that one of the biggest barriers to our young engineers, and it's not even just the young ones, it could also be faculty members, is the lack of the equipment and effective access to the entire procedure for prototyping which involves inception of the idea, then you've got to refine, test and pilot. Actually, the inception includes human-centered design, so, you need to be able to say, okay, this is supposed to be designed for this category of our demographics. All these things are human-centered, or user-centred design. We then started raising money to make that kind of a platform in Africa, and make the ecosystem easier for start-ups owned by Africans. We envisaged that somebody would come and take maybe six months to be able to create a prototype and pay us in the

process to be able to use our facilities. Engineers can now, if you look at the manufacturing landscape in Kenya, it's dominated by certain groups, for example multinationals, or those connected to predict facilities and stemming from a culture of manufacturing. We need to have a more effective national innovation system, which can be viewed as a system that effective audits its population for people with innovative ideas and channels them towards implementing those ideas for the benefit of all.

What are some of the key innovations or advancements that Gearbox Kenya has made in the field of biomedical and healthcare engineering?

If I point at some of the more remarkable Med-tech-type devices that have been designed at Gearbox, the most successful from an engineering perspective, I would probably say was the ventilator. In the midst of COVID, the whole world became aware of the need for ventilators. And so, the whole world started trying to design ventilators more easily. Kenya was no exception. There were very many efforts here in Kenya, many even from lay people and innovators who are out there. And natural, many of the universities started their own projects as well. Eventually, four succeeded, meaning that four were approved by the Poisons and Pharmacy Board and Kenya Bureau of Standards. The first was by Kenyatta University, and later on innovations from the University of Nairobi, Dedan Kimathi University of Technology, and one from Gearbox were approved.

Then another entity was called PregMum. The idea was that when a woman is pregnant, particularly in rural areas, at about six months into the pregnancy she needs to have the foetal heart rate monitored so that the health of the baby from the point of view of the heart rate is observed. So, a woman has to travel from wherever she is to a clinic that has the facility to monitor the heart rate. That can be very logistically challenging, making a portable device more sensible from a needs assessment. So, innovators came together and they designed that kind of a device. We helped them with the technical side so that it's placed on the belly and the heart rate is picked up, then transmitted through the cloud so the doctor, who could be anywhere in the world, can tell whether or not the baby is in good shape. From an engineering point of view, the device worked. The challenge was the business model, as most of those devices could not be afforded by the women in the rural areas. Who would own and deliver it to the point of use?

The third one, which is a very remarkable invention, was a device designed for the deaf and mute to translate sign language into spoken word. The deaf person wears a glove which has sensors along the fingers. So, when you start to do sign language, there's an app on the phone trained using machine learning, that now speaks everything that you're signing. This device is by Roy Alela, an AI expert, and Chalmis, electronics engineer. We supported them.

Another invention was an oxygen monitor; Sp02. So, you put it on the finger and it picks up your blood oxygen level. We designed one that takes the data out to the cloud immediately.

We also make hospital beds, trolleys and drip stands. So, we made those with the idea of presenting the government with an import substitution option that is low tech. So, that's what the economy requires; buy Kenya, build Kenya. Pre-Gearbox, we set up something called the Makerspace at University of Nairobi. We were able to design a suction machine and a phototherapy unit. These were innovations around maternity and newborn child health which work to cure jaundice. We also designed maternity beds.

What role do you believe engineering plays in improving access and quality of medical care? Are there any existing gaps?

Ideally, most technological innovations are based around engineering. When it comes to drug development, engineering has a big role because of obvious interactions with the human body where you need some kind of a delivery device. Engineering underpins aspects of the fourth industrial revolution, with the principle of serving humanity by making a lot of what we require easier to achieve. So, it applies in any human activity, medicine, of course, being one. The role is obvious in any economy. Kenya, however, lacks a national innovation system. We need a system that audits its own population to find who is innovating, or who can innovate, and facilitate them to do so for the benefit of the society. However, our education system is heavily theoretical, as opposed to what happens in countries like, say, Germany and South Korea, where they have dual education systems.

Engineers need to have a lot of access to equipment to be able to routinely measure the things that need to be measured, prototype and manufacture the things that can be designed and made locally so that we are not so dependent on imports. This should be coupled with training, especially on critical thinking and asking very basic fundamental physics questions around a problem. This will help in developing a base for incremental innovation as well as revolutionary innovations.

All this is captured in the triple helix, whereby government, together with the business community and academia community work hand in hand.

How do you see the integration of AI-powered diagnostics and robotics in surgery evolving in the Kenyan healthcare sector in the next few years?

AI is a hugely promising technology that will and is impacting everything. It is hugely exciting and scary, all at once. This is true for a couple of reasons; To begin with, a lot of what we do as humans can be done by AI better and more quickly, and this applies to engineering as well. In engineering, we do use a lot of software, i.e. coding. Engineers are very good at software development, because it's part and parcel of designing what needs to be done, e.g. creating control systems. Now an AI can generate the code for you. You don't need a human. But all it means is that we as Kenyans living in Kenya need to get into AI, because you cannot stop it.

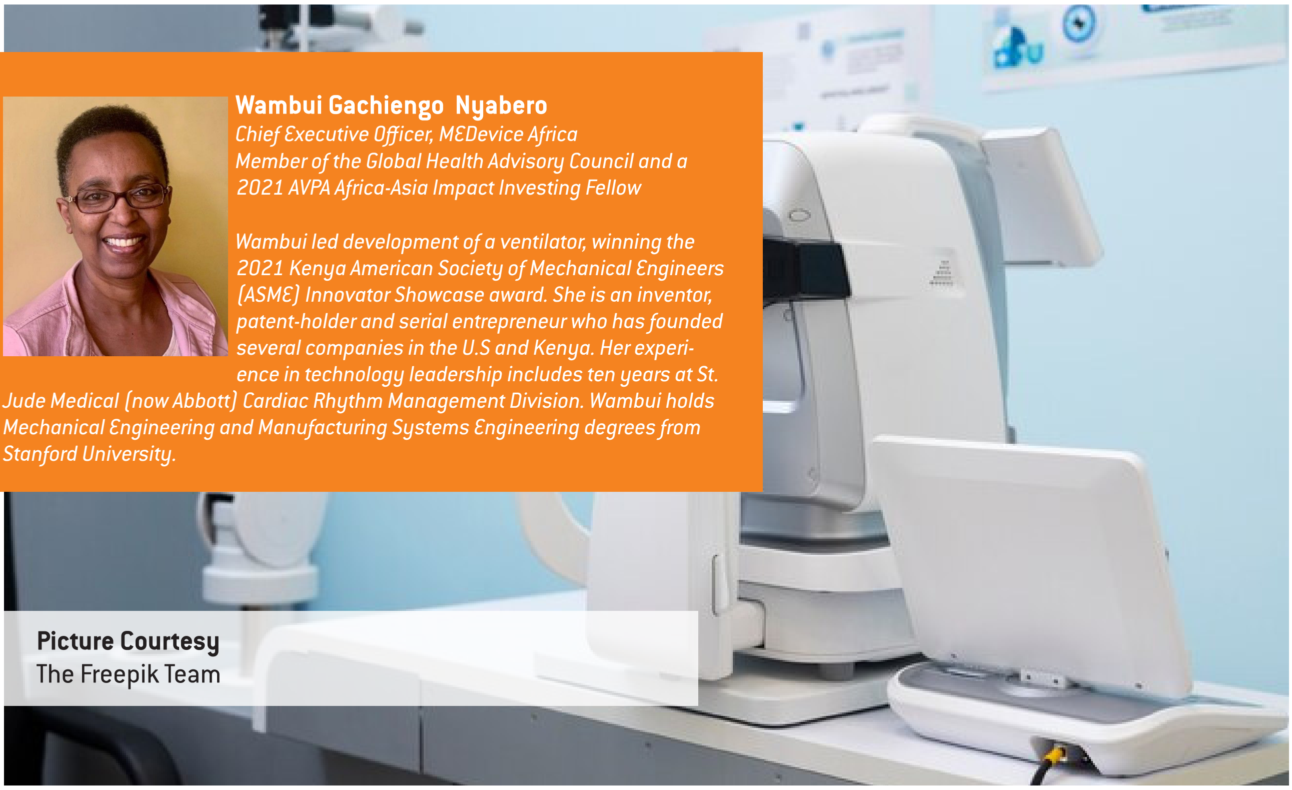
Where things stand at right now with AI is based on making agents; the term being used is that AI is increasingly 'agentic.' We need to be able to learn how to do that, because those agents are what can employ on an AI platform to develop AI solutions. There are several open platforms that we need to make sure that we're using and making available within universities and spaces like ours to our innovators so they know how to use them. But it's such an unknown area. What is going to come of it, nobody knows. What DeepSeek did the other day has upended all the major plans and strategies in the United States. They've shown that its possible to created a platform that costs a fraction of what Open AI and the rest have spent, and yet deliver the same performance. The government should be sitting with all the stakeholders, the universities and the business community to assess what's possible and what's not, and then invest resources at the recommendation of this triple helix advice.

We are far behind when it comes to Robotics. For instance, the CNC machines that we make and use at Gearbox are basically entry-level Robotics. We need to get better and better. One of the ways is through diaspora exposure. The government should be sponsoring engineers and other engineering stakeholders to countries that are more advanced than ours to help sharpen their skills and ensure they are exposed to more advancements they can bring back to the country to implement.

Looking ahead, what do you envision as the next frontier for biomedical and healthcare engineering in Kenya

Honestly, the current trajectory is not terrible. I have seen some efforts being pushed through certain regulations; 'Buy Kenya, Build Kenya' being one. Also, there are others set to promote youth within the supply chain of government and procurement scenarios. The enemy of progress at present is corruption within government. If we get good strong leadership which is committed to making these policies realities, I think we may start seeing some good changes.

MEDevice's Vision for Transforming Africa's MedTech Landscape



Wambui Gachiengo Nyabero
Chief Executive Officer, MEDevice Africa
Member of the Global Health Advisory Council and a 2021 AVPA Africa-Asia Impact Investing Fellow

Wambui led development of a ventilator, winning the 2021 Kenya American Society of Mechanical Engineers (ASME) Innovator Showcase award. She is an inventor, patent-holder and serial entrepreneur who has founded several companies in the U.S and Kenya. Her experience in technology leadership includes ten years at St. Jude Medical (now Abbott) Cardiac Rhythm Management Division. Wambui holds Mechanical Engineering and Manufacturing Systems Engineering degrees from Stanford University.

Picture Courtesy
The Freepik Team

What is the current state of Biomedical Engineering in Africa?

Healthcare in Africa faces a myriad of challenges, ranging from limited access to quality medical equipment to an over-reliance on imported technology that often fails to meet the unique needs of the continent. At MEDevice, we are pioneering a shift in the narrative by designing and developing medical equipment tailored to Africa's healthcare landscape. Established in 2020, MEDevice emerged in response to the COVID-19 pandemic with the development of Afrivent, a locally designed ventilator that addressed the dire shortage of ventilators in Kenyan hospitals. This initiative revealed a critical need, and opportunity, for Africa to build its own ecosystem for medical device innovation.

Our mission is to change the MedTech narrative in Africa by designing and developing contextually relevant, cost-effective, and sustainable medical solutions. We envision an Africa where medical equipment is not only available but also suited to the environmental, economic, and infrastructural constraints of the continent. Through our four strategic pillars-Advisory Services, Capacity Building, Innovation and Venture Building, and Manufacturing Excellence- we are driving the change towards an independent and innovative biomedical engineering industry.

In your view, what are the key challenges facing biomedical engineering in Africa today?

Biomedical engineering is a rapidly growing field worldwide, yet Africa lags in research, development, and commercialization of medical devices. Most hospitals and healthcare facilities heavily depend on imported equipment, which presents multiple challenges:

1. High Costs: Imported medical devices are expensive due to shipping, import taxes, and the high cost of proprietary technologies.

2. Limited Power Reliability: Many medical devices from Europe or North America are designed for stable power grids, making them less effective in African settings where power fluctuations and outages are frequent.

3. Maintenance Challenges: Repairing these devices requires expertise from manufacturers abroad, increasing downtime and operational costs.

4. Regulatory Barriers: The absence of clear regulatory pathways makes it difficult for local manufacturers to develop and commercialize new devices.

How is MEDevice tackling the challenges in Africa's biomedical

engineering industry?

To address these challenges, MEDevice has structured its operations around four key pillars that drive impactful innovation:

1. Advisory Services

Our advisory arm focuses on empowering innovators, healthcare institutions, and policymakers with the knowledge and strategic guidance required to navigate the complex biomedical landscape. We provide:

a. Market Research & Analysis: Identifying gaps and opportunities in the medical device market to inform product development.

b. Regulatory Compliance Support: Assisting companies in navigating the ambiguous regulatory framework in Kenya and Africa at large.

c. Go-to-Market Strategies: Developing market entry plans that ensure locally developed medical devices reach hospitals and clinics efficiently.

d. Strategic Partnerships & Intellectual Property: Helping innovators protect their inventions while facilitating collaborations between academia, industry, and government.

2. Capacity Building

A significant barrier to biomedical innovation in Africa is the insufficiency of hands-on talent. MEDevice bridges the gap between academia and industry by:

a. Developing Tailored Training Programs: Through our Engineering trainee program, we collaborate with universities to integrate hands-on biomedical engineering skills training into curricula, teaching CAD design skills, circuit design, prototyping and 3D printing among others, which are essential practical skills in medical device design.

b. Encouraging Innovation & Entrepreneurship: We equip young engineers with the business acumen necessary to turn their ideas into viable enterprises by offering trainings on IP, teaching on the market penetration strategies and business models suitable for their product.

c. Medical Device Procurement & Maintenance: We partner with healthcare institution for procurement of medical devices that serve their need and fit the context, training hospital technicians on the proper use and maintenance of medical devices to prolong their lifespan and effectiveness, as well as end-to-end equipment management.

3. Innovation & Venture Building

Africa needs not just more biomedical engineers but also entrepreneurs willing to take risks in the MedTech sector. To foster innovation, MEDevice provides:

a. Business Model Validation & Development: Ensuring new medical technologies have viable commercial models.

b. Investor Readiness & Funding Strategy: Preparing startups for funding rounds and connecting them with investors.

c. Venture Incubation: Partnering with researchers, engineers and healthcare providers to design and develop products, business and market positioning strategies.

4. Manufacturing Excellence

Local manufacturing of medical devices is crucial to breaking Africa's dependence on foreign technology. MEDevice is spearheading efforts to build a robust manufacturing ecosystem through:

a. Medical Device Commercialization: Supporting the transition from prototype to production.

b. Manufacturing Process Optimization: by helping local manufacturers improve efficiency and scalability.

c. Supply Chain Management: through partnerships with suppliers to establish reliable supply chains for raw materials and components.

d. Quality Assurance & Compliance: Supporting the local medical technology ecosystem in developing and manufacturing within Quality Management Systems (QMS) that include global medical technology standards such as ISO 13485.

e. Technology Transfer & Scale-Up Strategies: Enabling the local production of innovative medical technologies at a competitive scale.

What is the role of the government and industry players in advancing biomedical engineering in Africa?

For Africa to fully realize its potential in biomedical engineering, collaboration between the government, private sector, and academia is essential. Here's how each stakeholder can contribute:

Government:

1. Develop clear and supportive regulatory, tax and subsidy frameworks for medical device development.

2. Establish research and development hubs for biomedical engineering.

3. Encourage procurement of locally manufactured products.

Private Sector:

1. Invest in local MedTech startups.

2. Support skill development through mentorship and internship programs.

3. Facilitate access to manufacturing resources.

Healthcare Institutions:

1. Adopt and test locally developed medical devices.

2. Provide feedback for improvement and refinement.

Academia:

1. Develop curricula that align with industry needs and partner with industry to provide hands-on training experiences to students.

2. Promote interdisciplinary research in medical technology.

Mention the opportunities that lie ahead for biomedical engineering in Africa, and how stakeholders can drive innovation

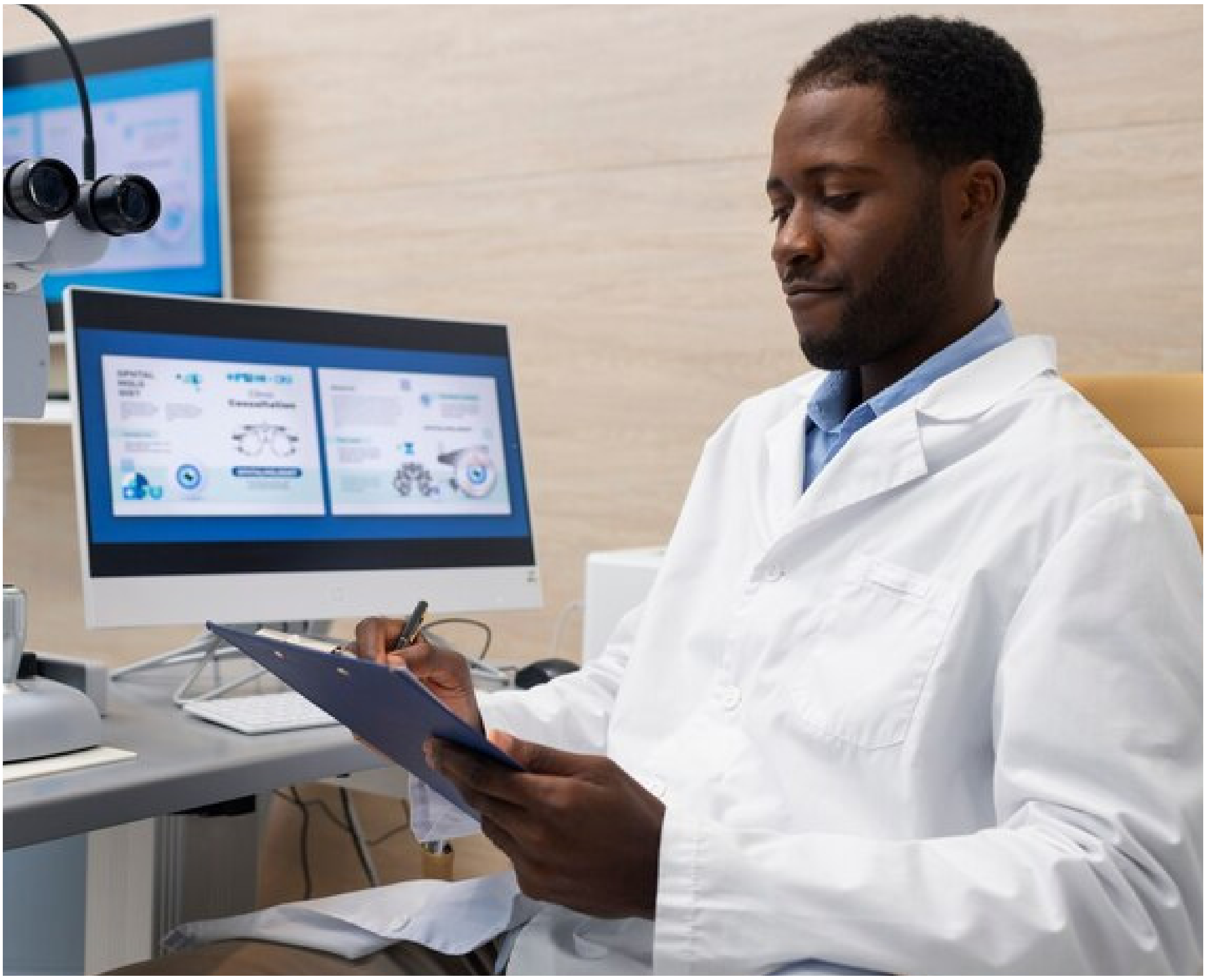
The future of biomedical engineering in Africa is filled with a plethora of opportunities. With initiatives like MEDevice, leading the charge, the continent is on the brink of a healthcare revolution. Local innovation will not only reduce dependency on imports but also lead to cost-effective, sustainable, and job-creating industries. African engineers have the talent, drive, and creativity needed to develop world-class, state of the art medical technologies. What is required now is the collective effort of all stakeholders to support, invest in, and champion homegrown solutions.

At MEDevice, we believe that African problems require African solutions. By leveraging our four-pillar strategy, we are committed to making this vision a reality. The era of over-reliance on foreign medical equipment is coming to an end—through strategic innovation and collaboration, Africa is poised to take charge of its MedTech future.

Way forward

Biomedical engineering is a critical pillar in improving healthcare across Africa. Through local innovation, strategic partnerships, and a commitment to manufacturing excellence, we can transform the continent's healthcare landscape. MEDevice remains at the forefront of this transformation, proving that Africa can design, develop, and manufacture world-class medical technologies that meet the unique needs of its people.

The time to act is now. Together, we can build a resilient, independent, and innovative healthcare system for Africa.



Transforming the South Coast Dongo Kundu: An engineering marvel boosting trade and tourism

Molly Otieno

The South Coast is on the cusp of a transformation, as the Mombasa Port Area Development (MPARD) project popularly known as the Dongo Kundu Southern Bypass nears its official commissioning. Spanning 8.96 kilometres, this dual carriageway is a game-changer for Mombasa and Kwale Counties, promising improved connectivity, enhanced trade, and a fresh chapter of economic growth. Although it is 99% complete, with only a small section of street lighting pending installation, the road is already open to traffic. This masterpiece offers a seamless alternative for commuters destined for the South Coast, bypassing the congestion of ferry crossings and reducing travel times significantly. This infrastructure marvel has quickly become a lifeline for residents and businesses, setting the stage for a new era of convenience and prosperity.

Beginning at the Mwache Interchange, the road winds through picturesque landscapes before converging at the Dongo Kundu Special Economic Zone (SEZ). Enroute, travellers are treated to awe-inspiring views of three architectural masterpieces: the Mwache Bridge (660 metres), the Tsunza Viaduct (690 metres), and the crowning jewel, the Mteza Bridge (1,440 metres). These structures, blending advanced technological engineering with environmental sensitivity, pay homage to the delicate mangrove ecosystem surrounding the Tsunza Peninsula.

For Mombasa Port, this road is a logistical boon. Its proximity to the new container terminal ensures efficient cargo movement, giving the region a competitive edge in trade. Additionally, the road is strategically located near the Standard Gauge Railway (SGR) terminus, streamlining the transfer of goods between rail and road networks. Moreover, the proximity to Moi International Airport has further amplified its impact, by providing a seamless connection for air freight and travellers.

This integration boosts the Coast as a more attractive hub for regional and international trade by creating a dynamic transport corridor that supports the entire logistics chain from sea to rail, road, and air, solidifying the region's position as a critical player in East Africa's economy.

The direct link to the Dongo Kundu SEZ is expected to invigorate industrial activities, attract investment, and create thousands of employment opportunities. Together, these elements make the road a cornerstone of economic growth and a catalyst for transforming Mombasa into a world-class trade and logistics hub.

Diani hotels and businesses are preparing for an influx of visitors. "This road will bring us the tourists we need, and that means more jobs for our community," exclaimed a local businessman. The benefits of this project are not just economic—they are deeply personal. For residents, the construction phase created jobs, putting food on tables and offering skills that will last a lifetime. "We have been waiting for this moment," one hotelier shared.

The Authority's Corporate Social Investment (CSI) initiatives improved livelihoods by providing food aid, while Tsunza and Mikanjuni communities benefitted from water kiosks and free water distribution. Schools were equipped with furniture, stationery, and computers, and scholarships were awarded to top-performing students, offering them a brighter future.

Healthwise, local clinics received medical support, while boda boda riders and boat operators were provided with safety gear, enhancing road and maritime safety. Beyond that, KeNHA supported local sports teams, donated equipment, and planted trees to ensure the environment thrives alongside development.

By protecting the natural beauty of the South Coast and the special care taken to ensure the Tsunza mangroves—home to diverse wildlife—were preserved, Dongo Kundu has proved to be more than a transportation corridor.

Standing on the new Mwache Bridge, one can feel the energy of what is to come. Traders are ready for accessibility to markets, tourists are excited for stress-free drives to the beach, and communities are looking forward to more opportunities knocking at their doors. As the official commissioning approaches, the Mwache Interchange to Dongo Kundu Road is already a success story, proof that when infrastructure is done right, it changes lives.

Opinion Editorial:
Harnessing technology to fuel Kenya's circular economy and economic growth

Edward Kariuki
Group Water Treatment Engineer

The dream of turning waste into 'gold' has remained largely unrealised in Kenya, leaving the country grappling with mounting waste, environmental pollution and health hazards.

Each Kenyan generates approximately half a kilogram of waste daily, amounting to eight million tonnes annually. Yet, only 38 per cent of this waste is collected, with less than 10 per cent recycled.

The rest clogs drainage systems, pollutes water bodies, and leads to severe health crises. According to the UN Environment Programme, contaminated water accounts for over half of the world's hospital admissions.

A UN report highlights that 90 per cent of wastewater in developing countries—including most African nations—is discharged untreated into rivers, lakes, or oceans. This contamination disrupts fisheries, livelihoods and ecosystems.

In Kenya, poor access to clean water significantly contributes to disease burdens and mortality rates. With rapid urbanisation and a growing population, the demand for water will only increase, making effective wastewater management an urgent necessity.

Fortunately, modern technology offers solutions for treating and repurposing wastewater to ensure sustainability and environmental conservation. Instead of merely disposing of wastewater, innovations are transforming it into valuable resources.

Bioremediation solutions such as constructed wetlands and plant-based filtration systems naturally break down pollutants, providing an eco-friendly way to clean water. Ultrafiltration and reverse osmosis remove even the smallest contaminants, including microplastics and heavy metals. Electrochemical treatments use electricity instead of chemicals to purify water, while advanced oxidation processes break down persistent pollutants such as pharmaceutical waste and pesticides. Modern treatment facilities now extract valuable nutrients like nitrogen and phosphorus for use as fertilizers and even generate energy from organic waste.

Kenya has a golden opportunity to address its waste management challenges. Sustainable practices could rejuvenate the economy by creating jobs in waste collection, sorting, and recycling, particularly for informal waste pickers. Proper waste management would also curb pollution, conserve valuable resources and improve public health by reducing exposure to hazardous materials.

Phytoremediation utilizes plants and microbes to absorb toxins, offering a natural method for treating wastewater. Biological nutrient removal eliminates excess nitrogen and phosphorus, preventing harmful algal blooms in lakes and rivers. Enhanced phosphorus removal further refines this process, capturing phosphorus from wastewater to be repurposed as fertilizer, reducing pollution while supporting agriculture.

Different wastewater treatment technologies vary in efficiency, cost and applicability. Traditional activated sludge treatment is reliable but less effective at removing certain pollutants. Membrane bioreactors are highly efficient and produce reusable water but require significant investment in maintenance and energy consumption.

Anaerobic digestion effectively treats organic waste while generating biogas, whereas constructed wetlands provide an eco-friendly alternative but require substantial land space and longer processing times. Advanced oxidation processes are highly effective but energy-intensive, while electrochemical treatments remove metals and salts but come with high energy costs.

Beyond environmental conservation, proper wastewater management plays a crucial role in economic growth. It prevents pollution in rivers, lakes, and oceans, safeguarding aquatic ecosystems. By ensuring safe water, communities experience fewer disease outbreaks, lowering healthcare costs and improving quality of life. Some treatment processes also mitigate climate change by capturing methane emissions and converting them into renewable energy.

Treating and reusing wastewater reduces dependency on freshwater sources, a critical advantage for drought-prone areas. Modern treatment plants can even turn waste into wealth by recovering nutrients, metals and energy, creating economic opportunities while reducing reliance on virgin resources.

However, water is just one part of the larger waste management puzzle. Effective handling of solid waste is equally crucial in promoting sustainability and resource conservation. Both wastewater and solid waste, if properly managed, can minimize environmental impact and contribute to a circular economy.

Kenya's private sector is already taking steps toward responsible waste management. Davis & Shirtliff Kenya, for instance, generates 492 tonnes of packaging waste annually, primarily consisting of cartons, plastic, polythene, woven bags and polystyrene. The company sorts packaging materials into recyclable and non-recyclable categories, ensuring clear segregation. Compliance with Extended Producer Responsibility regulations is maintained through partnerships with organizations such as PAKPRO, an industry-driven and financed producer responsibility organization that collaborates with waste collectors and recyclers to manage post-consumer waste.

Waste segregation plays a key role in sustainable waste management. Separating recyclables, organic waste, and non-recyclables significantly reduces landfill waste, preventing soil and groundwater contamination while minimizing greenhouse gas emissions.

Efficient waste segregation ensures materials such as paper, glass, metals, and plastics are repurposed rather than discarded. Composting organic waste further enhances soil quality and reduces landfill contributions. Proper segregation ensures that waste is sent to the correct disposal facilities, reducing costs and environmental impact.

Kenya should embrace technology-driven solutions to transform waste into economic and environmental opportunities. Investing in modern wastewater treatment, responsible waste management policies, and circular economy initiatives, the country can create a more sustainable future that benefits both people and the planet.

Engineering Solutions for Public Health: Advancements in Malaria Control through Biomedical and Healthcare Innovations

EiK Correspondence

The intersection of engineering and public health has ushered in transformative solutions for some of the world's most pressing challenges, including the fight against malaria. By integrating innovative engineering approaches with public health strategies, the global battle against this life-threatening disease has achieved notable progress.

Engineering in Public Health: A Crucial Nexus

Engineering for public health is the application of engineering principles to enhance population health and well-being. This multidisciplinary approach designs, implements, and maintains systems that support public health initiatives across various domains such as water and sanitation, disaster response, and healthcare infrastructure. At its core, it combines the technical precision of engineering with the human-centered approach of public health, creating environments and tools that prevent diseases and enhance overall health outcomes.

Historically, infrastructure designs have often overlooked public health impacts, leading to missed opportunities for creating health-promoting systems. Engineering solutions that prioritize public health at the design stage guided by data, predictive modeling, and interdisciplinary collaboration can preempt health risks and reduce costs associated with retrofitting or reactive measures. This paradigm shift promotes sustainability and resilience, particularly critical in combating diseases like malaria.

Understanding Malaria: A Persistent Threat

Malaria remains one of the most persistent public health challenges, particularly in sub-Saharan Africa. It is caused by Plasmodium parasites, transmitted through the bites of infected female Anopheles mosquitoes. This acute febrile illness manifests with symptoms such as high fever, chills, headaches, nausea, and muscle pain, often progressing to severe complications such as anemia and organ failure if untreated. Despite significant progress, malaria still claims hundreds of thousands of lives annually, necessitating innovative approaches to its prevention, diagnosis, and treatment.

Engineering and Biomedical Innovations in Malaria Control

The fight against malaria has seen groundbreaking advancements through engineering and biomedical innovations. These efforts target the disease at various stages, from vector control to treatment and diagnostics.

1. Vector Control

Vector control has long been a cornerstone of malaria prevention. Two key engineering innovations include:

Insecticide-Treated Nets (ITNs): These nets, impregnated with insecticides, act as both a barrier and a lethal trap for mosquitoes, significantly reducing malaria transmission.

Indoor Residual Spraying (IRS): Spraying insecticides on the walls and ceilings of homes targets mosquitoes that rest indoors, disrupting their life cycle and reducing infection rates.

2. Diagnostic Tools

Accurate and timely diagnosis is critical for malaria control. Key advancements include:

Rapid Diagnostic Tests (RDTs): Portable and user-friendly, these tests deliver accurate results in minutes, enabling prompt treatment.

Molecular Diagnostic Tools: Techniques like PCR (polymerase chain reaction) detect even low levels of malaria parasites, offering unmatched precision in diagnosis.

3. Drug Development

The introduction of artemisinin-based combination therapies (ACTs) has revolutionized malaria treatment. These drugs combine artemisinin with other compounds to combat resistance and ensure effective parasite clearance.

4. Malaria Vaccines

The RTS,S/AS01 (Mosquirix) vaccine, recommended by the WHO for children in sub-Saharan Africa, represents a major milestone. It has demonstrated the ability to reduce malaria cases and severe illness in young children, providing a promising tool in the fight against the disease.

5. Larval Source Management
Targeting mosquito breeding sites prevents larvae from maturing into adults. This approach involves environmental modifications, biological control agents, and chemical larvicides, addressing the root cause of mosquito proliferation.

Emerging Technologies: The Future of Malaria Control

Innovative engineering and healthcare solutions continue to evolve, addressing the challenges of drug and insecticide resistance and improving the efficiency of interventions.

1. Gene Drive Technology
This cutting-edge approach involves genetically modifying mosquitoes to either reduce their population or render them incapable of transmitting malaria. By altering mosquito genes, scientists aim to disrupt the parasite's lifecycle at its source.

2. Drone Technology
Drones equipped with advanced sensors and delivery systems are transforming mosquito surveillance and control. They identify breeding sites with precision and deploy insecticides or biological agents efficiently, making mosquito control efforts more targeted and cost-effective.

3. Monoclonal Antibodies
Engineered to neutralize specific components of the malaria parasite, monoclonal antibodies show promise in reducing infection rates and disease severity, particularly in vulnerable populations.

4. Artificial Intelligence (AI)
AI and machine learning are being used to predict malaria outbreaks, optimize resource allocation, and improve intervention strategies. By analyzing large datasets, AI identifies patterns that inform targeted control efforts and enhance public health responses.

Challenges and the Road Ahead

Despite these advancements, challenges remain. Drug and insecticide resistance, fluctuating funding, and the diversion of resources to emergent diseases like COVID-19 continue to hinder progress. Additionally, the need for stronger interdisciplinary collaboration between engineers and public health professionals remains crucial for scaling solutions.

Investment in research and development, alongside community engagement and education, is essential for sustaining the fight against malaria. Combining biomedical innovations with engineering ingenuity offers the potential for eradication, a goal that once seemed distant but now feels increasingly attainable. Engineering solutions in malaria control face several challenges, especially when it comes to biomedical and healthcare innovations. Some key challenges include:

Insecticide Resistance: The emergence and increased intensity of insecticide resistance have undermined the effectiveness of traditional vector control methods like insecticide-treated nets and indoor residual spraying.

Outdoor Transmission: Malaria transmission is not limited to indoor environments. Outdoor transmission poses a significant challenge as it requires different control strategies.

Technological Barriers: Implementing new technologies, such as larviciding, requires overcoming technical barriers related to delivery, targeting, coverage, and impact evaluation.

Funding and Policy Support: There is often poor global technical, policy, and funding support for new interventions. This can hinder the wider-scale implementation of innovative solutions.

Fragmented Implementation: The implementation of new technologies can be fragmented, with varying levels of experience and success across different regions.

Access to Innovations: Limited access to WHO prequalified larvicide products and other innovations can be a barrier to effective malaria control.

Infrastructure Requirements:
Developing and scaling up innovations often require significant investment in infrastructure, particularly in information and communication technologies and drone technologies.

Community Engagement: Engaging communities and ensuring their participation in malaria control efforts is crucial but can be challenging due to varying levels of awareness and acceptance.

Investment in research and development, alongside community engagement and education, is essential for sustaining the fight against malaria. Combining biomedical innovations with engineering ingenuity offers the potential for eradication, a goal that once seemed distant but now feels increasingly attainable. Addressing these challenges requires a coordinated effort from global health organizations, governments, and communities to develop and implement effective and sustainable malaria control strategies.

Conclusion

The integration of engineering solutions with public health strategies has proven to be a game-changer in malaria control. From advanced diagnostic tools to genetic and AI-driven technologies, the progress made underscores the importance of multidisciplinary approaches in tackling complex health challenges. With continued innovation, collaboration, and investment, the vision of a malaria-free world is within reach, ensuring healthier lives and brighter futures for millions worldwide.

Exploring the Role of Optometry and Opticians in Biomedical Engineering

EiK Correspondence

Picture Courtesy
The Freepik Team

Optometry, a healthcare profession dedicated to the eyes and the visual system, plays a vital role in diagnosing, treating, and managing eye conditions and vision problems. Optometrists provide a range of services, including prescribing corrective lenses, offering vision therapy, and managing certain eye diseases. Alongside them, opticians customize and maintain optical devices, ensuring optimal functionality and patient comfort. Together, these professionals are integral to the advancement of biomedical engineering, particularly in developing and maintaining cutting-edge ophthalmic technologies.

The Intersection of Optometry and Biomedical Engineering in Kenya

In Kenya, the collaboration between optometry and biomedical engineering is transformative. The field of biomedical engineering (BME) gained traction in the early 2000s when the government, with support from international partners such as the Austrian government, initiated artisan training programs at hospitals like Loitokitok. These programs equipped local professionals with skills to maintain and repair medical equipment, including ophthalmic devices.

By 2009, optometry education began to formalize, with institutions like the Kenya Medical Training College (KMTC) introducing optometry courses. This development highlighted the need for biomedical engineers specializing in ophthalmic devices, leading to the gradual integration of BME principles into optometry curricula. This integration ensured that optometrists not only excelled in diagnosing and treating eye conditions but also understood and maintained the sophisticated equipment they used.

This collaboration has significantly enhanced the quality of eye care services in Kenya, benefiting patients and professionals alike.

Contributions of Optometry and Opticians to Biomedical Engineering

Optometry and opticians have made significant contributions to biomedical engineering, particularly in the field of biomedical optical imaging. Here are a few key areas where their expertise has been instrumental:

Optical Coherence Tomography (OCT): This non-invasive imaging technique, widely used in ophthalmology, allows for high-resolution cross-sectional imaging of the retina. It has been adapted for use in other biomedical applications, such as imaging the skin, blood vessels, and other tissues.

Fluorescence Imaging: Techniques like fluorescence microscopy and two-photon fluorescence imaging are used to study biological tissues and cells. These methods have been applied in various biomedical research areas, including cancer detection and neuroscience.

Photoacoustic Imaging: This emerging technique combines optical and ultrasound imaging to provide high-contrast images of biological tissues. It has potential applications in diagnosing and monitoring diseases such as cancer and vascular disorders.

Endoscopy and Microscopy: Advances in optical design and imaging systems have led to the development of sophisticated endoscopic and microscopic tools. These tools are used for minimally invasive surgeries and detailed examination of internal organs.

Multimodal Imaging Systems: Combining different imaging modalities, such as optical coherence tomography and fluorescence imaging, allows for more comprehensive and accurate diagnostics.

These contributions highlight the interdisciplinary nature of biomedical engineering and the valuable role that optometry and opticians play in advancing medical technology. Optometry and opticians play distinct yet complementary roles in biomedical engineering. Here are some of the ways:

Optometry

1. Innovation in Eye Care Technology
Optometrists collaborate with biomedical engineers to develop diagnostic and treatment technologies. Their clinical insights shape the design and functionality of devices such as Optical Coherence Tomography (OCT) and specialized contact lenses.

2. Clinical Trials and Testing
Optometrists conduct trials to ensure new optical devices are safe and effective for patient use. Their feedback is invaluable in refining biomedical solutions.

3. Integration of Technology in Practice
They adopt advanced diagnostic tools, such as digital retinal imaging and automated perimetry, into their practices, enhancing patient care.

4. Patient Monitoring and Data Collection
Optometrists monitor patients using biomedical devices, collecting data that informs the continuous improvement of these technologies.

Opticians

1. Device Maintenance and Calibration
Opticians ensure that optical instruments are accurately calibrated and functioning correctly. This maintenance is crucial for reliable diagnostics.

2. Customization of Devices
By customizing glasses and contact lenses to meet individual needs, opticians enhance patient comfort and treatment efficacy.

3. Technical Support and Training
They provide technical support, train colleagues, and educate patients on the proper use of optical devices, improving outcomes and device longevity.

4. Quality Control and Assurance
Opticians inspect and test optical equipment, ensuring compliance with industry standards and optimal performance.

Biomedical Solutions Revolutionizing Eye Care

Biomedical solutions are revolutionizing eye care by introducing cutting-edge technologies and innovative treatments that enhance diagnosis, treatment, and management of ocular conditions. Here are some key advancements:

Optical Coherence Tomography (OCT)

OCT is a non-invasive imaging technique that uses light waves to take cross-section pictures of the retina. It allows ophthalmologists to see each of the retina's distinctive layers and measure their thickness1. This helps in diagnosing and monitoring conditions like macular degeneration, glaucoma, and diabetic retinopathy. OCT can also detect abnormalities in the optic nerve and other structures in the eye2.

Contact Lens Technology

Advancements in contact lens technology have led to the development of lenses that not only correct vision but also address specific eye conditions. For example, smart contact lenses can monitor intraocular pressure in glaucoma patients and even dispense medication. Photochromic lenses automatically adjust to light conditions, providing UV protection and reducing glare. Orthokeratology lenses temporarily reshape the cornea to correct myopia (nearsightedness).

Automated Perimetry

Automated perimetry is a test that assesses the visual field, helping in the management of glaucoma. It uses computerized systems to map out the patient's field of vision, detecting any blind spots or areas of reduced vision4. This test is crucial for early detection and monitoring of glaucoma progression.

Digital Retinal Imaging

Digital retinal imaging captures detailed images of the retina, allowing for early detection of eye diseases and monitoring treatment progress. It provides a visual record that can be compared over time to track changes in the retina1. This technology is particularly useful for conditions like diabetic retinopathy and age-related macular degeneration.

Telemedicine and Remote Monitoring

Telemedicine has become increasingly important in eye care, especially during the COVID-19 pandemic. It allows for virtual consultations and remote monitoring of patients, making eye care more accessible and convenient5. Patients can have their retinal images and other test results reviewed by specialists without needing to visit a clinic in person.

Advanced Lens Materials

Innovations in lens materials have led to the development of lenses that offer greater comfort, durability, and functionality. Hybrid lenses combine the clarity of rigid lenses with the comfort of soft lenses, making them suitable for people with irregular corneas. Extended-wear lenses are designed to be worn for longer periods, providing continuous vision correction without the need for frequent removal.

These advancements are transforming eye care, making it more effective, efficient, and patient-friendly.

Challenges Facing Optometry and Opticians in Biomedical Engineering

Collaboration between optometry, opticians, and biomedical engineering is promising, however, optometry and opticians face several challenges in the field of biomedical engineering, which can impact their ability to innovate and provide advanced eye care solutions. Here are some key challenges:

1. Keeping Pace with Technology
Rapid advancements require continuous education and training, which can be time-consuming and costly.

2. Integration of New Technologies
Introducing new devices into clinical settings requires understanding their functionality and ensuring proper maintenance, necessitating support from biomedical engineers.

3. Cost of Equipment
Advanced biomedical devices are expensive, limiting access for some practices and patients.

4. Regulatory Compliance
Navigating local and international regulations for new devices demands significant effort and resources.

5. Patient Education and Acceptance
Patients may resist new technologies, requiring optometrists and opticians to invest time in educating them about benefits and proper use.

6. Collaboration Barriers
Effective communication between optometrists, opticians, and biomedical engineers can be challenging due to differing professional terminologies.

7. Ethical Considerations
Issues such as patient privacy and informed consent are critical when implementing new technologies.

8. Limited Access to Training
Rural and underserved areas often lack resources and training opportunities, hindering progress in these regions.

Synergy for a Better Future

The partnership between optometry, opticians, and biomedical engineering is crucial for advancing eye care. Together, they contribute to product development, improve patient outcomes through innovative technologies, and ensure the quality and reliability of optical devices. Addressing the challenges they face requires a concerted effort among stakeholders, supported by continuous education, collaboration, and investment in resources. By fostering this synergy, the future of eye care looks brighter, offering enhanced services and improved quality of life for patients worldwide.

Renewable Energy Solutions for Healthcare Facilities: Harnessing Solar and Other Green Energy Sources to Power Critical Medical Equipment in Rural Areas

EiK Correspondence

National and regional power outages are becoming commonplace in Kenya. When this happens, the transport, hospitality and agricultural industries suffer great losses. In the air transport sector for instance, these lapses cause flight delays and strands travelers, as was the case at Jomo Kenyatta International Airport during one of these major outages. Hotels and entertainment spots lose clients, and therefore money, when the lack of energy curtails their ability to provide services. In the agricultural industry, not having energy back up results in the loss of perishable produce in an outage. All these consequences of unreliable national grid are mostly monetary in nature, but in the healthcare industry, when facilities lack reliable source of energy, the repercussions can be much worse even causing loss of life.

Energy shortfalls in rural healthcare facilities

The remote nature of some healthcare facilities make connection to the national grid a logistical nightmare. The upfront costs, the lack of infrastructure, lack of goodwill, sparse population of the surrounding communities and repressive policies are all contributing factors to these facilities not being connected to the national grid. Such connection presents a different set of problems altogether since the power can be both erratic and unstable, the frequent outages being a case in point.

In order to work at their full capacity, healthcare facilities require stable electricity to power critical life-saving medical equipment like ventilators and incubators. This calls for alternative sources of energy to either provide energy on a primary level for off-grid facilities, or supplement the existing power sources for smooth operations.

Role of solar energy and green energy sources in creating sustainable energy

Solar energy is one of the most viable sources of renewable energy not just in Kenya, but in Africa as a whole. According to the

International Energy Agency (IEA), Africa boasts 60% of the world's best solar resources, yet it only has installed 1% of its solar capacity. IRENA estimates Africa's solar photovoltaic (PV) technical potential at 7900 GW, which only goes to show the untapped potential for solar power generation not just for healthcare, but for its other industries.

Harnessing solar energy will not only save healthcare facilities in the rural areas much needed money in power bills, but will also give them the capacity to provide critical care. As it is, the lack of reliable power not only prevents them from providing services beyond the basic care, but it also subjects the existing equipment to the risk of damage. Apart from solar energy, other sources of green energy like biomass and wind energy are essential for a diverse energy mix.

Important considerations

While harnessing solar energy and other green energy sources sound good in the books, the success of their implementation in healthcare facilities in the rural areas relies on a data-driven approach and learning from the pitfalls of similar projects.

The initial cost can be a bit prohibitive, but in the long run the advantages of onsite power production validate these costs. More so, adopting solar and green energy sources removes the alternative polluting diesel generators out of the mix.

One of the biggest impediments to the use of renewable energy in healthcare facilities is maintenance, and ensuring that the integrated renewable systems are used optimally and efficiently. It is one thing to set up the renewable energy hardware, but without the manpower to keep it running the impact may not be that great.

The sustainability, and even the literal continuity of the renewable energy systems implemented in health facilities relies heavily on local expertise thus necessitating training. Just as important, monitoring and evaluation should be woven into the fabric of the renewable energy systems so that they do not fall into disrepair. These alternative energy sources have to be set to provide not just power, but power in the right voltage to run critical operations in these facilities.

That said, Kenya has a huge potential for exploiting its readily available green energy resources for the betterment of healthcare. This way, it ushers in an era of energy independence, while also reducing the reliance on fossil fuel.

Advancements in Pharmaceutical Engineering

EiK Correspondence

Picture Courtesy
The Freepik Team

The pharmaceutical industry in Kenya is transforming itself. Significant progress on drug discovery, production, and personalized care has taken place in this area. These modifications are intended to enhance the health care delivery systems not only in Kenya but also in the rest of Africa proficiently.

Artificial Intelligence in drug discovery

The discovery of drugs has been enhanced by artificial intelligence and machine learning which are being used in drug research today. AI algorithms are being used to predict how a particular drug will function, enhance its molecules and reduce the time of clinical trials by analysing large amounts of data. For instance, AI has been employed in the discovery of new antibiotics that are effective against bacteria that are difficult to eliminate. This has created a great impact in addressing some of the major health issues globally.

Advancements in bio-manufacturing

Bio-manufacturing technology is advancing fast thus resulting in better drug delivery systems. Improved quality control is achieved through continuous production processes and this results in reduced costs. Modular microfluidic devices provide a high degree of precision in drug formulation which is crucial for complex drug formulations.

Three-dimensional (3D) and personalized medicine

3D printing plays a major role in the precise creation of drug products which are customized to individual patients in order to enhance patient outcomes. The ability of 3D printing technologies such as binder jetting and fused deposition modelling to construct tablets with controlled release systems is an example of this.

Kenya's progress in Pharmaceutical Engineering

In as much as Kenya's healthcare is integrating various improvements from the international community, universities such as the Technical University of Kenya are ensuring that their curricula include, for instance, contemporary drug-related technologies. This is to ensure that the professionals are trained to work in different pharmaceutical sectors, including research and production. In the meantime, there have been innovative solutions to local challenges.For instance, Engineer Norah Magero invented the VacciBox, a portable solar-powered refrigerator for storing and delivering vaccines in far-off areas. This is important because it helps keep vaccines effective in places where electricity is not always accessible.

Government support and regulatory improvements

The Kenyan Government promotes the growth of the pharmaceutical industry. In May 2024, during the AFCFTA-Anchored Pharmaceutical Initiative Conference in Mombasa, the Cabinet Secretary for Health highlighted the need to make medical treatment more affordable in Africa due to the high cost of medicines. She underlined the obligation of the AFCFTA-administered pharmaceutical industry to reduce the cost of medicines and improve the quality of goods.

Pharmacy and Poisons Board (PPB) has also taken up digital advances in order to further safeguard the safety of medicines. PPB introduced the Pillscan, an advanced Near Infrared (NIR) invention in July 2024. This device is used at the PPB offices and entry points, to make it easier to detect counterfeit and substandard products on the spot.

International collaborations and recognitions

The pharmaceutical industry in Kenya has achieved worldwide recognition. Universal Corporation, a Kenyan pharmaceutical company, became the first African pharmaceutical company that was approved by the World Health Organization to produce the crucial malaria drug in November 2023. This achievement shows Kenya's competence in the manufacture of medicines and its resolve to deal with serious healthcare issues.

Challenges and future prospects

While the Kenyan pharmaceutical industry is making progress, it still relies heavily on imports of active pharmaceutical ingredients (APIs) and excipients, which account for 95 percent of the field requirements. In order to avoid the challenges and to reduce the reliance on imports, it is essential to identify and measure alternative suppliers, otherwise wasting money on the growing domestic manufacturing capacity.

Kenya's strengths in education, innovation, and regulations are preparing the way for the acceptance of new pharmaceutical technologies. The current convergence has the potential to revolutionize the healthcare sector by streamlining the production of medicines, personalizing treatment, and improving the overall well-being of Kenyans.

Cutting-Edge Developments in Rehabilitation Medicine

EiK Correspondence

Picture Courtesy
The Freepik Team

Rehabilitation medicine in the Republic of Kenya is undergoing fundamental transformation. Medical treatment is being revolutionized by innovation and forming the backbone of healthcare. Furthermore, the current transformation is being fuelled by the collaboration of healthcare professionals, addressing the various health needs. Regardless of obstacles such as limited resources and increasing demand, Kenya is making significant strides in rehabilitation by expanding access and using modern systems.

Kenya's rehabilitation medicine is significantly improved by technology, especially through telemedicine and computerized rehabilitation initiatives. With over 58 million mobile subscriptions, Kenya had a mobile penetration rate of approximately 123.8 % as of 2023, according to the Kenya National Bureau Statistics.

In rehabilitation, especially in the manufacture of prosthesis and orthotics, 3D printing has made a significant difference. A report by the National Council for People with Disabilities states that about 1.2 million persons live with wide range of disabilities. Before that, prosthetics were very expensive, ranging between KES 50,000 and KES 300,000 per limb. However, 3D printing has emerged as a viable solution, reducing the cost of prosthesis to between KES 5,000 and KES 20,000. Companies like 3D Africa, and Kilimanjaro Prosthetics are active in producing low-cost, custom-made prosthetics. These institutions are working together with health clinics all over Kenya to provide low-cost prosthetic limbs to the amputee in both urban and rural areas. That effort is crucial because the World Health Organization (WHO) reported in 2018 that 20% of the universe's community needs several types of assistive devices. Kenya urgently needs to build its domestic production capacity to meet this need, especially in remote areas.

Kenya is also taking up modern rehabilitation techniques such as rehabilitation robots and exoskeletons. The World Babk reports that more than 2.4 million Kenyans have cognitive problems, with stroke being a major cause of significant rehabilitation. The use of robots and the exoskeleton has gained recognition as a way of improving motor function in stroke patients and achieving significant recovery.

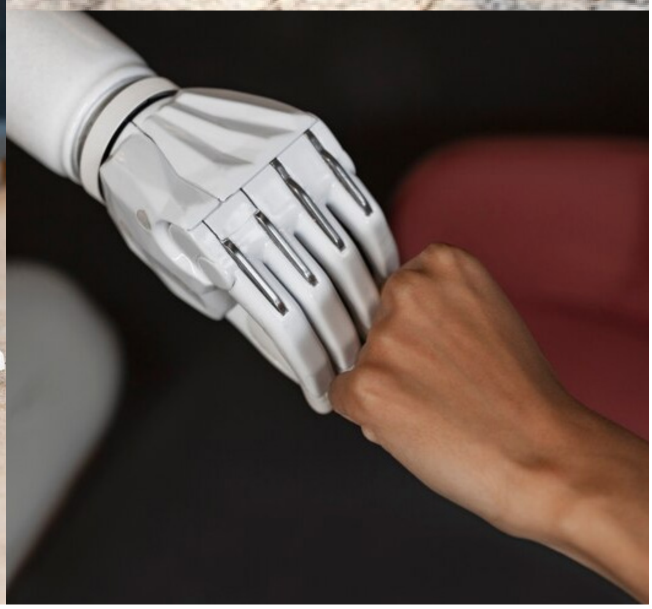
The Rehabilitation Centre of Excellence in Nairobi is using robotic devices such as Robokine and the Exoskeleton to assist stroke patients in their recovery of limb function. These devices facilitate neuroplasticity through exercise. The exoskeleton test is also being carried out at the Kenyatta National Hospital and other rehabilitation centres. Regardless of the cost obstacles, local engineers are adapting tools to the needs of the Kenyan patient. Ottobock Kenya Limited, a regional start-up, is developing a hybrid exoskeleton to make technological advancements more affordable and effective in Kenya.

Kenya is making significant progress in recovering patients with spinal cord injuries. With a high incidence of SCI (10,000 persons), largely due to natural disasters, Kenya has partnered with international organizations to develop personalized rehabilitation procedures. Experts are looking into root cell therapy and biotech innovations. The Nairobi Spinal Cord Injuries Rehabilitation Centre organizes clinical trials with neuroprosthetics to restore the agility of the affected limbs. The Spinal Cord Injuries Association of East Africa (KSCIA), on the other hand, is vigorously promoting knowledge and advocating access to focused rehabilitation support for SCI patients.

Rehabilitation medicine is increasingly becoming dependent on artificial intelligence (AI) and machine learning. Healthcare is expected to grow by 40 percent annually, mainly due to the surge of intelligent technology-based rehabilitation tools, according to a 2022 McKinsey & Company report. In Kenya, AI-powered tools are used to enhance a personalized rehabilitation plan for patients using data from wearable devices, gesture detectors, and responses from patients. A rehabilitation research initiative using motion detectors to monitor stroke recovery has been set up by the University of Nairobi. This architecture analyses patient motion and generates data-driven evaluation to guide the therapist, thereby reducing the reliance on subjective evaluation.

Advancements in regional expertise are essential for the continued development of rehabilitation medicine. Nevertheless, Kenya has over 25,000 registered health professionals, and yet there is a severe shortage of rehabilitation specialists. The University of Nairobi and Kenyatta University are providing a focused curriculum on Rehabilitation Technology, Health Care, and Computerized Wellness Innovations. Collaboration between Kenyan universities and world institutions at MIT and Oxford enhances the exchange of information. This has resulted in over 300 Kenyan professionals being trained abroad with a view to increasing their specific knowledge and capabilities in the nation.

Despite Kenya's development in rehabilitation medicine, obstacles still prevail. Access to progressive treatment is hindered by inadequate infrastructure, expensive systems, and a shortage of dedicated staff. However, investments in digital infrastructure, research partnerships, and local innovation position Kenya are a potential hub for high-tech and accessible rehabilitation care. Telemedicine, automated reasoning, 3D printing, and robotic therapy are promised to develop in Kenya. However, collaboration between engineers, health care professionals, and policymakers is crucial to ensure that these technologies benefit citizens primarily.



Robotics in Surgery: Adoption and impact of robotic-assisted surgeries in Kenyan healthcare

EiK Correspondence

Picture Courtesy
The Freepik Team

The medical field is currently one of the most tech-forward spaces, with mind-blowing inventions sprouting by the day in different parts of the world. From the portable MRI scanner, wearable artificial kidney to most recently, AI-assisted robotic surgery, there is no shortage of MedTech devices and procedures in the market specifically designed to improve treatment efficiency.

Robotic surgery often involves the insertion on miniature robotic instruments and a camera into the body via relatively smaller incisions. The surgeon in charge of the procedure then controls via a console, with the powerful camera blowing up the surgery area so the surgeon may be precise.

Robotic-Assisted Surgery History

Robotic-assisted surgery was first introduced into the market towards the end of the 19th century. According to an article published by The Surgical Clinic titled 'The History of Robot-Assisted Surgery,' the PUMA 560 System, the PROBOT, and the ROBODOC system are a few of the notable names that pioneered the use of robots in surgery.

Come early 2000s, a few other companies stepped into the space to claim a share of the market. As the article 'The History of Robot-Assisted Surgery' by The Surgical Clinic suggests, the ZEUS robotic system and the da Vinci Surgical System are two of the robotic surgery systems that stood out in terms of groundbreaking surgical procedures at that time.

Later, in 2003, the ZEUS system was halted when Intuitive Surgical, the company that owns da Vinci System, purchased and added it to its arsenal of assets. The da Vinci System has since become a household name in the robotic surgery space, having been used in several novel surgeries that opened the floodgates for more companies, including Johnson & Johnson, to develop interest in the space, as reported by The Surgical Clinic in 'The History of Robot-Assisted Surgery.'

Robotic-Assisted Surgery in Kenya

In Kenya, robotic-assisted surgery began to pique the interest of medical practitioners significantly around 2014 when the Apollo Bramwel Hospital in Mauritius launched a program to train Kenyan surgeons on how to perform robot laparoscopic surgery. In an exclusive YouTube interview by Citizen TV Kenya with the title 'Surgery Using Robots Unveiled in Nairobi,' a doctor explains the benefits of this surgery. He mentions less aggression, less pain, less invasiveness, and faster recovery as some of the main advantages of robotic-assisted surgery.

Following this training, several hospitals have, in the recent past, began adopting robotic-assisted surgeries in an effort to keep up with current global standards in the MedTech space. One of them is the Kenya Laparoscopic Surgery Services, a medical institution that consists of a team of board-certified surgeons who specialize in a variety of surgical procedures that run the gamut from gastrointestinal to gynecological surgeries. The Apollo Hospital also markets itself as a healthcare center with an able team of surgeons armed with up-to-date knowledge on minimally invasive surgery, including robotic-assisted surgery.

The Kenyatta University Teaching, Referral and Research Hospital (KUTRRH) also made headlines in the MedTech world towards the end of 2022 when it received the CyberKnife System equipment, a product of Accuray company that is used to treat various types of cancer non-invasively. As reported by an article on the hospital website dated 6th October 2022 and titled 'KUTRRH receives the CyberKnife,' Kenya was the second African country to receive this technology after Egypt, and medical practitioners were hopeful it would improve the capacity of the hospital to handle cancer diagnoses and treatment.

In the article, the then KUTRRH Board Chairperson, Professor Olive Mugenda, noted that the equipment would change the cancer treatment landscape in Kenya since most patients would no longer have to travel to other medically advanced countries for CyberKnife treatment. The then KUTRRH CEO also expressed his gratitude for having received the equipment, further noting that several patients had already made enquiries on the availability of the robotic-assisted surgery services, some even making bookings prior to the arrival of the CyberKnife.

So far, Kenyan patients and medical practitioners alike have embraced robotic-assisted surgeries not only for their improved precision, but also the fact that they involve less invasiveness and a faster recovery period. In an article by Indiana University (IU) titled 'IU Welcomes Ten Kenyan Medical Trainees,' several Kenyan medical trainees applaud the efficiency of robotic-assisted surgery, having witnessed it firsthand at IU.

Such benchmarking activities enable medical practitioners with interest in the field to gain more knowledge on it, which would hopefully increase its currently low adoption. The low adoption can be attributed to several factors, the main one being cost considerations, as revealed in the aforementioned YouTube video 'Surgery Using Robots Unveiled in Nairobi' by Citizen TV Kenya. The future of robotic-assisted surgery in Kenya remains bright, with hopes that insurance companies will be more willing to cover it and its cost will be more affordable to the average Kenyan.

Advancing Engineering Excellence:
Recognizing and Accrediting Engineering Programs in Kenya

Introduction

The Engineers Board of Kenya (EBK) is mandated to recognize engineering programs offered both locally and internationally to ensure they meet global standards. The journey of engineering education in Kenya began in Nairobi with the first School of Engineering in 1956 (Royal Technical College of East Africa), which offered just four programs: Civil, Electrical, Mechanical, and Agricultural Engineering. Since then, the engineering landscape has significantly evolved, with EBK now recognizing a wide range of specialized fields, including Mining, Mechatronics, and Biomedical Engineering, among others. This expansion reflects the growing demand for diverse engineering expertise to drive Kenya's socio-economic development. A comprehensive list of accredited programs is available on the EBK website https://eackenya.go.ke/wp-content/uploads/2025/02/RECOGNIZED-ENGINEERING-DEGREE-PROGRAMMES-_-EAC-STANDARD.pdf .

This article delves into EBK's progress in recognizing engineering programs, milestone towards joining International Engineering Alliance through Washington Accord, and the strategic vision for the future.

EBK's Recognition Function

Recognition is at the heart of EBK's mission to guarantee that engineering graduates possess the requisite skills and knowledge. As of the latest data, 90% of engineering programs offered by Kenyan institutions have received recognition from EBK, covering wide range disciplines as stated above. This rigorous process involves curriculum review, faculty qualification assessments, and facility inspections to ensure compliance with international standards. Out of all engineering programs evaluated across 15 universities, 90% (70) programs have been recognised. The remaining programs are at various stages of review, with a target to achieve 100% recognition by 2026.

Progress with the Washington Accord

Kenya's provisional membership in the Washington Accord (WA) by June 2027 is a milestone towards global recognition of Kenyan engineering qualifications. Kenya shall be the fourth African countries after South Africa, Nigeria and Mauritius. EBK has implemented measures to align curricula and recognition standards with WA requirements, with a goal of achieving full signatory status by 2027. This move is expected to open doors for Kenyan engineers to work in 23 member countries without the need for additional qualification assessments.

Future Outlook

EBK's vision extends beyond recognition. Plans are underway to establish a collaborative framework between academia, industry, the State Department of Roads (SDoR), and the Ministry of Water, Sanitation and Irrigation. This partnership aims to promote industry-driven curricula and internship placements, ensuring that graduates are job-ready. Achieving 100% recognition by 2026, provisional WA membership by June 2025, and expanded pathways for technologists will significantly enhance the global competitiveness of Kenyan engineers.

EBK, in collaboration with the Commission for University Education (CUE), universities, and industry stakeholders, remains committed to producing globally competitive engineers. By ensuring quality education, enhancing pathways, and fostering industry-academia partnerships, EBK is poised to catalyze Kenya's economic transformation through a robust engineering workforce.

Engineering Success: Overcoming Career Challenges, Embracing Entrepreneurship, and Learning from Eng. Fukwo Wafula's Journey

Eng. Ezekiel Fukwo Wafula
Director, KeNHA

Picture Courtesy
The Freepik Team

Let's be honest here, folks, the general public thinks engineers are boring. But here's the truth – these professionals are more than blueprints, numbers, and the occasional hard hat. Think again!

The Institution of Engineers of Kenya recently hosted an electrifying talk on their YouTube channel featuring Eng. Ezekiel Fukwo Wafula, a gentleman whose journey from humble beginnings to professional triumph reads like a New York Times bestseller novel.

Born, raised, schooled, and employed within a 10-kilometer radius, Eng. Fukwo's story proves that success isn't just about where you start, but where you are willing to go. His first encounter with engineering? A love-at-first-sight moment with, wait for it... an excavator. Yes, you read that right!

"I was so fascinated by how the guy looked in the regalia. The way they had dressed, the helmet, and how the excavator was scooping the soil," he recalls. That childhood spark set him on a path from Starehe Boys Center, the University of Nairobi, and over 20 years of shaping Kenya's road and design infrastructure.

Ask any engineer with a fistful of experience, and they'll tell you for free that the road to engineering greatness isn't always paved with perfectly measured asphalt. Eng. Fukwo took an unexpected turn into entrepreneurship after university, armed with just KES. 800 and a dream.

His first gig? Building classrooms for a children's home.

"Patience, putting up a brave face, networking, and having faith in my qualifications were key in bagging my first contract," he shared. For young engineers fresh out of campus feeling stuck, this is the kind of inspiration you need tangible proof that the struggle is part of the journey to your dreams.

They say, "No man is an island." So, let's talk mentorship. Eng. Fukwo credits his early career breakthrough and trajectory to mentors like Eng. Stanley Mwawasi, emphasizing how guidance and networking can accelerate professional and personal growth.

Speaking of innovation, he didn't just climb the engineering ladder, he built a few rungs along the way. He pioneered the 'Framework Contracting Model,' ensuring standby contractors are always ready to address emergencies during projects.

"Good enough, it was adopted, is still being implemented in the authority, and has even been enhanced," he said proudly.

That's not all. He also set up mentorship models within KeNHA (Kenya National Highways Authority), which saw him and the authority bag IEK accolades.

Beyond blueprints and site visits, Eng. Fukwo is passionate about sustainable practices, road safety, and embracing new technology like AI in engineering. His captivating story is a testament to resilience, faith, adaptability, situational awareness, and the power of dreaming big.

He wisely coins it, "As long as you have a desire and are focused, you'll attain whatever you want. But it also requires patience, trust in God, respect, and resilience."

Want to hear more of this brilliance? Watch the full interview on the IEK YouTube page because the future of engineering is being built right now! If you have a similar story and would like to share it with the world, drop us an email at iek@iekenya.org, and we'll reach out to you!

Empowering the Next Generation:
Engineering Students' Vision for a Sustainable Future

John Juguna
(DESA) Representative

The President of the Institution of Engineers of Kenya (IEK), Eng. Shammah Kiteme; the Chairman of the Engineers Board of Kenya, Eng. Erastus Mwongera; the 1st Vice President, Eng. Harrison Keter; the 2nd Vice President, Eng. Christine Ogut; the Honorary Secretary, Eng. Jacton Mwembe; IEK Council members present; the Chair of the Council of Engineering Deans, Eng. Prof. Bernard Ikua; the Registrar of the Engineers Board of Kenya, Eng. Margaret Ogai; distinguished panelists; esteemed engineers; dear students—ladies and gentlemen, good evening.

Earlier today, we all gathered at the University of Nairobi grounds and also at other venues as organized by the various IEK branches to commemorate the World Engineering Day, a day that is dedicated to recognize and appreciate the work and contributions of engineers to the society. We would like to appreciate the idea of having the Career Week as part of these celebrations, so as to engage with us students and young engineers on critical issues such as career opportunities, emerging trends, policy changes, and challenges in the profession. It also gives us a platform to share our opinions and express our concerns hoping that you will address them. This shows the commitment to nurturing the next generation of engineers. It is our sincere hope that this will continue to be a safe avenue where our voices are heard and our issues addressed.

We as the students, would like to commend IEK for their efforts which they have been putting to guide us on securing attachment opportunities. We also appreciate the EBK Internship Program. However, we urge that you introduce a structured system to facilitate placing all engineering students for industrial attachments and internships once they have graduated. Additionally, the duration of the EBK Internship Program should be extended such that upon completion, graduates can proceed directly to do board exams and become professional engineers. It is our belief that this can be achieved through Memorandums of Understanding (MoUs) with key stakeholders in the engineering field especially those with consulting firms, contractors, government agencies, and ministries. This will help in ensuring that our graduate engineers have a defined transition path to help them get professional status recognition. Despite undergoing equally under the same rigorous training, we fail to understand how medical doctors and pharmacists get well compensated during their internships while engineers are left on their own after graduation. Something need to be done to address these gaps and ensure that the engineers are fairly compensated. We would also like you to advocate for paid industrial attachments.

According to records, IEK currently has approximately 900 student members, yet the total number of engineering students in Kenya is significantly higher. For instance, the Faculty of Engineering at the University of Nairobi alone has well over 1500 students. This is more than IEK's total student membership. Clearly, there exists a gap that needs to be addressed. Efforts that are devoted to this initiate should be initiated with having strategies like bringing the Council of Engineering Deans on board and creating incentives for student membership that will motivate and attract more students to join. We suggest offering free certification programs like Computer-Aided Design (CAD), Building Information Modeling (BIM), and Project Management to boost the skill set of the registered student members. We also suggest that you continue offering discounted or free access to the industry events and other IEK, EBK & ACEK organized activities.

We commend the IEK, EBK, and ACEK for organizing student forums, and as you continue doing so, we request that you establish a formal reporting mechanism. There should be a mechanism for tracking progress for the implementation of the proposals that we submit during such events. We have participated in the career weeks twice before, AGMs, SGMs, Barazas and other similar forums where we as students raised our concerns. However, there has been no structured follow-up on the issues raised. We acknowledge that progress has been made in some areas that we are witnessing but it will be prudent to have a system that tracks and reports on the implementation of student proposals. We suggest that there be having progress reports communicated formally and shared periodically, outlining the status of each single proposal raised and submitted during these forums.

We applaud IEK for pooling engineers together and increasing their level of engagement with the students. This has been evident in the collaborations in student events like mentorships, dinners, summits and we are grateful for this. We acknowledge the excellent work being done by the IEK Future Leaders Committee (FLC) led by Eng. Annette Ingaiza and Eng. Collins Chang'ole in amplifying student voices and for their outreach programs.

We also commend Eng. Jenifer Gache's Women in Engineering Committee (WEC) for their She4She mentorship which has contributed to the growing number of registered female engineers in Kenya. However, borrowing a phrase from the political space «we need a seat at the table». We humbly request for at least guaranteed 2 slots (1 male & 1 female) within the future leaders committee and 2 slots in the Women in Engineering Committee (WEC) reserved for students. This will ensure that student perspectives are consistently represented in decision-making processes and that you are in touch with the actual happening of the student membership. We also suggest pairing of all student mentees irrespective of gender with professional mentors for continuous mentorship and guidance in their growth. This will ensure that all members get the necessary support they need to get along in the profession.

The journey to Washington Accord accreditation by EBK is a commendable milestone, and we appreciate the Board's dedication to this process. Achieving this recognition will not only enhance our global competitiveness but also affirm the quality of engineering education in the Kenyan universities. This will enhance the employability of our graduates. It will also elevate the engineering programs to global standards. However, for all our engineering students to really benefit from the accreditation, EBK, who we thank for being in this platform must accelerate the accreditation of the remaining courses and ensure that every engineering program offered in the country is recognized by the board. While we appreciate the efforts of having majority of the programs that had issues under your guidance they have been sorted out and have been accredited, e.g. BSc. Biomedical Engineering (Kenyatta University), BEng. Aeronautical engineering (TUK) and many others, some programs, however, such as BSc. Medical Engineering (TUM), BSc. Telecommunication and Information Engineering (TUK), BSc. Chemical Engineering (DeKUT) among others is not yet accredited as per the current records in the EBK website.

It is disheartening to see students who pass their high school exams, get admitted to pursue a degree program through a government body (KUCCPS), complete their studies at a public university, only to later be told by the regulator EBK, yet another government entity that their degrees are not recognized and they cannot be registered. Universities and other academic institutions play a major role in this thus they must take responsibility, but as the regulatory body, EBK must also put mechanisms in place to ensure that no student is admitted into a program that is not accredited. This can be achieved by collaborating with the Council of Engineering Deans which will help ensure that future graduates have a clear pathway to professional registration.

The world of engineering is evolving immensely with rapid technological advancements and other policies. Thirty years ago, we heavily relied on fossil fuel yet today, we are witnessing a global shift towards renewable energy. The discussion on climate action plans for adaptation and mitigation from the effects of climate change is an ongoing area of interest and requires attention from engineers to ensure resilient engineering solutions are implemented. Internet of Things (IoT) was the new thing making headlines some 10 years ago but today we are talking of Artificial Intelligence (AI) and augmented reality. Until recently, traditional reinforced concrete was the gold standard for structural engineering but now carbon fiber composites and 3D-printed buildings are gaining ground. Similarly, we have witnessed policy changes such as climate action regulations and new safety standards which are reshaping the manner in which engineering is practiced.

It is our belief that curricula reforms should be made regularly and they should consider incorporating emerging technologies and other new policies in our education system. This will help ensure that the curricula are updated to keep balance of the changing engineering landscape. To ensure that our graduates meet the industry needs of today and the future, hands on training on topics like AI, machine learning and renewable energy technologies would be helpful in matching the job market needs. To achieve this, academia should have a close linkage with the industry so that those who practice can regularly update those in academia on the required skills and also the new technologies. Moreover, students should be introduced to newly enacted policies that impact engineering while they are still in school as it will ensure that graduates are well-prepared for the realities of the profession.

The IEK plays a critical role in facilitating knowledge exchange which promotes engineering excellence through their events like conventions, seminars, industrial visits, trainings and publications. They keep us informed and updated with the happenings of the profession. We appreciate the continued support offered by IEK, EBK & ACEK to students in their events, trainings and publications and we hope that you will continue to support the growth and development of young engineers.

We are committed to continue working with you all in shaping our sustainable future through engineering.

Use of ICT in Healthcare Engineering

Information and Communication Technology (ICT) advancements are at the forefront of revolutionizing healthcare engineering with a footprint spanning telehealth, cutting-edge MedTech devices among other laudable innovations. At the nexus between ICT and healthcare engineering is a whole world of mind-blowing medical advancements that make treatment easier and more efficient for both healthcare practitioners and patients.

One of the oldest examples of the use of ICT in healthcare engineering would be in imaging and diagnostics. The use of ICT in imaging and diagnostics dates as far as the 1980s, when scientists sought to use computers in medical diagnoses to improve accuracy. Over the years, ICT application in medical imaging has only got better, and with a twist of artificial intelligence (AI) too. With the help of AI, medical practitioners are able to obtain more accurate medical scans faster, which then translates into faster diagnoses and on-time treatment for patients.

Another facet of healthcare engineering that has benefitted immeasurably from ICT is robotic surgery. For about three decades now, medical practitioners have been enjoying the perks of AI- assisted surgery, although with different levels of efficiency. Taking the lead in this space is the da Vinci System owned by Intuitive Surgical. This device, among others of its kind, enables surgeons to carry out minimally-invasive surgeries with the help of AI. Aside from the reduced invasiveness, patients who have undergone AI-assisted robotic surgeries also report less pain and a faster recovery period.

In addition to AI-assisted robotic surgery, there are several other devices that are changing the game in the equipment engineering space with the help of ICT. To begin with, medical practitioners are now able to apply 3D printing in producing customized prosthetics. According to a New York Post article "Israel's war with Hamas has resulted in some cutting-edge, astonishing medical advancements," Sheba Medical Center in Tel Aviv, Israel, was able to reconstruct the face of an IDF officer who had been injured during an air raid, by developing a meticulously-designed model of a skull.

This is just one of the many groundbreaking procedures hospitals have been able do using 3D printing technology, as the article reports. Synergy3DMed, a digital health company in Israel, also produced a personalized implant using 3D printing to help reconstruct the damaged skull of a military dog that had been injured during a Gaza operation. It is important to note that this technology has been existence for a while now, but it is only recently that its application was integrated into the medical space to create prosthetics in a few hours as opposed to weeks, which is the standard duration it usually takes.

ICT has also proven to be quite instrumental for in-patient care management. Hill-Rom Holdings, an American medical technology company, currently sells a bed called the Centrella Smart + Bed, a patient bed designed to help medical professionals manage life-changing health events better. At the touch of a button, one is able access several in-built features of this bed, such as a Nurse Call communication system, a real-time tracking of a patient's vitals, and audio patient prompts. Another noteworthy mention would be the Oura ring, a product of Oura Health, which is worn on the finger and actively collects health metrics such as heart rate, temperature, stress levels, and blood oxygen.

The internet is awash with stories of people who have benefitted from health trackers such as the Oura Ring. A viral example is an Instagram video of a 26-year-old Paralympic star, Hunter Woodhall, who claims that one time, the Oura Ring alerted him of the symptoms of appendicitis and as such, may have "saved his life." As reported in the SELF article titled "Hunter Woodhall

Says His Oura Ring Might Have 'Saved' His Life – Here's How," the track star was able to identify the signs of appendicitis with the help of the Oura app which flagged unusual health metrics from his ring. He was then able to visit a hospital and get an emergency surgery to remove his enlarged appendix.

ICT cuts across several industries, leaving an indelible mark in its wake. The healthcare engineering sector has ICT at its core, and the evidence of that is the innumerable medical advancements for which it is responsible. With constant improvement in technology, there's little doubt the healthcare engineering space is going to keep flourishing, thanks in no small part to ICT.

The Evolution and Impact of Biomechanics Sensors in Kenya's Biomedical Engineering Sector

Joseph Anvar Alot
Policy Research and Partnership Manager, IEK

Introduction

In the rapidly evolving field of biomedical engineering, biomechanics sensors have emerged as game-changers, transforming patient care, rehabilitation and medical diagnostics. These sensors, which capture and analyze human movement and physiological data, have become integral to the development of assistive technologies, sports science and remote health monitoring. In Kenya, the adoption of biomechanics sensors is steadily growing, driven by an increasing demand for innovative healthcare solutions. From early adoption in research institutions to practical applications in hospitals and rehabilitation centers, the country is carving a niche for itself in this transformative field.

Recent advancements in bioengineering, driven by nanotechnology, flexible electronics and artificial intelligence, are paving the way for smarter, smaller and more energy-efficient sensors. These innovations promise to further integrate biomechanical sensors into personalized medicine and preventive healthcare, significantly enhancing our understanding of human physiology and transforming healthcare delivery.

Biomedical sensors are essential devices in healthcare, designed to collect critical information about the human body and its pathologies. They are classified into three main types: physical sensors, which measure parameters like blood pressure, temperature and blood flow; chemical sensors, which detect concentrations of substances such as glucose or pH levels in body fluids; and biosensors, which identify biological molecules like enzymes, hormones, and DNA. Additionally, electrochemical sensors utilize electrochemical reactions to detect specific substances, making them valuable in chemical and biomedical applications. Sensors can also be categorized based on their sensing mechanism (e.g., mechanical, optical, thermal), the physical parameters they measure (e.g., resistance, temperature, flow), and their calibration signals, which ensure consistent and reliable output in relation to the measurand.

The packaging of biomedical sensors is a critical factor in their design and functionality, especially for implantable devices. These sensors must be biocompatible, durable and safe to interact with the body without causing harm, such as inflammation, infection or clotting. Materials like polymers are often used to protect the sensor while allowing necessary chemical diffusion. Proper packaging ensures the sensor's longevity and reliability, preventing issues like sensitivity loss or tissue damage. For example, implantable sensors must withstand body fluids and resist protein absorption or cellular deposition, which could impair their function over time. This highlights the importance of selecting appropriate materials and designs to maintain sensor performance and patient safety.

When selecting sensors, key performance characteristics must be considered. These include measurement range, sensitivity, accuracy, precision, resolution, reproducibility, offset, linearity, response time, drift, and hysteresis. Measurement range defines the operational limits of the sensor, while sensitivity indicates how much the output changes in response to an input change. Accuracy and precision ensure reliable and reproducible measurements, whereas resolution determines the smallest detectable input change. Response time reflects how quickly a sensor reacts to input changes, and drift refers to unwanted changes in sensor readings over time. Hysteresis describes the dependence of the input-output relationship on the direction of input change. Understanding these characteristics is crucial for choosing the right sensor for specific biomedical applications, ensuring optimal performance and accurate data collection.

Common Biomechanics Sensors and Their Applications

Biomechanics sensors play a critical role in monitoring, analyzing, and enhancing human movement and physiological functions. In Kenya, these sensors are increasingly used in medical rehabilitation, prosthetic development, and sports science. Some of the most commonly used biomechanics sensors include force sensors, which are utilized in prosthetic limbs and rehabilitation to measure walking efficiency and balance. Pressure sensors are applied in foot pressure mapping for diabetic care and orthopedic assessments. Accelerometers are used in fall detection, gait analysis, and sports training, while electromyography (EMG) sensors measure muscle activity to aid stroke recovery and prosthetic limb integration. Electroencephalography (EEG) sensors are used in neurological studies and brain-machine interfaces. Gyroscopes assist in motion tracking, commonly applied in sports biomechanics and rehabilitation. Inertial Measurement Units (IMUs) monitor three-dimensional body movement, particularly in sports and medical research, and optical sensors are utilized in motion capture for gait analysis and physical therapy. Bioimpedance sensors help assess hydration levels and body composition, while strain gauges measure mechanical deformation in prosthetics and assistive devices.

The Adoption of Biomechanics Sensors in Kenya

Kenya's foray into biomechanics and biomedical engineering began gaining momentum primarily through academic and research collaborations. The need for effective rehabilitation solutions, especially for accident survivors and individuals with mobility impairments, catalyzed the adoption of biomechanics sensors in hospitals and physiotherapy clinics.

One notable advancement has been the incorporation of motion capture and force sensors in gait analysis laboratories across select Kenyan universities and rehabilitation centers. These labs have been instrumental in assisting patients with prosthetics, monitoring movement disorders, and refining surgical techniques. Moreover, the rise of wearable sensor technologies, such as smart insoles and electromyography-based rehabilitation devices, is expanding the application of biomechanics beyond clinical settings to personal health monitoring and fitness tracking.

Academic Pathways: Where to Study Biomechanics in Kenya

As the demand for biomechanics expertise grows, Kenyan universities have responded by integrating biomedical engineering into their curricula. Today, several institutions in Kenya offer degree programs in biomedical engineering and related fields, covering biomechanics, sensor technology, rehabilitation engineering, and prosthetics development. Leading institutions include Kenyatta University, which provides a program in Biomedical Engineering, Jomo Kenyatta University of Agriculture and Technology (JKUAT), which offers a BSc. in Applied Bioengineering and an MSc. in Biomechanical Engineering and The Technical University of Mombasa (TUM) which offer a BSc. in Medical Engineering. These programs integrate biomechanics research, assistive technologies and biomedical applications to equip students with the skills needed to drive innovation in biomechanics, medical device development and healthcare solutions.

Regulatory Landscape:

Policies Governing Biomechanics in Kenya

The development and application of biomechanics sensors in Kenya are subject to both national and international regulations to ensure their safety and effectiveness in medical use. Several regulatory bodies oversee the compliance and implementation of these technologies. Locally, the Kenya Medical Practitioners and Dentists Council (KMPDC) regulates the medical application of biomechanics devices, while the Kenya Bureau of Standards (KEBS) ensures the quality and safety of biomechanics sensors and assistive technologies. The National Commission for Science, Technology and Innovation (NACOSTI) oversees biomechanics-related research and innovation.

Internationally, organizations such as the World Health Organization (WHO) provide guidelines on medical device safety and efficacy, while the International Organization for Standardization (ISO 13485) sets quality standards for medical devices, including biomechanics sensors. The U.S. Food and Drug Administration (FDA) regulates medical-grade sensors for global markets, and the European Medical Device Regulation (MDR) governs compliance of biomechanical devices in the EU. Adherence to these regulatory frameworks ensures that Kenya remains aligned with global best practices, enabling the safe integration of biomechanics technologies into the healthcare system.

The Future of Biomechanics in Kenya

Kenya is poised for significant advancements in biomechanics, with a growing emphasis on research, local manufacturing and technology-driven healthcare solutions. The future of biomechanics in the country will be shaped by several key trends. Increased investment in research and manufacturing will lead to the production of affordable, sensor-integrated prosthetics and rehabilitation devices. The adoption of smart biomechanics sensors in fitness and telehealth solutions will enhance personal health management.

AI-driven analysis of biomechanics data will improve diagnostics and rehabilitation strategies. Professional sports teams and athletes will increasingly rely on biomechanics sensors for performance optimization and injury prevention. Increased government and private sector collaborations will drive the development and adoption of biomechanics solutions, making them more accessible to the public. The integration of biomechanics sensors in telemedicine will enhance rehabilitation access, particularly in rural areas.

Conclusion

With continued investment in research, education, and regulation, Kenya has the potential to grow rapidly in the space of biomechanics innovation. As the industry grows, fostering collaborations between academia, healthcare institutions, and the private sector will be key in unlocking the full potential of biomechanics technology in Kenya's healthcare system.

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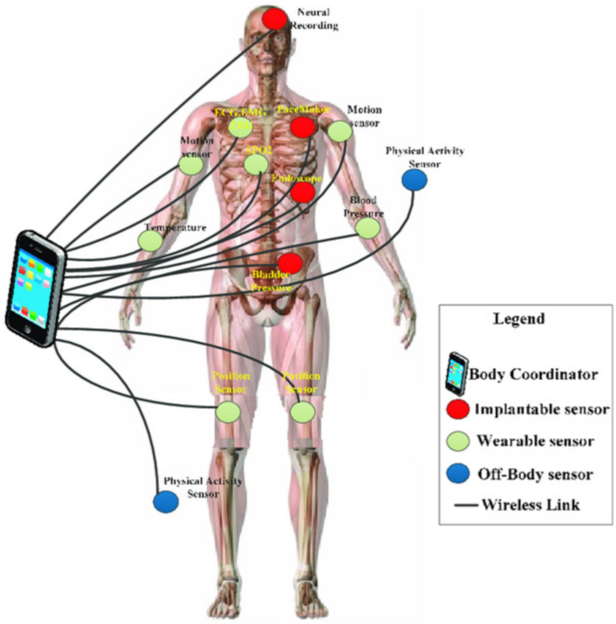
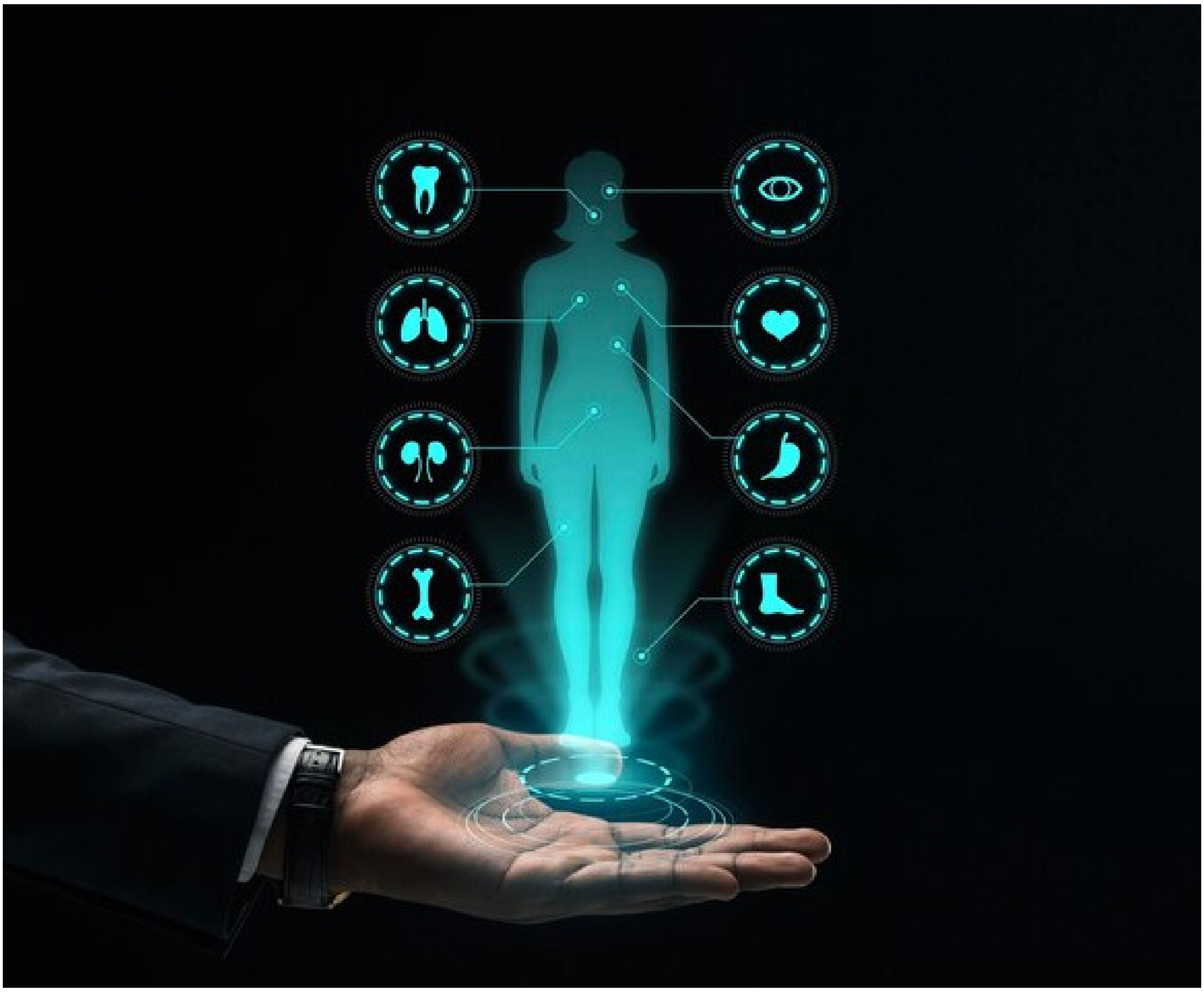


Typical example of biomedical sensor (BMS) deployment.



IEK Membership Report

The IEK membership committee meets every month to consider applications for membership of the various classes received at the secretariat. The IEK council at its, 531st, 532nd and 533rd council accepted the following members under various membership categories as shown below;

MEMBERSHIP CLASS	NUMBER ACCEPTED-531ST COUNCIL	NUMBER ACCEPTED-532ND COUNCIL	NUMBER ACCEPTED-533RD COUNCIL	TOTAL
FELLOW	3	-	-	3
CORPORATE	151	17	67	235
GRADUATE	69	42	72	183
GRADUATE ENGINEERING TECHNOLOGIST	9	2	3	14
GRADUATE ENGINEERING TECHNICIAN	16	-	3	19
STUDENT	11	5	18	34
TOTAL	**259**	**66**	**163**	**488**

During the period, we had 3 members who transferred from the class Corporate to Fellow member and 235 from Graduate to Corporate member. In addition, we had 183 graduates, 14 graduate engineering technologists, 19 graduate engineering technicians and 34 students were accepted as members.

Gender Data

Class	Male	Female	Percentage (Male)	Percentage (Female)
Fellow	3	0	100%	0%
Corporate	191	44	81%	19%
Graduate	156	27	85%	15%
Graduate Engineering Technologist	11	3	89%	21%
Graduate Engineering Technician	17	2	89%	11%
Student	18	16	53%	47%
TOTAL	**396**	**92**	**81%**	**19%**

Summary

Gender	No.	Percentage
Male	396	81%
Female	92	19%
	488	**100%**

531ST APPROVAL

FELLOW

	NAME	MEMBER NO.
1	Donald Fredrick Mahaga	F.1624
	Howard Ashihundu M'mayi	F.3249
	Owen Munene Ndung'u	F.5526

CORPORATE

SNO.	NAME	MEMBER NO.
1.	Abdalla Mohamed Raisi	M.9147
2.	Abdiaziz Mohamed Ali Omar	M.11359
3.	Abdifahad Adow Ibrahim	M.8749
4.	Acadius Amukongo Ambutu	M.11181
5.	Aisha Muthoni	M.5728
6.	Akuku Tillen Oronge	M.9012
7.	Albert Njeru Karoki	M.8154
8.	Alistair Teela Akute	M.5692
9.	Andrew Kipkogei Tuitoek	M.7596
10.	Angelica Oduori	M.8425
11.	Anita Jerop Zembi	M.7718
12.	Anthony Muthondeki Muribi	M.10273
13.	Antony Musyoka Mulinge	M.10885
14.	Antony Paul Orege	M.8576
15.	Bash Gedi Abdille	M.2739
16.	Benard Ouma Alunda	M.7959
17.	Benjamin Karanja Kamau	M.9354
18.	Benjamin Ombok Ochieng	M.9015
19.	Benson Lukania Joginda	M.2875
20.	Boaz Kamau Waweru	M.10547
21.	Bob Ayoti Osoro	M.10078
22.	Brenda Kwamboka Mong'are	M.7340
23.	Charles Kyalo Sila	M.12118
24.	Charles Nguli Peter	M.6748
25.	Christopher Kuru Kimani	M.13200
26.	Cornelius Kipkeu Rutto	M.11497
27.	Cosmas Cheruiyot Tonui	M.9307
28.	Cyrus Njonde Maina	M.13279
29.	Daniel Gakumbi Wachira	M.8950
30.	David Oyolo Chapia	M.9421
31.	Davis Mukotsa Wabwire	M.8149

SNO.	NAME	MEMBER NO.
32.	Denis Nyambane Machiegwa	M.11400
33.	Denish Ochieng Odira	M.10431
34.	Dennis Kipchirchir Borus	M.7271
35.	Dennis Ngundo Mwania	M.8585
36.	Diana Elizabeth Njeri	M.8617
37.	Dorcas Bonareri Makworo	M.6761
38.	Douglas Oisara Kibagendi	M.10210
39.	Edwin Simon Ng'ang'a Kimathi	M.10706
40.	Edwin Wambugu Wanyiri	M.9134
41.	Elijah Musango Munyao	M.10768
42.	Eliud Chege Kimani	M.4822
43.	Eliud Nyongesa Juma	M.10096
44.	Elizabeth Kavuu Kiilu	M.7404
45.	Emelda Apiyo K'ogai	M.9561
46.	Emmanuel Ishimwe Muhirwa	M.11286
47.	Ephraim Warutere Mureu	M.13844
48.	Eric Atingo Otieno	M.5330
49.	Eric Mbugua Muthee	M.12991
50.	Otieno Erick Rangili	M.10198
51.	Esther Kemunto Komendah	M.9064
52.	Esther Wangonyo Macharia	M.10131
53.	Eunice Mwende Mululu	M.10572
54.	Evans Kipkoech Rono	M.9743
55.	Ezekiel Bosire Ogao	M.11893
56.	Felix Odete Owino	M.11190
57.	Florence Nasimiyu Chebet Wekesa	M.6779
58.	Francis Mmbuka Eboso	M.11784
59.	Francis Mutangili Mwau	M.7529
60.	Garry Karanja Chege	M.9507
61.	Geoffrey Hoseah Okoth	M.11502
62.	Geoffrey Wainaina Ndichu	M.10987
63.	George Morara Onsomu	M.9315
64.	Gideon Thuo Njoroge	M.10447
65.	Gilberto Oroo Omwenga	M.10867
66.	Grace Esther Opar	M.10713
67.	Harris Mwawasi Kirigha	M.8973
68.	Hassan Mohamed Khalif	M.7802
69.	Ibrahim Mohamed Abdi	M.8435
70.	Immaculate Mwatha Ndaka	M.9466
71.	Innocent Peter Ombeki	M.10084
72.	Maryanne Wanjiku Irungu	M.4574
73.	Isaiah Makori Onkundi	M.11305
74.	Jack Wambugu Chege	M.6660
75.	Jacob Oluoch Akuno	M.9879
76.	James Muriithi Kamau	M.11327
77.	James Mutinda Peter	M.8434
78.	James Omondi Juma	M.10018
79.	James Tobias Omondi Okoth	M.8979
80.	Jared Kipkorir Kemei	M.7826

SNO.	NAME	MEMBER NO.
81.	Jared Ng'onda Adamba	M.7532
82.	John Mwangi Muigai	M.8474
83.	John Njoroge Kangethe	M.10821
84.	Johnson Rimba Kai	M.9554
85.	Sang Joseph Kipyegon	M.10373
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107.	Mwania Mativo	M.8094
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109.	Nicholas Walumoli Misiko	M.12001
110.	Nyamunga Omondi Leonard	M.11648
111.	Ochieng Harrison Odhiambo	M.10328
112.	Odhiambo Samuel Nyambenya	M.9328
113.	Ogutu John Bosco	M.10663
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117.	Kirui Patrick	M.10725
118.	Siele Patrick	M.10901
119.	Peter Ngetich	M.9001
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122.	Polycarp Kamau Gacheru	M.6436
123.	Reuben Gitonga Njeru	M.9041
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125.	Salim Bush Saidi	M.8844
126.	Shaban Onyango Ojwang'	M.13481
127.	Sharon Cherop	M.9822
128.	Sheila Chepkoech	M.7711
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130.	Simon Mwale	M.8850
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132.	Sylvia Khayeli Muhanji	M.9174
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138.	Victor Muchui Kanyithia	M.7523
139.	Victor Omondi Olando	M.8065
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141.	Vincent Ben Jumba	M.8506
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151.	Zakayo Gitonga	M.3125

532ND APPROVAL

CORPORATE

SNO	NAME	MEMBER NO.
1.	Antony Kanyiri Mwangi	M.13788
2.	Brian Kipkoech Chirchir	M.8310
3.	Erick Murimi Wangui	M.10413
4.	Eshiphan Githinji Mwangi	M.6664
5.	John Nzomo Mwanza	M.9611
6.	Joseph Mwaura Muigai	M.13225
7.	Kevin Mutua Katana	M.8746
8.	Kipleting Limo	M.7021
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17.	Yona Emmanuel Otsyula	M.10962

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2.	Amos Mwangi Muiruri	M.13914
3.	Ann Jelimo Kibet	M.12162
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8.	Bonface Ngaru Waweru	M.8942
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13.	Chris Chamia Chamia	M.13529
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17.	Daniel Koskei Simbeiwet	M.8467
18.	David Ajowi Akeyo	M.13989
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34.	Hillary Kiprono Ruto	M.8627
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36.	James Wilberforce Makhandia Odhiambo	M.6518
37.	Japhet Kipwarwa Cheptarus	M.12999
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39.	John Wamathai Kuria	M.9597
40.	Jones Nyachio Ondieki	M.7840
41.	Ken Ian Maina Kamangu	M.8985
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43.	Kenneth Mwangi Kariuki	M.8703
44.	Lawrence Lutta Inzofu	M.9629
45.	Leah Wagio Kihiko	M.8821
46.	Liyai Ronnie Iminyi	M.10505
47.	Luke Owino Okoth	M.9670

SNO	NAME	MEMBER NO.
48.	Mauti Nyabwanga Thomas	M.12206
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50.	Nicholas Wafula Owade	M.8092
51.	Nicky Cheruiyot Kazungu	M.10733
52.	Patrick Kimani Murigi	M.5572
53.	Peter Kigari Kamau	M.8171
54.	Robert Njuguna Njoroge	M.6520
55.	Ronald Omondi Nyangaga	M.10898
56.	Rose Wanja Kinyua	M.13351
57.	Salim Charo Kassim	M.8812
58.	Salome Jelagat Cheboi	M.10747
59.	Sammy Mwai Muthoka	M.12942
60.	Sospeter Esibitar Lotuko	M.6369
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62.	Stephen Kyalo Kiilu	M.7498
63.	Stephen Okoth Angwen	M.7898
64.	Susan Sein Mepukori	M.12711
65.	Victor Mabuka Wochuna	M.7864
66.	Winfred Anyango Otieno	M.8062
67.	Yonni Ohanga Muruka	M.10157

The council invites Engineers and affiliate firms to apply for membership in the various membership classes, kindly follow the link members.iekenya.org to register or scan the QR Code below to apply for membership;

STUDENTS' VOICES

Name: Caroline M. Muriithi

Age: 23

University: Kenyatta University

Major/Program: BSc. Biomedical Engineering

Year of Study: 4th

Innovations in Medical Engineering

Innovation has always been the backbone of medical progress. From the earliest surgical instruments to today's AI-assisted diagnostics, engineering has advanced healthcare dramatically. As technology accelerates, the intersection of biomedical engineering and medicine is creating solutions that enhance patient outcomes and redefine healthcare delivery. In Kenya, where access to quality healthcare remains uneven, biomedical innovation is not just an advancement—it's a necessity.

Globally, research drives promising innovations. Artificial intelligence and machine learning improve diagnostic accuracy and tailor treatments for cancer and cardiovascular diseases. Smartwatches and biosensors continuously monitor vital signs, helping manage chronic conditions like diabetes. Point-of-care diagnostics offer portable testing for HIV, malaria, and other illnesses, enabling rapid detection. Precision medicine combined with genomic engineering provides patient-specific solutions, while biomedical data science leverages vast datasets to inform policy and simulate disease spread.

In Kenya, local institutions and companies are developing homegrown healthcare solutions. The Kenya Medical Research Institute (KEMRI) leads with pivotal research and innovations like the KEMRI-Welcome Trust malaria rapid diagnostic test, facilitating swift malaria detection and treatment. Kenyatta University trains students in low-cost medical device development in its advanced lab, and Revital Healthcare in Kilifi produces affordable, high-quality test kits nationwide.

Telemedicine further expands access. The Digital Health Act promotes digitized records and virtual care via platforms like Ilara Health and Sasa Doctor, while locally made medical devices and Zipline's drones deliver essential supplies. Enhanced research, collaboration, and government support remain crucial for Kenya to lead in biomedical engineering.

Name: Mwiti Dorcas Mukiri

Age: 21

University: Kenyatta University

Major/Program: BSc. Biomedical Engineering

Year of Study: 3rd

Medical equipment are vital items to deliver quality services in health facilities. However, access to good quality, affordable and appropriate health-care is often compromised by the numerous equipment management challenges. Keeping up with the rapidly advancing technology and ensuring adequate training of technicians poses as a great challenge compromising on the accuracy and efficiency of crucial medical equipment. Maintenance and repair costs strain budgets forcing most facilities to make compromises on maintenance and repair. Complying with the set equipment regulations especially those that involve meticulous documentation and regular inspections proves to be complex and time-consuming. Other key challenges include proper equipment storage, spare part availability and unexpected machine breakdown, all impacting service delivery.

The intersection of engineering and healthcare fosters innovation, improving patient care and efficiency. Engineers design advanced medical devices, optimize hospital infrastructure, and address challenges that ultimately transform healthcare to meet the evolving needs of diverse populations. 3D printing for prosthetics to create affordable and customized prosthetics enhances quality of life for people with disability, solar powered medical devices ensure device functionality in areas with limited access to electricity and telemedicine accessibility such as the iDeliver platform in Kenyan hospitals for comprehensive maternal care, ensures increased access to quality care remotely while reducing cost for the same among other engineering solutions lead to significant improvements in health care.

STUDENTS' VOICES

Name: Khalil Feisal Awadh

University: Kenyatta University

Major/Program: BSc. Biomedical Engineering

Reg No: J23/5505/2020

Year of Study: 4th

Medical device advancement in Kenya depends heavily on prototyping because it closes the distance between innovation and practical application. Through prototyping, engineers can evaluate designs and improve them ensuring medical devices meet local healthcare requirements within safety and regulatory standards. Established organizations like Kenya Medical Research Institute (KEMRI) and upcoming startups such as MEDevice devote their efforts to using prototyping techniques to develop product solutions that address Kenya's unusual healthcare problems including scarce resources and heavy disease burden.

The next generation of biomedical engineers receives training through Kenyan universities which serve as important institutions for their education. Institutions like Kenyatta University and Technical University of Mombasa provide specialized biomedical engineering programs to educate students about prototyping techniques, device design and healthcare innovation. My involvement in an MIT-KU collaboration united cutting-edge prototyping methods with local creative abilities to generate novel healthcare answers and teach sustainable production methods.

My personal internship experience at Kenyatta National Hospital allowed me to understand the maintenance difficulties healthcare providers face when repairing medical equipment in limited-resource environments. Through this experience, I learned that prototyping remains crucial for producing tough equipment which needs minimal maintenance. The available opportunities have equipped me and my peers to make substantial impacts on Kenya's healthcare system by converting innovative concepts into concrete improvements in patient care.

Name: Brian Gichuki

Age: 23

University: Kenyatta University

Major/Program: BSc. Biomedical Engineering

Year of Study: 5th

Cutting-Edge Developments in Rehabilitation Medicine.

Increasing rehabilitation service demands have necessitated innovative strategies which address them such as: Virtual reality, Augmented reality therapy and motion capture systems.

Virtual reality therapy is based on the principles of neurorehabilitation aiming to improve both physical and psychological well-being. By carefully modulating visual and auditory stimuli, VR therapy enables clinicians to construct immersive, interactive environments that systematically challenge patients' balance, coordination, and muscular strength.

Augmented Reality by projecting walking targets, guiding the proper movement of weaker limbs, and providing physical therapists with data to give effective feedback. There is an AR game designed to provide home-based neurorehabilitation for children with cerebral palsy. The system combines electromyography electrodes and accelerometers in an armband to provide data. A trained classifier determines whether the target neuromotor performance of the arm is achieved as the user moves a virtual object through therapist-prescribed motions.

Inertial motion capture technology, which makes use of Inertial Measurement Units (IMUs). IMUs combine the technology of three separate sensors: an accelerometer, gyroscope, and magnetometer to provide a measure of the acceleration, rotation speed, and direction of an object or body segment under locomotion with sub-millimetre accuracy.

These cutting-edge developments provide a safe and adaptable rehabilitation setting, allowing individuals to engage in therapeutic exercises without the constraints or anxieties often associated with conventional rehabilitation techniques.

STUDENTS' VOICES

Name: Daniel Oucho

Age: 20

University: Technical University of Mombasa

Major/Program: Diploma in Medical Engineering

Year of Study:2nd

Role: Department Representative (Delegate)

Role of Engineers in Hospital Systems

Engineers play a crucial role in ensuring hospitals function effectively. They design and maintain essential systems like ventilation for clean air, borehole and water purification systems for safe water supply, and backup generators to ensure hospitals run smoothly even during power outages. With many public hospitals facing infrastructure challenges, engineers step in to create cost-effective and locally sourced solutions, improving healthcare delivery and patient safety.

Biomedical Equipment

Hospitals often struggle with maintaining critical medical equipment due to high costs, outdated technology, and a lack of skilled personnel. Engineers help by refurbishing old equipment, sourcing affordable spare parts, and developing innovative maintenance solutions. Major healthcare institutions rely on biomedical engineers to keep life-saving machines operational, ensuring uninterrupted patient care.

Innovations in Medical Engineering

Significant strides are being made in medical engineering through research institutions, Kenya Medical Research Institute (KEMRI) and universities such as the Technical University of Mombasa (TUM). Engineers are designing low-cost incubators for premature babies, solar-powered medical devices for rural areas, and mobile health apps to connect patients with doctors. Telemedicine is also growing, allowing patients in remote areas to consult specialists without the need for long travel. These innovations are transforming healthcare, making it more accessible and efficient for all.

Name: Samuel Omondi

University: Technical University of Mombasa

Major/Program: BSc in Medical Engineering

Year of Study: 3rd

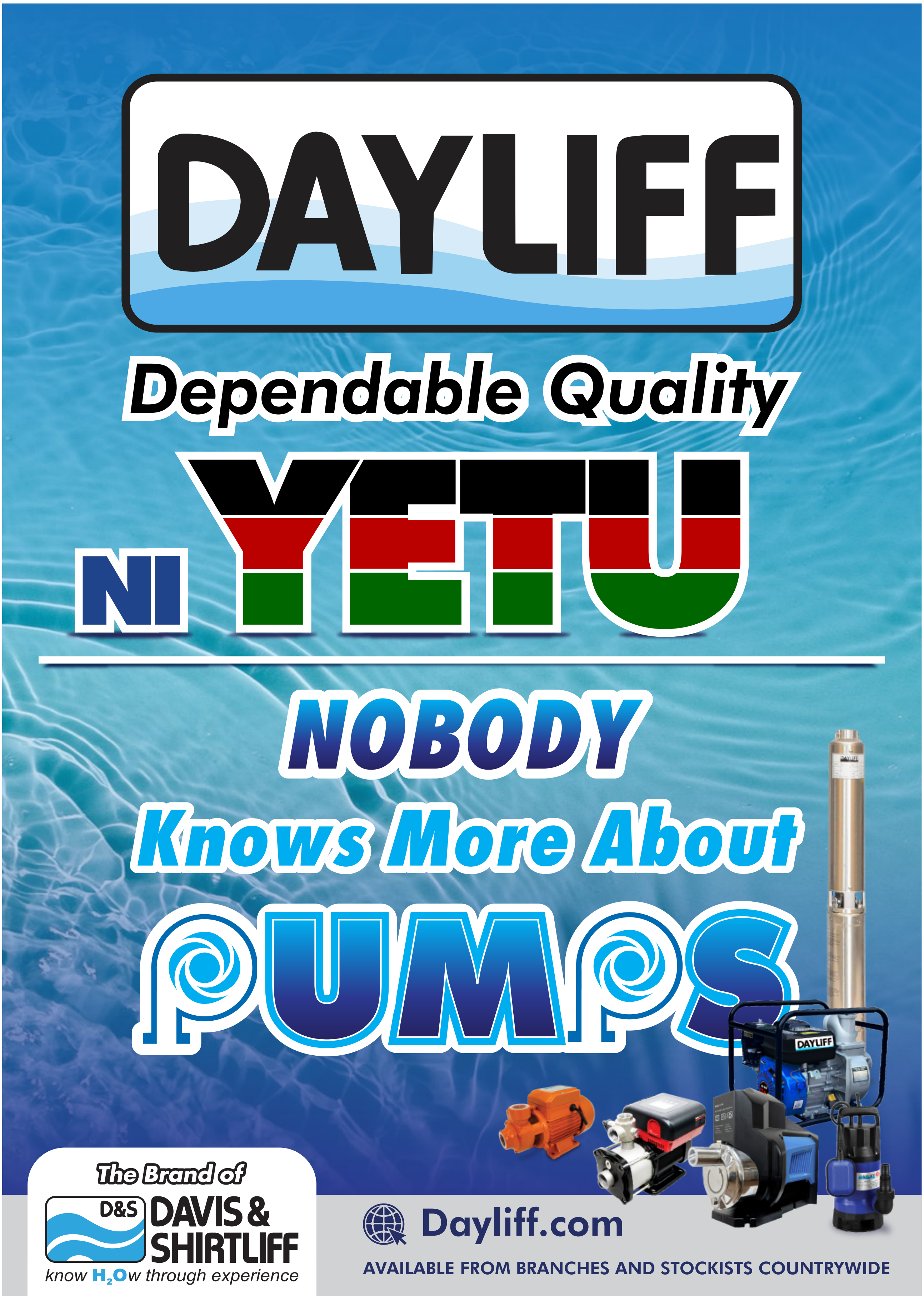
Local Biomedical Engineering Innovations in Kenyan Healthcare

With the global focus in AI, it is transforming healthcare. AI-powered medical devices have improved precision and enhanced efficiency in patient care. Wearable technology is now playing a significant role in real-time health monitoring. These devices are embedded with advanced biosensors that track vital signs and integrate with IoT systems to provide continuous health updates. More areas include; Smart prosthetics with pressure sensors and neural interface technologies like Neuralink, which have potential applications in treating neurological disorders.

TUM has supported the County Government through local innovation, developing cost-effective ventilators and advancing medical device manufacturing. KEMRI leads biomedical research in the region, evaluating medical devices and advocating for regulatory frameworks to foster innovation. These efforts reduce dependence on imports, positioning Kenya as a growing innovation hub.

Telehealth became a vital healthcare tool during the COVID-19 pandemic. Today, telemedicine continues to support remote consultations between patients and specialists through medical apps. Medical Engineers have developed electronic health records (EHRs) to secure patient data storage and retrieval. Also, cloud-based patient monitoring is being incorporated in healthcare with the support of the ICT sector.

With sustained investment, Kenya can become a regional leader in biomedical innovation, improving healthcare accessibility and quality.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