# Engineering in KENYA

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# WOMEN IN ENGINEERING

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# Call for Papers

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 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 August, 2026** for our next issue, whose theme is **Geospatial 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 the 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**

# In this **Issue**


Professional Journey and Empowering Women in Engineering:


Engineering Excellence and Gender Diversity:The Role of IEK in Advancing Women Engineers in Kenya


Breaking Barriers in Academia: Women Engineers Shaping Research, Innovation, and Higher Education Leadership


Women Transforming Transportation Infrastructure: Engineering Sustainable and Inclusive Futures in Kenya

# Message From the Editor

Eng. Prof. Alex Muumbo

***A Landmark Moment for Engineering in Kenya***

It is with immense pride, deep conviction, and a profound sense of historical responsibility that I present this special edition of Engineering in Kenya Magazine an issue dedicated entirely to celebrating, amplifying, and critically examining the role of women in engineering in Kenya. This is not merely a themed publication; it is a document of record, a mirror held up to our profession, and a clarion call for the transformative work that still lies ahead.

Engineering has always been at the heart of Kenya's development story. From the railways that stitched together a nation, to the dams that harness our rivers, to the highways that connect our cities and countryside, engineering has shaped the physical and economic landscape of this country. Yet for too long, the architects of this transformation have been predominantly drawn from one half of our population. This issue marks a deliberate, overdue, and joyful correction of that story.

The Institution of Engineers of Kenya (IEK), as the apex professional body for engineers in this country, has a solemn duty not only to uphold standards of technical excellence but also to champion the conditions under which all engineers regardless of gender, background, or circumstance can thrive. This special issue is the most comprehensive statement we have made on that commitment. It draws together journalism, analysis, and the lived testimonies of some of Kenya's most distinguished women engineers. In reading it, you will encounter a profession in transformation.

***The Architectural Argument: Why Diversity Is a Technical Imperative***

The first major theme running through this issue is one that goes to the very core of our profession: engineering inclusive infrastructure and why diversity matters in technical decision-making. This is not a social argument dressed in engineering language. It is, in the most rigorous sense, a technical argument.

Engineering decisions shape who has access to clean water, whose community is protected by flood infrastructure, whose mobility needs are served by transport design, and whose energy security is guaranteed by the grid. When the rooms where these decisions are made lack diverse voices, the outputs of those rooms carry the blind spots of their composition. Studies from across the engineering world consistently show that gender-diverse teams produce more innovative, more comprehensive, and more socially attuned solutions. This is not sentiment. It is engineering evidence.

In Kenya's context, the stakes are particularly high. Our infrastructure agenda framed by the Vision 2030 development blueprint and accelerated by successive government programs demands solutions that work for all Kenyans. The majority of rural water point users are women. The primary users of public transport infrastructure are women. The households managing energy poverty on a daily basis are, disproportionately, headed by women. If women are not present in the technical decisions that design these systems, we are designing with half the data.

> *Inclusive engineering is not about charity towards women it is about integrity in the engineering process itself. Diversity is a quality control mechanism for the profession.*

The articles in this issue make this case with rigor and candour. They examine how the profession has historically structured itself in ways that inadvertently and sometimes deliberately excluded women from technical leadership, and they outline what genuinely inclusive technical decision-making looks like in practice. I commend them to every engineer, male or female, who cares about the quality of what our profession produces.

***Institutions as Instruments of Change***

Professional institutions are not passive entities. They are active shapers of professional culture, gatekeepers of standards, and, when they choose to be, powerful levers of transformation. The second major theme of this issue examines how engineering professional bodies EBK and IEK specifically are supporting women leaders.

The IEK Women Engineers Chapter deserves special recognition in this foreword. Since its establishment, the Chapter has worked tirelessly to create a community of practice, mentorship, and advocacy within the profession. It has provided spaces where women engineers can speak plainly about the challenges they face, find solidarity with peers, access mentorship from senior practitioners, and advocate

collectively for institutional change. The contributions in this issue from women who have been shaped by and who have shaped the Chapter are testimony to the power of organized professional solidarity.

But institutional support cannot end at the creation of a special interest chapter. It must permeate the whole body. It must be reflected in the composition of our committees, the design of our conferences, the accessibility of our certification pathways, and the culture of our member interactions. This issue challenges us as an institution to honestly assess the gap between our stated values and our lived practices and to close that gap with deliberate, measurable action.

We are encouraged by the progress that is visible. Women now hold leadership positions in EBK leadership, IEK branches, committees, and at the national level in ways that were not true a generation ago. But encouragement must not breed complacency. The articles and testimonies in this issue are clear: structural barriers remain, unconscious bias persists, and the pipeline of women engineering students is not yet translating into proportional representation in engineering leadership at the rate that the profession requires.

***Breaking Ground: The Unvarnished Challenges***

This issue does not shy away from difficulty. A major journalistic theme the challenges women face in engineering projects is addressed with the honesty that the subject demands. Breaking ground, as the phrase suggests, is never easy. It requires confronting resistance, navigating terrain that was not designed with you in mind, and persisting when the path is unclear.

Women engineers in Kenya report a consistent set of challenges: sites and site cultures that can be hostile or unwelcoming; professional networks that were built on social connections from which women have historically been excluded; family and caregiving responsibilities that are disproportionately allocated to women and that compete with the demands of engineering careers; educational pathways that, despite progress, still lose girls at critical transition points; and a symbolic environment in textbooks, in advertising, in cultural narratives that rarely pictures women as engineers.

These are not complaints. They are engineering problems. And like any engineering problem, they yield to systematic analysis and deliberate intervention. The contributors to this section have done that analysis. They have identified the points of failure in the pipeline, named the structural dynamics that perpetuate them, and in many cases, described practical interventions that work. Their work is a resource not just for women navigating these challenges, but for every manager, educator, mentor, and institutional leader who has a role in shaping the environment that either perpetuates or dismantles those barriers.

***Voices That Define an Era***

The most powerful dimension of this issue is the collection of testimonies and analyses from prominent women engineers across Kenya. Together, they constitute an oral and intellectual history of women's participation in Kenyan engineering at a critical moment of transition. I want to draw your attention to the scope of what they cover, because it is genuinely extraordinary.

Our contributors address breaking barriers in technical professions — describing what it takes to enter, establish credibility, and eventually lead in fields that were not designed to receive women as full participants. Their stories are not uniform. Some describe hostility that was overt; others describe the more insidious challenge of invisibility. But all describe the extraordinary capacity required to persist and prevail, and the responsibility they feel towards the women who will follow them.

On leading consulting engineering in Kenya, this issue presents some of the country's most accomplished women in the consulting space. Their contributions challenge the notion that consulting engineering with its client management, project leadership, and business development demands is a male domain. They describe how they have built practices, led teams, managed complex projects, and in many cases, built organizations from the ground up. Their success stories are a rebuke to the assumptions that limited their early careers, and a roadmap for the women who come after them.

The challenge of balancing teaching, research, and leadership is taken up by women in academia whose contributions to engineering education in Kenya have shaped a generation of practitioners. These are women who have navigated the triple demands of the academic career while often also carrying the invisible labor of mentorship, student welfare, and institutional equity work that falls disproportionately on women in universities. Their reflections are among the most personally resonant in this issue and among the most important for institutions of higher learning to read carefully.

> *When a woman professor succeeds in engineering, she does not succeed alone. She carries with her every girl who watched her and believed, for the first time, that this could be her future too.*

The articles on engineering excellence and gender diversity affirm a truth that too often gets lost in diversity conversations: that IEK's mandate is excellence, and that excellence is inseparable from inclusion. The most technically excellent engineering community this country can build is one that draws on the full talent of all its citizens. The women featured in this issue have advanced the technical frontier of their specializations in structures, in water resources, in environmental systems, in electrical engineering, in manufacturing. Their work is excellent on any measure. IEK's role in advancing them, and in creating conditions for more like them to emerge, is not a departure from our excellence mandate. It is an expression of it.

The future of consulting engineering is examined through the lens of women's growing influence, and the picture that emerges is one of significant opportunity alongside persistent challenge. The consulting sector is evolving rapidly driven by the energy transition, by the digital transformation of engineering practice, by changes in public procurement, and by the demands of infrastructure-heavy development agendas across the continent. Women engineers who are positioning themselves in this space are not just entering a profession; they are entering a profession in transition, where new entrants with the right skills and positioning can shape the field rather than merely inherit it.

The IEK Women Engineers Chapter, whose work is explored in depth in this issue, represents an institutional innovation that deserves recognition beyond the engineering profession. By creating a structured community of practice with a mentorship programme, advocacy function, and professional development focus, the Chapter has demonstrated how professional institutions can actively accelerate transformation rather than passively waiting for demographic change to occur organically.

Perhaps nowhere is the intersection of engineering and national development more visible than in energy. The contributions on women leading in energy describe careers at the very frontier of Kenya's energy transformation in geothermal development at the Olkaria fields, in renewable energy integration, in nuclear energy, in rural electrification, and in the regulatory architecture that governs our energy sector. These are women who are literally powering Kenya's future. Their journeys illuminate what is possible, and what support structures made it possible.

Kenya's transport infrastructure is another arena where women engineers are making transformative contributions. From road design and bridge engineering to urban transport planning and railway infrastructure, this issue profiles women who are reshaping the physical connective tissue of the country. The challenges are considerable construction sites remain among the most gender-hostile professional environments in any sector but the achievements described here are commensurate with those challenges.

Finally, the contributions on building the future digitally reflect the rapidly evolving frontier where engineering and digital technology converge. Women in software engineering, in Building Information Modelling, in smart infrastructure, and in engineering data analytics are not just adapting to a digital world they are building it. This is perhaps the arena where gender dynamics in engineering are most visibly shifting, and the contributors to this section are both evidence of that shift and advocates for accelerating it.

***A Message to the Wider Engineering Community***

I want to speak directly in this foreword to the full breadth of the IEK membership to the men who constitute the current majority, to the young engineers of both sexes who are just beginning their careers, and to the institutional leaders who shape the conditions of professional practice.

To our male colleagues: the conversation in this issue is not one from which you are excluded. The argument for gender-inclusive engineering is not an argument against men it is an argument for a better profession that serves a better national purpose. The best male engineers I know are the fiercest advocates for inclusion, because they understand that the quality of their work depends on the quality of the teams and institutions around them. I ask every male engineer who reads this issue to reflect honestly on his own sphere of influence his team, his firm, his mentorship relationships, his committee positions and to ask what active steps he is taking to ensure that sphere reflects the talent that exists across the full gender spectrum.

To young engineers beginning their careers: you are entering the profession at a moment of genuine possibility. The women whose stories are told in this issue broke ground so that the terrain is more navigable for you. For young women, I want to say plainly: there is a place for you in this profession at the highest levels, and the IEK is committed to building the pathways that get you there. For young men, I want to say equally plainly: your generation has the opportunity to normalize a kind of professional culture that your predecessors did not always model a culture where talent is recognized regardless of gender, where mentorship flows in all directions, and where the engineering team looks like the society it serves.

To institutional leaders in universities, in government, in the private sector, in professional bodies this issue is both a celebration and a challenge. It celebrates what has been achieved. But it also documents, with precision, what has not yet been achieved. The gap between aspiration and reality is real, it is measurable, and it is closing too slowly. We call on all institutional leaders to set concrete targets, to hold themselves accountable, and to resource the transformation rather than merely endorsing it in policy statements.

***The Road Ahead***

Engineering is a forward-looking discipline. It deals in futures in what will be built, what systems will be designed, what problems will be solved. As we look ahead, the question for our profession is not whether women will play a central role in Kenya's engineering future. They will. The evidence of this issue is proof of that. The question is whether the profession will be deliberate and active in accelerating that future, or whether it will leave it to chance and the slow grinding of demographic change.

The IEK Editorial Board's decision to dedicate an issue to Women in Engineering is itself a statement of intent. It says that our professional conversation about excellence, innovation, and the future of engineering in Kenya must foreground the voices, experiences, and leadership of women. It says that we recognize the value of what those voices bring not as a concession to external pressure, but as a professional conviction grounded in evidence.

We intend this issue to be used. We intend it to be read in universities, where it should inform how engineering departments design their cultures and curricula. We intend it to be read in engineering firms, where it should prompt honest conversations about promotion, pay, project assignment, and professional development practices. We intend it to be read in government, where it should influence how public sector engineering bodies structure their hiring, development, and leadership pipelines. And we intend it to be read in IEK itself, as a document against which we measure our own progress in the years ahead.

We do not build this future for women in engineering. We build it with them and in doing so, we build a stronger engineering profession for everyone.

***Gratitude and Acknowledgement***

No issue of this scope is produced without extraordinary effort from many quarters. I wish to express my deep gratitude to all the women engineers who shared their stories, analyses, and expertise for this publication. Your willingness to be candid about your achievements, your challenges, and your hopes is the foundation on which this issue rests.

I thank the IEK Secretariat, the Editorial Board members, the peer reviewers, and the editorial and design teams whose professionalism is visible on every page. I thank the IEK Women Engineers Chapter leadership for their partnership in shaping the content and outreach of this issue. And I thank the leadership of IEK for supporting a publication that makes a bold institutional statement.

Most of all, I thank the women engineers of Kenya those featured here, those who have worked in quiet determination for decades before this moment, and those still in school today who will one day lead this profession. You are the reason this issue exists. You are the reason it matters.

# Message From the Chairperson Caretaker Committee

**Eng. Hillary J Nyaanga,CE, FIEK, MACEK**

**Chairperson Caretaker Committee, Institution of Engineers of Kenya**

This special edition of Engineering in Kenya Magazine (EiK issue 27) is dedicated to celebrating the remarkable achievements, leadership, innovation, and transformative contributions of women in engineering.

This publication comes at a defining moment for both the engineering profession and our nation. As Kenya advances its aspirations for industrialization, sustainable development, climate resilience, digital transformation, and inclusive economic growth, the engineering profession remains at the center of delivering the solutions that will shape our future. Equally important is ensuring that this future is designed, built, and led by the full spectrum of talent available to our nation.

For many years, engineering has been perceived as a predominantly male profession. However, the stories, insights, technical contributions, and professional journeys captured in this edition demonstrate a different reality; one in which women engineers are increasingly leading infrastructure projects, driving innovation, shaping policy, advancing research, transforming industries, mentoring future professionals, and contributing significantly to national development.

Within these pages, readers will encounter compelling perspectives from distinguished women engineers working across diverse sectors including energy, transportation, consulting engineering, academia, digital construction, manufacturing, environmental sustainability, infrastructure development, and emerging technologies. The publication highlights not only personal journeys of determination and professional excellence but also the broader transformation taking place within the engineering ecosystem.

The articles explore critical topics that are shaping the future of our profession. They address the importance of diversity and inclusion in technical decision-making, the role of professional institutions in creating opportunities for women engineers, the challenges that continue to affect career progression, and the interventions necessary to build a more equitable and representative profession.

Equally significant are the discussions on mentorship, leadership development, policy advocacy, digital transformation, sustainable infrastructure, circular economy principles, smart technologies, engineering research, and innovation. These themes remind us that engineering is not only about designing systems and structures; it is about improving lives, strengthening communities, and creating solutions that serve society in meaningful and lasting ways.

I am particularly encouraged by the strong focus on mentorship and professional development reflected throughout this edition. The experiences shared by accomplished women engineers demonstrate the transformative impact of mentorship, sponsorship, networking, and leadership opportunities. Their stories serve as powerful reminders that success is rarely achieved in isolation; it is nurtured through supportive institutions, collaborative professional networks, and individuals who are willing to create opportunities for others.

The IEK remains firmly committed to fostering an environment where all engineers can thrive and achieve their full potential. Through the Women Engineers Committee, the Women Engineers Chapter, student outreach initiatives, mentorship programmes, leadership development activities, technical forums, and strategic partnerships, IEK continues to strengthen pathways that support the growth and advancement of women within the profession.

The progress documented in this publication is encouraging. More women are joining engineering programmes, attaining professional registration, leading organizations, contributing to research, and occupying influential positions in both public and private sectors. Nevertheless, we recognize that significant work remains. Structural barriers, unconscious bias, workplace challenges, and underrepresentation in some technical and leadership spaces continue to require deliberate and sustained attention.

As engineers, we are trained to identify problems, analyze root causes, and develop practical solutions. The challenge of achieving greater gender inclusion within engineering is no different. It requires evidence-based interventions, institutional commitment, measurable actions, and collective responsibility. It requires all of us professional bodies, employers, universities, policymakers, industry leaders, and individual practitioners to work together in creating a profession that fully benefits from the talents, perspectives, and leadership of both women and men.

I therefore encourage every member of the Institution of Engineers of Kenya, every engineering student, every practitioner, and every stakeholder within the engineering ecosystem to

read this edition thoughtfully and engage with its contents deeply. The insights presented here are not intended solely for women engineers; they are relevant to the entire profession. They challenge us to think differently, lead more inclusively, innovate more effectively, and build institutions that reflect the diversity of the society we serve.

This publication is also a testament to the intellectual depth, technical excellence, and professional leadership that exist within our engineering community. The contributors have shared their experiences with remarkable honesty, wisdom, and courage. Their voices enrich our collective understanding of what it means to lead, innovate, and succeed in engineering.

On behalf of the Institution of Engineers of Kenya, I extend my sincere appreciation to all the authors, contributors, interviewees, researchers, and thought leaders whose work has made this publication possible. Your willingness to share your experiences and expertise has created a valuable resource that will inform, inspire, and empower both current and future generations of engineers.

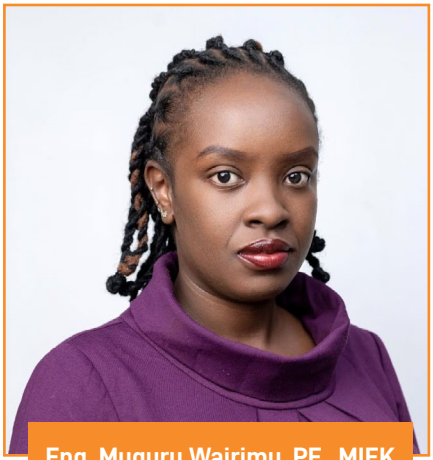
I also wish to commend the IEK Editorial Board, the Editorial Team, reviewers, designers, and Secretariat staff for their dedication, professionalism, and commitment in producing a publication of such depth and quality. Your efforts continue to strengthen Engineering in Kenya Magazine as an important platform for professional discourse, knowledge sharing, and thought leadership within the engineering fraternity.

Finally, I pay tribute to the women engineers of Kenya those who pioneered pathways when few existed, those who continue to break barriers today, and those who are just beginning their journeys. Your resilience, excellence, innovation, and leadership continue to enrich our profession and inspire the generations that follow.

As you read this special edition, I invite you to reflect on the progress we have made, the opportunities that lie ahead, and our collective responsibility to build a stronger, more inclusive, and more innovative engineering profession.

Together, let us continue engineering a future that reflects the very best of our profession and the very best of our nation.

# Message From the Secretary Caretaker Committee



Eng. Muguru Wairimu, PE , MIEK,
Secretary Caretaker committee

The Institution of Engineers of Kenya continues to play a pivotal role in shaping the engineering profession in Kenya and beyond, with a firm commitment to excellence, innovation, inclusivity, and sustainable development. In line with this mandate, the IEK Editorial Board is proud to present this special edition themed "Women in Engineering", which highlights the transformative role of women engineers in advancing the profession, driving innovation, and contributing to national and global development agendas.

This edition comes at a time when the IEK, through its Council and various technical organs, continues to deepen its commitment to diversity, equity, and inclusion within the engineering ecosystem. Central to this commitment is the Women Engineers Committee (WEC), whose sustained efforts have significantly elevated the participation, visibility, and leadership of women within the profession. The Committee's work is not only reshaping institutional culture but also strengthening the engineering pipeline from academia to professional practice.

Since the establishment of the Women Engineers Chapter in 2018, the Committee has steadily expanded its influence through structured mentorship programs, targeted policy advocacy, leadership development initiatives, and community engagement activities. These interventions have been strategically designed to address the systemic and structural barriers that continue to limit the full participation of women in engineering. Over time, WEC has evolved into a dynamic platform that nurtures talent, amplifies women's voices, and fosters a supportive professional environment.

The year 2025 marked a particularly significant period of growth and impact. The Committee successfully organized seven mentorship sessions, technical forums, and leadership workshops aimed at strengthening the professional capacity of women engineers across various career stages. These engagements have yielded tangible outcomes, including the recruitment of 333 new student members and the transition of 426 female engineers into corporate membership. This dual achievement reflects both a strengthened entry pipeline and enhanced career progression pathways for women within the engineering profession.

In strengthening governance and institutional coordination, the Committee has also established and reinforced representative structures across IEK branches, ensuring that women engineers are adequately represented at all levels of the Institution.

Trough WEC, IEK developed Women Engineers Student Associations in universities thus creating a critical foundation for early engagement, mentorship, and professional identity formation among aspiring engineers.

In recognition of the importance of visibility and communication in modern professional engagement, IEK has expanded its digital outreach through active management of dedicated platforms on X (formerly Twitter), LinkedIn, Instagram, and Facebook. These platforms have significantly enhanced engagement with members, stakeholders, and the broader public, while also amplifying the visibility of women engineers and their contributions to society.

Among the flagship initiatives undertaken by IEK council through its WEC Committee was the celebration of International Women in Engineering Day, which provided a powerful platform to recognize and honor the contributions of women engineers. The event featured Excellence Awards, Product Innovation Awards, and Content Creation Awards, highlighting outstanding achievements across the profession. In addition, speed mentoring sessions supported by the Royal Academy of Engineering offered invaluable networking and professional development opportunities, attracting more than 150 participants and fostering meaningful intergenerational engagement.

The IEK council further demonstrated its organizational strength through the successful hosting of the 7th Women Engineers Summit, which attracted 422 participants and generated key recommendations, including the proposal for a standalone summit to further elevate discourse on women in engineering. Building on this momentum, the inaugural Women Engineers Convention was subsequently convened, bringing together over 350 participants and reinforcing IEK's leadership in advancing gender inclusion within the engineering sector.

At the policy and partnership level, WEC has made commendable progress through collaboration with the Association of Professional Women Engineers of Nigeria in establishing a Gender Policy Sub-Committee. This initiative is tasked with developing a comprehensive gender policy framework for the Institution, with stakeholder consultations currently underway. This milestone reflects IEK's commitment to embedding gender considerations into institutional governance and professional practice.

Further strengthening its advocacy role, the Committee partnered with Women in Real Estate (WIRE) to promote safer and more inclusive professional environments within the built sector. This included participation

in validation workshops addressing sexual harassment prevention and workplace inclusion, reinforcing the importance of dignity, respect, and safety in engineering workplaces.

Mentorship remains a cornerstone of the Committee's strategy. Through the *She2She mentorship programme*, women engineers have benefited from structured mentorship engagements, including experiential networking activities such as walks at the Nairobi Safari Walk and Karura Forest. The programme culminated in December 2025 with the graduation of Cohort One, marking a significant milestone in mentorship-driven professional development, where participants were formally recognized for their growth and achievements.

Complementing this, IEK WEC chapter has implemented a series of capacity-building webinars focusing on critical professional competencies such as contract negotiation and job search strategies, teamwork and workplace dynamics, financial literacy and wealth management, as well as emotional and social intelligence for career advancement. These interventions continue to equip women engineers with the holistic skills required to thrive in an evolving professional landscape.

WEC Committee has also actively contributed to nurturing the next generation of engineers through youth-focused initiatives, including the 5th STEAM Virtual Art Competition organized under the Federation of African Engineering Organizations Women in Engineering platform, themed "Together We Engineer." This initiative has played a vital role in encouraging creativity, innovation, and early interest in engineering careers among young girls, thereby strengthening the future pipeline of women engineers.

As we reflect on these achievements, it is evident that the Women Engineers Committee has made remarkable progress in advancing the IEK Council's strategic vision of inclusivity, professional excellence, and sustainable growth of the engineering profession. The initiatives highlighted in this edition demonstrate that meaningful transformation is not only possible but already underway, driven by collaboration, leadership, and a shared commitment to progress.

We therefore commend the Women Engineers Committee for its dedication and impact, and we reaffirm IEK's continued support in strengthening and scaling these efforts. It is our collective responsibility to ensure that the engineering profession becomes increasingly inclusive, diverse, and responsive to the needs of society.

We trust that this edition will inspire reflection, dialogue, and renewed commitment to advancing the role of women in engineering.

# **Professional Journey and Empowering Women in Engineering:** The Role of the IEK Women Engineers Chapter



**Eng. Jenniffer Gache, PE, FIEK,**
**Chairperson, Women Engineers Committee (WEC), Institution of Engineers of Kenya**

Engineering has traditionally been one of the most male-dominated professions. However, over the years, I have witnessed encouraging progress as more women enter the profession, assume leadership positions, and make significant contributions across various engineering disciplines. While challenges still exist, the future is increasingly promising, and I believe women have an important role to play in shaping the profession and driving sustainable development.

My journey into engineering was inspired by a passion for problem-solving and a desire to contribute to meaningful change through technical solutions. Throughout my academic and professional career, I have been fortunate to work in spaces that have strengthened my technical expertise, leadership skills, and understanding of the impact engineers can have on society.

As my career progressed, I became increasingly aware of the unique challenges faced by women engineers. Despite the growing number of women joining the profession, many continue to face barriers related to visibility, mentorship, leadership opportunities, and professional growth. These experiences motivated me to become actively involved in initiatives that support and empower women engineers.

This commitment has been strengthened through my involvement with the Institution of Engineers of Kenya (IEK) Women Engineers Committee (WEC). The committee serves as a platform for empowering women engineers by promoting professional development, leadership growth, mentorship, networking, advocacy, and inclusivity within the profession.

One of the most important lessons I have learned is that mentorship can significantly influence career growth. Many young engineers possess the technical capability to succeed but often require guidance, exposure, and encouragement to navigate their professional journeys. Through the Women Engineers Committee, mentorship has therefore remained one of our key priorities.

Over the last two years, we have implemented several initiatives aimed at strengthening the participation and visibility of women engineers across Kenya. A major milestone during my tenure was the successful convening of a standalone Women Engineers Committee (WEC) Summit in May 2025. The summit brought together engineers, industry leaders, and stakeholders to discuss leadership, diversity, innovation, and professional development while creating opportunities for networking and collaboration. The event significantly raised the visibility of women engineers and highlighted their growing contribution to the profession.

We have also strengthened structured mentorship programmes through initiatives such as the **She2She Programme,** mentorship walks, webinars, speed mentoring sessions, and networking forums that connect experienced professionals with students and early-career engineers. These programmes have created safe spaces for learning, sharing experiences, building confidence, and supporting career progression among women engineers.

Recognizing the importance of nurturing future talent, the committee has actively participated in mentorship and career guidance programmes in schools and universities across the country, including engagements with girls' schools, engineering student associations, and young professionals. Through these interactions, we seek to inspire more young women to pursue careers in science, technology, engineering, and mathematics while demonstrating that engineering is both accessible and rewarding.

Another area of focus has been increasing the visibility of women engineers. Through dedicated WEC social media platforms, professional forums, international engagements, and recognition programmes such as the Excellence Awards, we continue to celebrate achievements, share success stories, and showcase the valuable contributions women are making within the profession. Visibility is important because it provides role models for the next generation and demonstrates that women belong in technical and leadership spaces.

During my tenure, we have also witnessed encouraging progress in the recognition of women engineers. We recorded the highest number of women receiving awards both within the Institution and from other local and international organizations. In addition, a growing number of women engineers secured appointments to government boards, councils, committees, and international bodies. These achievements demonstrate the impact of investing in mentorship, visibility, leadership development, and professional support systems for women in engineering.

The committee has also prioritized leadership development and advocacy. Through courtesy engagements with national leaders, collaboration with professional organizations locally and internationally, support for women-led initiatives, and the ongoing development of a Gender Policy, we are contributing to conversations that support greater inclusivity and equal opportunities within engineering. These efforts are helping to create an environment where women can thrive professionally and confidently pursue leadership roles.

While progress has been made, there is still more work to be done. Women remain underrepresented in some technical and decision-making positions, and challenges related to workplace culture, professional advancement, and representation continue to exist. Addressing these challenges requires collaboration among professional institutions, industry leaders, academic institutions, and government agencies.

I remain encouraged by the positive changes taking place across the profession. More women are entering engineering programmes, taking up leadership positions, and gaining recognition for their contributions in industry, academia, and public service. This progress demonstrates that targeted interventions, mentorship, and professional support systems can make a meaningful difference.

My vision is to see a future where women are equally represented across technical, leadership, research, and policy spaces within engineering. I envision a profession where every girl with an interest in engineering is supported by strong mentorship structures, inclusive policies, and visible role models who inspire her to pursue her ambitions without limitations.

The work of the IEK Women Engineers Committee continues to be guided by this vision. Through mentorship, leadership development, advocacy, networking, and professional recognition, we are creating opportunities that empower women engineers to contribute fully to the profession and society. As we continue this journey, we are also preparing for another Women Engineers Summit scheduled for July in celebration of International Women in Engineering Day. I remain optimistic that through collective effort, we can build a stronger and more inclusive engineering community that benefits from the talent, innovation, and leadership of all its members.

**I envision a profession where every girl with an interest in engineering is supported by strong mentorship structures, inclusive policies, and visible role models who inspire her to pursue her ambitions without limitations.**

# **Engineering a Regenerative Future:** Innovation, Circularity and Leadership for Sustainable Development

**Aarti Shah,**
**CEO,**
**Co-REGEN**

*Biodata: Aarti guides companies towards achieving environmental and social impact, enhances cross-border co-operation, and takes research from the valley of death into commercialization. Aarti founded Co-REGEN in 2020 to coach and match businesses with gasification and mining solutions, and steward them, to accelerate climate action. Co-benefits include reliable, dispatchable power, clean heat, healthy soils, ecosystem services and circularity. In the UNIDO Accelerate-to-Demonstrate Greener Tea project, Aarti is responsible for stakeholder relations, including the tea value chain, public sector and the external advisory board.*

*As a senior executive at Thomson Reuters (then a $12.5 billion company), responsible for businesses across industrialized and emerging economies, she drove profitable routes to market for technology solutions in the financial and professional services, and has since then operated in energy, climate and food systems, and other real economy sectors. A systems thinker, she brings clarity, prioritization and action where there has previously been intransigence or an unchallenged status quo. She balances short- and long-term priorities, consistently delivering results while remaining agile.*

*Aarti has a degree in computer science and French from the University of Bristol in the UK*

Engineering has always been about solving problems. Whether designing infrastructure, developing technologies, or improving systems, engineers play a critical role in shaping how societies function and how resources are managed. Today, as the world tackles climate change, resource depletion, energy insecurity, and broken food and health systems, the engineering profession has an even greater responsibility to develop holistic solutions that are technically sound, economically viable, and environmentally regenerative. I deliberately use regeneration rather than sustainability, as we must leave the world in a better place that we find it.

My professional journey has been driven by innovation and systems thinking. I began my career as an information and communication technology (ICT) graduate at Reuters, a global data, news, and workflow solutions provider for the financial markets, businesses and media. As an example, around twenty years ago, we were sending low latency, high frequency data to financial institutions' computers co-located in exchanges, so that the algorithms could trade as quickly as possible. We were using natural language processing to score news stories on how positive, neutral or negative they were about the stocks reported in them.

After leaving what was now Thomson Reuters in 2016, I became interested in how data, technology, engineering, and innovation could be applied to address environmental and societal challenges. This led me into consulting and later to founding Co-REGEN, an organization focused on accelerating climate action through regenerative and circular solutions.

Linear economic models assume that resources are abundant and can be extracted, used, and discarded. However, growing environmental pressures require a different approach. Circular economy principles enable us to keep materials, products, and resources in use for as long as possible, minimizing waste and maximizing value.

We advise organizations on adopting new business models through renewable energy, resource efficiency, re-building soils, environmental action and so on. This means understanding the many interconnected challenges, identifying technologies and behaviours to address these, developing partnerships, and supporting investment readiness, to move innovative ideas from concept to implementation.

Through the **UNIDO Accelerate-to-Demonstrate Greener Tea Project,** funded by the UK Government, we are supporting the deployment of a biomass gasification plant that will generate renewable power and heat, and biochar that can be returned to the soil. The model demonstrates how engineering can create integrated solutions that address multiple challenges simultaneously; clean energy production, fertiliser efficiency,

soil restoration, climate resilience, and a better-quality cup of tea.

What excites me most about engineering is its ability to connect disciplines and create systems-level solutions. Modernising the tea sector, for example, cannot be achieved through isolated interventions. It requires engineers, technicians, crop scientists, policymakers, financiers, and communities working together to understand complex challenges and design solutions that create long-term value.

That said, engineers are uniquely positioned to lead a just transition. From product design and manufacturing to infrastructure development and energy systems, engineering decisions influence how efficiently resources are utilized and how effectively materials can be recovered, reused, or repurposed. Whether working with metals, minerals, water systems, energy infrastructure, or agricultural technologies, engineers must increasingly think beyond immediate functionality and consider lifecycle impacts.

The opportunities for young engineers in this space are enormous. In Kenya, continuous access to water (not boreholes!), reliable power, resilient and efficient transportation, waste management, climate-smart agriculture for nutritious food, and urban development all present opportunities for engineers to make meaningful contributions.

Take Nairobi as an example. We are destroying trees and urban agriculture to widen roads for private vehicles and build beacon-to-beacon properties, but without mass rapid transit, goods and people will keep getting stuck in congestion and without green spaces, we are making the city hotter. In the absence of well-managed water supply, we put up tanks and are depleting our aquifers. Buildings collapse or start requiring maintenance far too soon. Each of these issues represents an engineering challenge requiring technical expertise, systems thinking, and long-term planning. Similar opportunities exist across agriculture, manufacturing, healthcare, mining, and renewable energy sectors.

Digital technology will also play a significant role in shaping the future of engineering. Artificial Intelligence (AI), data science, digital twins, geospatial technologies, and automation are transforming how engineers design, monitor, and optimize systems. However, technology should not be viewed as a solution in itself. Instead, it should be considered one of many tools available.

The starting point must always be understanding the problem we want to solve – and often that means addressing the root cause, not just the symptoms. Then, engineers can determine how technologies such as AI can contribute to improved decision-making, efficiency, and innovation. Technology is most effective when combined with strong engineering principles, practical field experience, governance, and a clear understanding of social and environmental contexts.

I also believe that engineers must become more involved in policy discussions. Any technology requires supportive regulatory frameworks, financing mechanisms, and institutional structures to achieve large-scale impact. Engineering expertise should extend beyond technical implementation to include active participation in shaping standards and building skills.

Women of course have a critical role to play in this transformation, but we will remain underrepresented in technical and leadership positions unless society changes. Girls can often discount certain professions as young as 4 or 6 years old. We must make engineering visible and attractive as families and communities.

> **For young engineers, my message is simple: identify the problems that genuinely interest you, remain curious, and never stop learning.**

Organizations also have a responsibility to create environments where women can thrive. This includes identifying high potential talent. Sponsorship, where experienced leaders actively advocate for emerging professionals, can be particularly effective in accelerating career growth. Try reverse mentoring, too. We intentionally chose to have a young woman, Liz Mubari, on our Greener Tea advisory board.

Looking ahead, I am optimistic about the future of engineering. We are already breaching planetary boundaries. Engineers have the knowledge, creativity, and problem-solving capabilities required to build more resilient and inclusive systems, but to be effective, we must see greater collaboration between industry, academia, government, and communities to ensure that innovation translates into practical solutions with measurable impact.

For young engineers, my message is simple: identify the problems that genuinely interest you, remain curious, and never stop learning. One lesson I learned early in my career is the importance of speaking up and contributing ideas, even if you feel outnumbered or less experienced. Technical competence is essential, but confidence and the willingness to engage in discussions are equally important. Innovative solutions emerge when individuals challenge conventional thinking or assumptions, and offer fresh perspectives. So, push open doors. Share knowledge. In resource-constrained environments, use frugal innovation. And have a sense of urgency.

# **Breaking Frontiers:** My Journey in Global Infrastructure and the Future of Women in Engineering

**Eng. Phostine Wekesa,**
**Senior Engineer,**
**United Nations Office for Project Services (UNOPS)**

In the high-stakes arena of global infrastructure, technical expertise is often the baseline. True leadership, however, is forged at the intersection of complex problem-solving and the ability to navigate diverse professional environments. Throughout my career, from local field operations to managing international projects, I have realized that the evolving landscape for women in engineering demands resilience, sharp judgement, and a willingness to break frontiers. A pivotal early-career moment occurred at the Kisumu Oil Jetty, involving intricate pipeline installations and offshore bridge construction. Moving away from heavily supervised roles, this assignment required me to make independent technical decisions under intense pressure. I learned quickly that professional authority is not given, but earned through judgement. This was cemented as I navigated disagreements with contractors over design interpretations, standing my ground by relying firmly on my engineering drawings and technical standards.

This foundational resilience proved vital as my career expanded globally with the United Nations Office for Project Services (UNOPS) in humanitarian contexts across Asia, the Pacific, and Africa. I frequently operate in fragile settings where data is limited, access is difficult, and timelines are urgent. These high-pressure environments motivated me to pursue international accreditation through the Institution of Civil Engineers, a credential I liken to a professional driving license that formalizes competence and builds confidence. In these complex settings,

**I have realized that the evolving landscape for women in engineering demands resilience, sharp judgement, and a willingness to break frontiers.**

I practice disciplined adaptability, meaning I maintain strict engineering standards while remaining flexible enough to respond to real-world constraints.

A cornerstone of my engineering philosophy is the belief that technical execution and the Sustainable Development Goals (SDGs) are deeply interconnected. This was best illustrated when I led a $100 million-plus water infrastructure programme across multiple municipalities in a post-disaster setting. Despite facing difficult terrain and logistical hurdles, we delivered the project through multidisciplinary teamwork and stringent quality assurance. Witnessing communities gain access to clean water close to their homes was the ultimate reward, reinforcing my conviction that infrastructure must be technically sound and socially appropriate. Having achieved global credentials, I am also a strong advocate for contextualizing international engineering frameworks to fit our local realities. While frameworks like Eurocodes provide invaluable guidance, they must be adapted to reflect African Climates, local materials, and regional construction practices. I champion the use of professional judgement to balance global standards with local practicality, calling for greater regional involvement in developing localized standards.

Beyond technical delivery, I believe leadership must be people-centered, prioritizing inclusion, shared ownership, and cultural sensitivity. My mission to empower others led me to found the Madam Engineer Initiative (MIE), a community-based organization dedicated to mentoring young female engineers and advocating for STEM uptake in high schools and higher learning institutions. MIE has gained incredible ground in Nairobi, partnering with bodies like the Institution of Engineers of Kenya (IEK) to deliver mentorship, career guidance, mental health conversations, and financial support for girls pursuing STEM fields.

My story should not merely be an exception, but the standard, because the future of global infrastructure demands diverse leadership that understands technical complexities and nuanced community needs. Therefore, I am issuing a clarion call to action to the entire engineering fraternity, specifically the Institution of Engineers of Kenya (IEK) and its partners to move beyond symbolic gestures and actively invest in the next generation of female engineers. Industry leaders must commit to providing authentic mentorship, creating structured pathways, and dismantling the barriers that hinder early-career professionals. By deliberately sponsoring young women to attend global conferences and lead critical projects, we can transform the landscape of African engineering. Ultimately, true excellence requires building an industry where women are recognized and empowered to design, build, and lead the infrastructure of tomorrow, free from gender bias.

## Madam Engineer Initiative Pictorials

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# BREAKING BARRIERS IN TECHNICAL PROFESSIONS: ADVANCING WOMEN IN ENGINEERING

**Eng. Margaret Ogai, CE, FIEK,**

The engineering profession is undergoing a transformation that is as much about rapid technological advancement, globalization, cultural evolution, as it is upholding ethics and integrity. Women engineers are stepping into increasingly consequential spaces across regulation, infrastructure development, private practice, and policy leadership, demonstrating that their expertise is foundational to our national growth. Yet the distance between raw talent and sustained trajectory remains a landscape we must intentionally map. While technical ability provides the baseline entry point into this demanding discipline, what truly determines how far a career expands over the long arc is the collective weight of strategic choices, structural shields, and the active reclamation of technical authority.

For women engineers, navigating these milestones carries a distinct professional responsibility. The conversation is rightfully shifting away from basic statistics toward the deeper, more complex questions of institutional influence, regulatory equity, and lasting legacy. From my early experiences in private sector design to my tenure steering the regulatory framework of our built environment as the Registrar and Chief Executive Officer of the Engineers Board of Kenya, these dynamics are realities I have proactively lived and shaped. In this conversation, I reflect on what it takes to not only enter the technical profession, but to remain within it, establish absolute credibility, and clear a predictable path for the generations coming behind us.

**Women, Technical Authority, and Engineering Governance**

To look back at the landscape of Kenyan engineering in the early 1990s is to recall a terrain defined by its profound solitude for women. When I graduated and entered the field, the roster of active women engineers nationwide could be counted on a single hand. My entry into this formidable space was driven not merely by academic interest, but by a deeply personal, generational legacy. My late father had once set out to pursue engineering, a dream prematurely severed by the prohibitive economic realities of his era. In stepping across the threshold of professional practice, I bore the quiet weight of that unfulfilled aspiration. It was an inheritance that demanded nothing less than total professional commitment.

Yet, the early realities of corporate and field practice quickly revealed that technical credentials do not automatically translate into technical authority. Within the traditional, conservative echelons of engineering, a woman's competence is rarely granted by baseline assumption; it must be systematically established, defended, and reclaimed. In the initial decade of my career, navigating the private sector, I encountered the subtle, pervasive mechanisms of institutional gatekeeping. In high-

stakes workshops and technical forums, there existed a reflexive, default assumption regarding gendered labor: as a young woman engineer, I was routinely nominated to act as the secretary of technical working groups. Initially, one might misinterpret this as an honor or an acknowledgment of diligence. However, as my professional maturity evolved, I recognized this for what it truly was - a polite marginalization that relegated women to the softer, administrative peripherals of technical discourse.

I chose to rebel against this quiet containment. I established an uncompromising personal boundary: if I cannot lead this technical group as its chairperson, I will remain a pure technical member, injecting my insights directly into the core design strategy rather than recording the ideas of others. Authority is never given; it must be intentionally claimed. This early friction with conservative skepticism taught me that technical visibility without foundational substance is entirely hollow. To survive and command authority in spaces characterized by intense scrutiny, one must possess an undeniable core of technical excellence. I resolved to out-prepare the room, treating every design calculation, site instruction, and project brief as an immutable statement of capability.

**The Leaky Pipeline and the Mirage of Progress**

Today, we take comfort in expanding university enrollments, noting with pride that women represent a significant portion of engineering cohorts across our premier institutions. We look at graduation lists and celebrate the reality that young women are disproportionately claiming top honors and dominating academic excellence registers. But as a former regulator, I am compelled to look beyond these comforting metrics and confront the systemic attrition that occurs at the transition from academia to professional practice.

The engineering pipeline in Kenya remains dangerously porous. While our baseline national numbers indicate that women comprise approximately fourteen percent of the registered professional engineering body, this figure masks a harsher economic reality. We are faced with a structural unemployment crisis within the engineering fraternity that hovers at around forty percent, and alarmingly, this burden falls heaviest upon young women graduates. Through my work at the Engineers Board of Kenya, I routinely listened to the frustrations of brilliant, young graduate engineers. They face a double disadvantage. Corporate hiring practices continue to harbor deep, unspoken prejudices regarding the biological milestones of a woman's life. Potential employers explicitly or implicitly withhold opportunities from women in their mid-to-late twenties, citing anxieties over the perceived disruption of childbearing and parental leave.

Consequently, young men are systematically preferred for demanding field postings, while women engineers are sequestered in design offices or altogether bypassed. This structural exclusion triggers a tragic economic migration. Frustrated by stagnant compensation packages and a lack of predictable career progression, our finest minds leave the profession entirely. They sell their intellect, analytical capabilities, and logic to the banking sector, corporate consulting, and global technology ecosystems where the value proposition is clear and immediate.

To counter this, during my tenure as Registrar, we championed the reinvigoration of the Graduate Engineers Internship Program. We recognized that the transition from a university degree to professional registration requires an institutional shield. We institutionalized an explicit thirty percent minimum quota for women within every recruitment cohort to ensure equity of opportunity. Interestingly, our regulatory data revealed a compelling paradox: while women faced immense hurdles securing these training placements, their subsequent pass rate in the rigorous professional registration examinations was consistently higher than that of their male peers. Women engineers approach professional scrutiny with a meticulous mindset. They do not attempt to navigate through professional assessments on bravado; they arrive over-prepared, technically sound, and thoroughly grounded in design, contract management, and project execution.

**Structural Deficits**

The conversation regarding professional advancement cannot be divorced from the macro-economic and regulatory framework governing our built environment. Throughout my tenure, I frequently encountered the critique that our technical standards and competency thresholds are too rigid, acting as institutional gatekeepers. I reject this framing entirely. Our professional benchmarks are not rigid; they are merely aligned with global parameters of safety, public trust, and liability. The crisis we face is not an excess of standards, but a profound deficit in system compliance.

Let us speak with candor: a staggering 50% of construction and infrastructural works across this nation are currently executed without the direct, documented involvement of professional engineers. The catastrophic structural failures that dominate our news cycles are the direct consequence of this systemic lawlessness. Drawings are approved in county offices by individuals completely devoid of professional engineering qualifications. Site instructions are routinely issued by unlicensed actors. This represents an immense, artificially suppressed market for engineering talent. If we were to elevate our national regulatory compliance levels to a baseline of near-total enforcement, we would immediately unlock thousands of legitimate professional roles for our graduate and professional engineers, effectively erasing the unemployment crisis.

Furthermore, we must confront the historic undervaluing of engineering expertise within public policy. What structural changes are needed to value engineering expertise properly? To offer a newly graduated engineer

a meager, entry-level starting stipend is not at parity to the structural compensation packages afforded to our peers in the medical or legal professional. It reflects an institutional failure to recognize that engineering capability is the primary engine of macroeconomic development. When I look at global models like China, I note that their transformative infrastructural narrative was driven by a state apparatus led at every tier by technical professionals - engineers occupying the highest seats of political and economic governance. If Kenya is to achieve its ambitious development targets, the government must issue clear exemptions to the current public-sector employment freeze, deliberately injecting qualified engineers into every level of our state machinery.

**From Participation to Total Influence**

How then do we shift the paradigm for women from passive technical participation to total institutional influence? It requires a deliberate transition away from the insular comfort of pure calculation into the broader spheres of governance, finance, and policy formulation. In my own journey, after spending an instructive decade within the private sector securing my professional and consulting engineering credentials, I made a conscious choice to transition into the public sector. I was driven by a deep curiosity regarding how state resources are allocated, how infrastructure funds are structured, and how national regulations are drafted. I wanted to be in the room where final policy decisions occur.

For women engineers, professional societies like the Institution of Engineers of Kenya and specialized structures like the Women Engineers Chapter are absolutely vital. Early in your career, when you are isolated within an indifferent corporate environment, the society provides an invaluable ecosystem of peer mentorship and psychological fortification. But as you ascend, you must look for more than just advice; you must cultivate corporate and institutional sponsors. A mentor advises you; a sponsor champions you in spaces where you are not yet permitted to sit. We need high-level champions - both male and female peers - who will explicitly state in boardroom discussions that we must give these women engineers the infrastructure projects because they have the core technical capability to deliver.

**Regulatory Frameworks as a Shield for Meritocracy**

We must also utilize the statutory provisions already available to us. The Constitution of Kenya and our public procurement laws explicitly reserve opportunities for marginalized categories, including women. Yet, within the massive economy of engineering consultancies and major infrastructure construction, women remain vastly underrepresented. We must become assertive. We must loudly demand compliance with these margins. If an agency advertises multiple director-level technical positions and all are filled by men, we must possess the collective resolve to call out that non-compliance.

Crucially, this advancement must occur within a clean framework of meritocracy. Let us be brutally honest about the shadow realities of professional life: women are frequently subjected to a completely different set of non-technical pressures than men. While men are often pressured for financial considerations, young women engineers routinely encounter the insidious challenge of personal harassment and demands for favors in exchange for promotion or project allocation. Throughout my career, brilliant young women have come to my office in distress, confessing that they are abandoning promising corporate roles because the workplace atmosphere has become predatory and unlivable.

This is where a powerful, unyielding regulatory framework becomes a shield. By codifying clear career progression guidelines and transparent compliance metrics, we eliminate the grey areas of human discretion where exploitation thrives. We must return to a system where professional growth is dictated entirely by pure technical competence, leaving no room for compromised environments.

**Reclaiming the Margin within Consulting Spaces**

As I transition beyond formal public governance, my focus naturally expands toward the consultancy arena and social enterprise. Within our engineering networks, the structural financial leverage defined under public procurement rules represents a critical tool for young professionals. In Kenya, statutory frameworks dictate that thirty percent of public procurement opportunities should belong explicitly to women and marginalized groups. However, within large-scale civil works and major engineering consultancies, this economic margin remains drastically under-utilized. Our distinct comparative advantage as women engineers resides firmly within the consulting domain, where analytical precision, design mastery, and senior project management form the true core of structural delivery.

We must become as demanding as our male colleagues in claiming these parameters. Men are fiercely assertive regarding promotions and project awards, and women engineers must match that aggressive perspective. When state infrastructure contracts are negotiated or institutional boards are assembled, we must look past symbolic comfort or passive compliance records. If an organization appoints multiple male project directors, we must challenge the layout directly. True inclusion means ensuring that our technical authority is backed by total economic and professional parity within private practice and consulting boardrooms.

**Facing the Horizon**

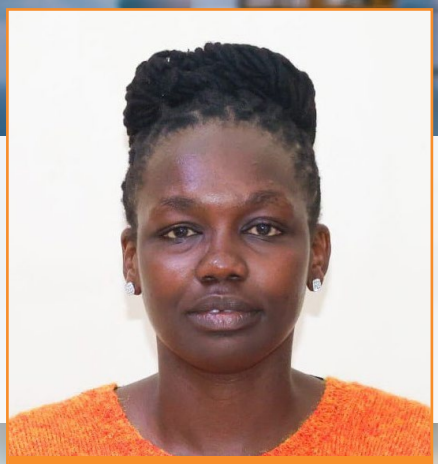
As we look toward the future, the nature of our profession is undergoing a profound evolution. We are operating within an increasingly unpredictable and complex world. The traditional, predictable paths of engineering are being redefined by digital transformation, sustainability demands, and increasingly complex infrastructure systems. I am

completely confident that women engineers are uniquely equipped to ride this wave of change as great as our male counterparts. Digital transformation has flattened the playing field, creating open access to technical visibility. When we transitioned from manual typewriters and drafting tables to computer-aided design in the 1990s, those of us who adjusted rapidly saw our productivity skyrocket, making our value undeniable. The exact same phenomenon is repeating today with emerging data diagnostics and green building systems. The playing field is being leveled.

My parting charge to the generation of young women engineers stepping into the profession today is simple: do not wait for validation, and do not seek permission to lead. Equip yourself with unmatched technical capability. Master the emerging specializations that will define the next fifty years of infrastructure. Leverage our professional societies to illuminate the path toward future technologies. We are the drivers of Africa's economic transformation; we are the answer to the continent's historic challenges. Start where you are, use what you have, and accept nothing less than total excellence. Women engineers' momentum is completely unstoppable.

> My parting charge to the generation of young women engineers stepping into the profession today is simple: **do not wait for validation, and do not seek permission to lead.**

# **Engineering Excellence and Gender Diversity:** The Role of IEK in Advancing Women Engineers in Kenya



**Eng. Maureen Auka, CEO the Institution of Engineers of Kenya (IEK)**

In the engineering profession, women are assuming increasingly visible roles across practice, industry, academia, and institutional leadership, and their contributions are no longer incidental. Yet the gap between talent and trajectory remains. Some engineers expand their influence steadily; others find that competence alone does not carry them as far as it should.

Technical ability is the entry point, not the differentiator. What shapes a career over the long arc is the accumulated weight of choices made consistently and quietly, long before their significance becomes apparent. The decision to remain visible when invisibility would be easier. To pursue responsibility before feeling entirely ready. To invest in relationships that challenge rather than simply affirm.

For women engineers, these choices carry particular freight. The profession is gradually shifting its conversation beyond representation toward the harder questions of progression, influence, and legacy. From my early years in railway engineering to my current role as Chief Executive Officer of the Institution of Engineers of Kenya, these are questions I have lived rather than merely observed. In this conversation with Engineering in Kenya Magazine, I reflect on what it takes to not only enter the profession, but to remain in it, grow within it, and help shape what it becomes.

## The Power of Seeing What Is Possible

Early in my career, women in senior engineering leadership were rarely visible. That changed through a Women in Engineering Leadership Program sponsored by my former employer. I found myself among women leading major institutions and organizations, and what struck me most was not the scale of their accomplishments but their openness. They spoke candidly, shared hard lessons, and offered encouragement without reservation. What had seemed exceptional suddenly felt within reach. If leadership had previously felt like a destination reserved for others, these women made it feel like a road that could be walked.

That encounter prompted a more deliberate investment in my own development. I pursued further studies, leadership training, and professional opportunities that stretched me well beyond my technical responsibilities. But exposure, however valuable, is only part of the equation. It shifts what you believe is possible. It does not do the work of getting there. Possibility may be revealed by others; the responsibility to pursue it remains entirely one's own.

This is something I now carry into how I engage with younger engineers. The obligation does not end at one's own advancement. Those who have been given access have a responsibility to create it for others. Progress is not a private achievement. It is, at its most meaningful, something passed forward.

## Creating Professional Belonging

Belonging is not something that announces itself. For most women in engineering, it is recognized only in retrospect, in the moment the profession stops feeling like a space being navigated and begins feeling like one genuinely inhabited.

The factors that determine whether a woman develops a lasting sense of belonging are not primarily structural. They are relational. A career is sustained less by ambition alone than by the environment in which that ambition is either fed or starved. The circles we inhabit are not incidental to professional growth; they are its conditions. There is something I have noticed about circles that are too comfortable: when you are the person everyone turns to, when no voice in the room unsettles your thinking or

outpaces your experience, the circle has stopped doing its work. It has become a mirror where it ought to be a window.

The engineers who stay are those who find people worth staying for, mentors whose guidance arrived at the right moment, colleagues whose ambition was contagious, networks that offered genuine exposure rather than the performance of it. This is what belonging actually looks like when it functions: not the comfort of familiarity, but the harder, more sustaining confidence that comes from being genuinely understood and deliberately challenged in the same breath.

For women, the professional and the personal are rarely separate negotiations. The demands compound in ways that are not always visible, which is precisely why a strong support structure is not a luxury. It is load-bearing. And it does not need to come from expected directions. Some of the people who mattered most in my own journey were men who chose, without being asked, to open doors and share ground. That choice, to invest in someone else's growth with no obvious return, is what professional community at its most honest actually looks like.

## Making Expertise Visible and Inclusion Structural

Embedding inclusion means ensuring that women who are present within the profession are shaping it, contributing to its body of knowledge, and leaving a legible mark on its intellectual life. But that work must live inside the institution's DNA, not on its margins.

Engineering knowledge advances through documentation. What is not written does not travel. What does not travel do not accumulate. And what does not accumulate is, for all practical purposes, lost. Women engineers remain significantly underrepresented across technical publications, conference presentations, and knowledge-sharing platforms, not because the expertise is absent, but because expertise and visibility are not the same thing. Hard-earned insights from complex projects, approaches refined across years of practice, they never find their way into a paper, a journal, or a conference proceeding. The knowledge exists. It simply does not leave the room. And so the profession continues without it, narrower for the absence it cannot see.

At IEK, I have worked to ensure that inclusion is not housed in a dedicated committee or surfaced during commemorative moments and then quietly set aside. Questions of diversity must surface within broader conversations about leadership, governance, and institutional participation, present not because a program demands it, but because the institution has accepted them as part of its normal functioning. Culture is not legislated into existence. It forms through the accumulation of decisions that come to define what an institution considers ordinary.

Through partnerships with bodies such as FAEO and the Chinese Engineering Academy, IEK is equally working to expand the visibility of Kenyan women engineers on international platforms. Awareness precedes participation. Many women engineers who have both the competence and the ambition to contribute to global professional conversations simply do not know the platforms exist. Part of the institution's responsibility is to close that gap, ensuring that women engineers are not only informed of these opportunities but actively encouraged to pursue them.

## Leadership Is Accumulated, Not Appointed

Walking through that door requires more than awareness of its existence. It requires a woman who has been prepared, over time and through experience, to believe that what lies on the other side belongs to her as much as to anyone else.

Leadership is rarely appointed. It is accumulated. The women who occupy positions of institutional influence are seldom those who waited for an invitation. They are those who were already present in the spaces where the profession does its less celebrated work, committee service, branch activities, voluntary engagement. The unglamorous fabric of participation that rarely draws attention but quietly builds the credibility that leadership requires. Confidence is produced by participation. And representation operates by the same logic. Women

> Embedding inclusion means ensuring that women who are present within the profession are shaping it, contributing to its body of knowledge, and leaving a legible mark on its intellectual life.

move toward leadership when they have seen it occupied by someone who looks like them, not as symbolic comfort, but as proof that the path exists and has been walked.

What accelerates that journey is the presence of mentors and sponsors who do not wait to be asked, those who identify potential early, name it plainly, and stay invested in its development long enough to see it arrive somewhere. Institutions must create the pathways. But pathways are only as useful as those willing to walk them. The door and the step forward belong to different hands, and progress requires both.

There is also the question of professional progression within the formal structure of the profession itself. Too many women engineers pause at the threshold of Corporate Membership or stall before attaining the status of Professional Engineer or Consulting Engineer. The registration pathway is not simply a bureaucratic milestone. It is the structure through which a woman signals, to herself and to the profession, that she has chosen to plant herself here, to build, to lead, and to be counted among those who have shaped the field. Every stage of that progression expands what is available to her, the opportunities, the platform, the influence, and the capacity to open similar doors for those who come after.

### What the Profession Owes the Next Generation

A river does not boast of the distance it has travelled. The land it has shaped speaks for it.

Progress will be evident when women are advancing steadily through every formal stage of the profession, from Student Engineer through to Fellow, from committee membership through to Council, in numbers that make their presence unremarkable. Not a handful of names that can be pointed to with pride, but a sustained and widening pipeline. The most telling indicator will not be statistical. It will be the moment young women entering the profession no longer regard leadership as an exceptional outcome reserved for the unusually determined, but as a natural expectation.

That shift is cultural, and culture is harder to measure than policy. More women are entering the profession, more are visible across its disciplines, and institutions like IEK have increasingly treated inclusion as a question of professional integrity rather than a peripheral concern. And yet unconscious bias does not dissolve with policy. It persists in the quiet recalibration that happens when a woman speaks with authority in rooms not yet accustomed to receiving it from her. In the uneven standard that requires some engineers to prove themselves repeatedly across the same ground. In the gap between a workplace that tolerates women's presence and one that genuinely draws on their authority.

The profession has changed who is in the room. The deeper question is whether the room itself has changed. True inclusion is not measured by attendance. It is measured by whose instincts are trusted, whose ideas are built upon, and whose leadership is followed without the need for prior explanation. These are not abstract standards. They are the daily experience of professional life, and they are what women engineers encounter, or fail to encounter, every time they walk into a consequential space.

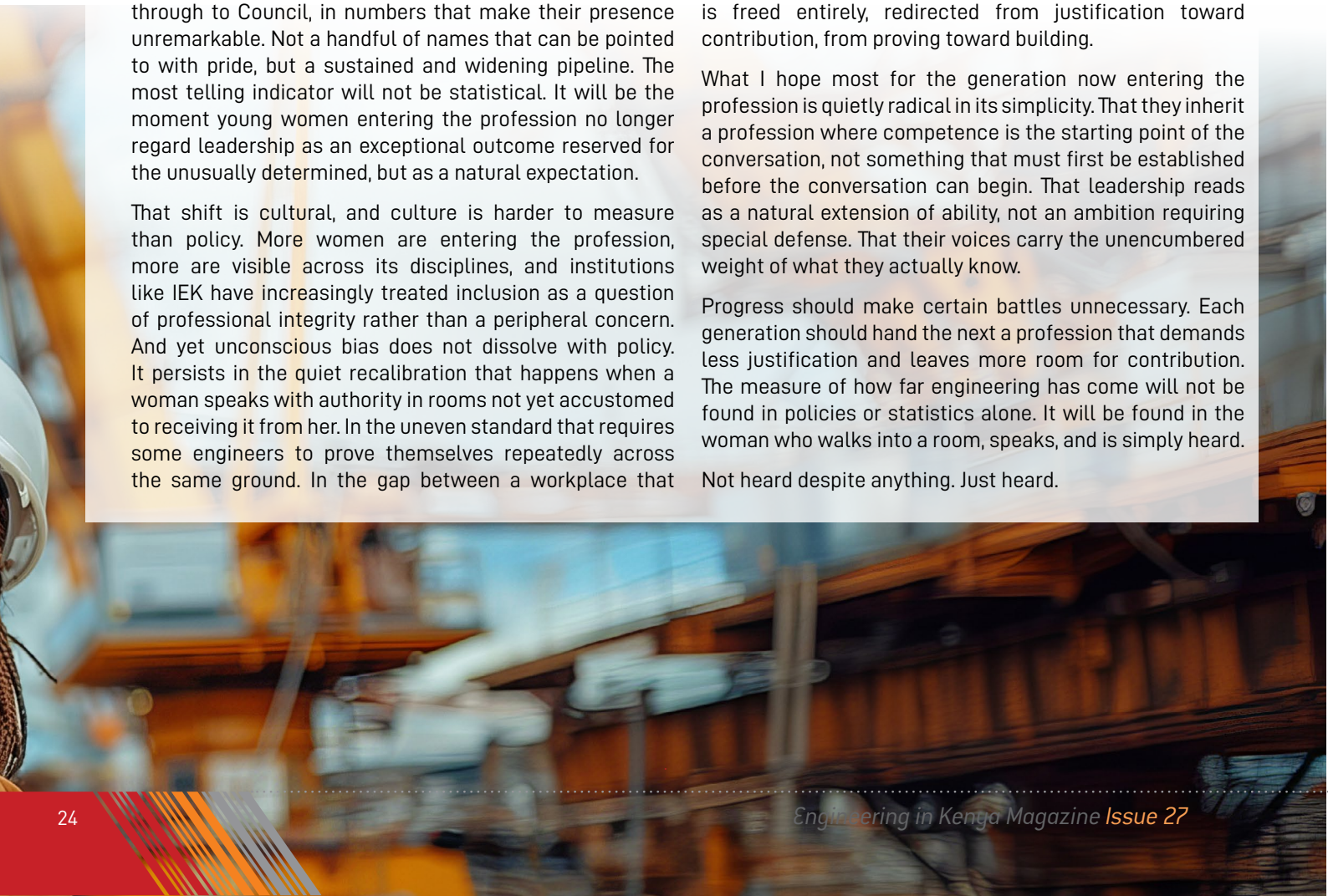
Changing that experience requires more than goodwill. It requires institutions that hold themselves accountable not just for who they admit, but for what those people are permitted to become once they are inside. It requires colleagues who understand that inclusion is not a favour extended to the few but a condition that makes the whole profession stronger. And it requires women themselves to resist the pull toward invisibility, to claim space, to document their work, to seek registration, to step into leadership before they feel entirely ready, and to refuse to let the weight of proof-giving become the defining feature of their careers.

There is a particular cost carried by women who have built careers in engineering that rarely appears in any formal accounting. It is the energy spent not on the work itself, but on the continuous, largely unspoken labour of establishing that one belongs there. That energy is not without limit, and the profession must reckon honestly with the burden of requiring it. The goal is a profession in which that energy is freed entirely, redirected from justification toward contribution, from proving toward building.

What I hope most for the generation now entering the profession is quietly radical in its simplicity. That they inherit a profession where competence is the starting point of the conversation, not something that must first be established before the conversation can begin. That leadership reads as a natural extension of ability, not an ambition requiring special defense. That their voices carry the unencumbered weight of what they actually know.

Progress should make certain battles unnecessary. Each generation should hand the next a profession that demands less justification and leaves more room for contribution. The measure of how far engineering has come will not be found in policies or statistics alone. It will be found in the woman who walks into a room, speaks, and is simply heard.

Not heard despite anything. Just heard.



# **Building the Future Digitally:** My Journey in BIM and Smart Construction

**By Eng.Wambui Maina**
**Senior Digital Engineering and BIM Manager at Mace**

The construction industry is at a pivotal crossroads, moving away from traditional, fragmented processes toward a more integrated, data-driven future. My own career transition from structural engineering into the specialized field of Building Information Modelling was born from a recognition that our built environment requires smarter, more precise ways of working. My journey was heavily shaped by my time at Howard Humphreys/Atkins, where I first experienced the value of digital information management. My experience working on the Britam Tower project underscored the indispensable role of effective information management in uniting diverse disciplines and ensuring the successful delivery of complex, high-stakes outcomes.

This technical curiosity led me to pursue a master's degree, during which I investigated how this modelling approach can mitigate the time and cost overruns that soften plague 2D-based construction projects.

As a BIM Manager, my role is as diverse as the projects I oversee. My daily responsibilities adapt to the specific requirements of each project stage, ensuring that digital delivery is consistent, comprehensive, and structured across all operational phases:

I. Assessment and Need: Aligning information requirements with organizational goals and asset needs at project initiation.

II. Invitation to Tender and Review: Defining clear exchange information requirements for bidders and meticulously reviewing technical submissions.

III. Appointment and Mobilisation: Establishing contractual information management arrangements, testing agreed processes and plans, ensuring operational readiness and mitigation of identified risks.

IV. Collaborative Production and Delivery: Overseeing and supporting teams to coordinate information in line with established standards, processes, and requirements.

V. Information Model Delivery: Managing the formal review, validation, and acceptance of information models at defined project milestones.

VI. Project Closeout and Handover: Finalizing and handing over the complete Project Information Model for its transition into the operational Asset Information Model.

Success in this role requires more than just technical proficiency; it demands collaborative leadership and clear, actionable communication. A defining moment in my career occurred while delivering a high-pressure, mixed-use development with rapidly evolving architectural briefs. By moving away from reactive coordination and establishing a single source of truth through Autodesk Construction Cloud, we were able to manage requests for information, track design updates in real-time, and maintain alignment across disciplines. This project, among others, affirmed that robust information management is the backbone of delivering complex, modern infrastructure.

Despite the clear benefits, BIM adoption in Kenya remains in its early, fragmented stages. While awareness is high, widespread application across the full construction and operational lifecycle is still nascent. To bridge this gap, we must champion a national ISO 19650-aligned framework, enhance academic capacity building, and provide the financial incentives necessary for mid-tier contractors to invest in these digital tools. Rather than attempting a full overhaul, contractors should focus on high-impact, incremental improvements using structured workflows for coordination and sequencing to realize immediate, measurable value. Furthermore, the industry must embrace emerging technologies like AI-driven risk management, reality capture using LiDAR and photogrammetry, and drone-based monitoring, while also pushing for IoT sensor integration to track environmental performance and long-term asset value.

Early in my career, I built technical authority and stakeholder influence through clear communication, technical credibility and collaborative leadership. I have been fortunate to have had the guidance of inspiring mentors such as Mary Wamae, Eng. Mbui, Eng. Machocho, and my current line manager, Jamile Tuma. I am committed to paying this forward, particularly through my work with the global Women in BIM Mentorship Programme. For the next generation of female engineers, my advice is simple: ground yourself in strong technical foundations, but look beyond software production to the broader principles of information governance. We must become architects of data, not just models. By developing skills in data analytics and automation, we move beyond the limitations of legacy CAD and position ourselves to lead the transformation of the built environment. We are not just building structures; we are building a more transparent, efficient, and sustainable future for Kenya. The data is clear, the tools are in our hands, and the responsibility to innovate is ours to embrace.

*The Britam Tower Project highlighted the critical need for effective information management and coordinated design across multiple specialist disciplines.*

# **Mlinzi-Volt:** IoT-Based Distribution Transformer Monitoring and Anti-Theft System

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## ABSTRACT

The operational failures of distribution transformers and vandalism pose serious threats to dependability in distribution networks, impacting economic growth. This study presents MlinziVolt, an IoT-based transformer monitoring and theft prevention system designed to enhance grid security and reliability. MlinziVolt continuously monitors transformer parameters and provides real-time alerts upon detecting unauthorized access, tampering, or potential vandalism, improving security and deterring theft. The system utilizes IoT-enabled sensors to track critical parameters such as oil levels, voltage, current, and temperature, transmitting data to a centralized monitoring station for analysis. Additionally, GPS tracking ensures real-time location monitoring, while electric fencing and obstacle sensors actively detect and prevent unauthorized intrusions. Through simulations and testing, MlinziVolt demonstrates its potential to enhance transformer security, optimize predictive maintenance, reduce operational costs, and ensure a stable power supply. This integrated approach supports advancements in smart grid technology, strengthening the reliability and efficiency of electricity distribution networks.

**Key words:** Distribution transformer, Security, IoT Monitoring, GPS, Real-Time, Predictive Maintenance

## INTRODUCTION

Distribution transformers, which are placed on electric poles, are rarely monitored. Consequently, in the event of transformer failure, there is often a delay in power restoration as it takes time for the maintenance team to arrive at the site. In Kenya, it is quite common to hear reports of transformer theft or vandalism. An article published on 22nd May 2024 by Joseph Muhia states that "Kenya Power has announced that a total of 78 transformers worth Ksh.78 million have been vandalized since the beginning of 2024. The company's CEO, Dr. Joseph Siror, revealed that between May 2022 and December 2023, the country lost 441 transformers worth about Ksh.396 million." [1] To address these challenges, a monitoring system is essential for utility providers to remain competitive in the marketplace. Sudden breakdowns need to be mitigated to minimize downtime, reduce maintenance costs, and extend the lifespan of distribution transformers. Therefore, this paper, proposes Mlinzi-Volt, an IoT-based distribution transformer health monitoring and theft protection system that enables authorities to remotely surveil transformers. [2] The system is equipped with various sensors, including a GPS tracker to determine the transformer's position. [3] It also utilizes an infrared sensor to detect intruders near the transformer. Additionally, temperature and oil level sensors monitor the internal conditions of the transformer, while current and voltage parameters are tracked in real time. Monitoring these parameters facilitates early detection of anomalies, preventing potential failures and enabling timely maintenance. Mlinzi-Volt integrates an ESP module, a Wi-Fi-based communication device that enables real-time data transmission from the sensors to a central monitoring station. This feature supports remote monitoring and control, allowing operators to take swift action based on sensor data. If the system detects anomalies in any of the measured parameters, it sends an alert to the control center. Distribution transformers are indispensable components of the electrical power grid, playing a critical role in delivering electricity to end users. [4] These transformers step down high-voltage electricity from transmission lines to lower voltages that can be safely used in homes and businesses. Given their strategic importance and widespread deployment, ensuring their continuous operation and security is vital for maintaining the reliability and efficiency of the power supply. Traditional transformer monitoring systems are typically limited in scope and functionality, relying on

periodic physical inspections and basic fault detection mechanisms. These approaches are inadequate for providing real-time insights into transformer health and security, often detecting issues only after they have occurred. This reactive approach leads to delayed responses to operational failures or theft. Mlinzi-Volt, a real-time monitoring system for distribution transformers with an integrated anti-theft system using IoT, leverages IoT and GPS technologies to transform traditional transformer monitoring into a more sophisticated and secure process. [5]

## LITERATURE REVIEW

Bongale, et al (2022) designed for fault detection system in Distribution transformers using GSM modems, microcontrollers, and various sensors. This system measures key parameters such as oil level, temperature and circuit status (open or short circuit) and sends alerts via SMS to responsible personnel. The primary objective is to automate fault detection and convey critical information to control rooms for prompt corrective action. The system's implementation aims to enhance stability, accuracy, and safety in power distribution, while also contributing to economic development by improving power system reliability. [6]

V. Aarthi, et al (2021) focuses on a GSM-based fault identification and location scheme aimed at enhancing fault detection accuracy and reducing the response time for rectification. This approach is designed to protect transformers from damage by providing precise fault location information in the distribution system. The proposed project implements a system that uses CTs and PTs, an AT-mega 8 microcontroller, and a GSM modem to automatically detect and classify faults and sends the data to the engineer in charge of maintenance and repair.[7]

Okokpujie Kennedy et, al (2017) proposed the application of GSM technology to monitor faults and quick isolation in order to improve the efficiency and reliability of the power systems but was limited to Voltage and current profile observation, winding and oil temperature, vibrations and humidity monitoring. [8]

Rohit R. Pawar et, al (2017) designed a system that which allows the values of the parameters to be sent to monitoring node through GPRS. [9] If any emergency condition occurs, message will be sent to the corresponding engineer through GSM and similarly on webpage. But GPRS base system has drawbacks: Can have high latency especially in text messaging, Expensive to add terminal above four and transit delay of data, etc.

Erick Kithinji et, al (2017) The authors address the significant issue of transformer vandalism. This system employs Arduino hardware, sensors, and GSM communication to monitor transformer activity.[10] When a vandal is detected near a transformer, the system raises an alarm and sends notifications to control room officers or security personnel. The system also provides details about the transformer's location and identification for efficient response. Their system includes sensors programmed using Arduino to detect unauthorized presence near transformers, triggering alarms and sending alerts.

Theophilus Wellem et, al (2012) They proposed a microcontroller-based room temperature monitoring system; which focused only on temperature monitoring of the distribution transformer. This has so many limitations because other parameters like voltage, current and oil level were not monitored. .[11]

## METHODS/ METHODOLOGY

The Mlinzi-Volt system developed in this paper has two main functions:

i. Providing protection to distribution transformers from theft.
ii. Delivering real-time transformer health reports to the relevant authorities

### *Theft Protection Methodology*

To protect transformers from theft, Mlinzi-Volt utilizes IR sensors to detect movement near the transformer. The system is programmed with specific threshold values, below which a notification is sent to the authority via the cloud, and a buzzer alarm is activated. If the sensor values drop below the threshold, Mlinzi-Volt immediately alerts the authority with the precise location of the transformer. Simultaneously, the buzzer sounds to notify nearby individuals of an ongoing theft attempt. In such an event, a relay is also triggered, energizing the electric fence to deter unauthorized access.

### *Monitoring Methodology*

Mlinzi-Volt is designed to monitor key parameters of a distribution transformer, including temperature, oil level (for oil-cooled transformers), and electrical parameters such as current and voltage on the secondary side. The system uses predefined threshold values that vary depending on the transformer type and size. If Mlinzi-Volt detects any anomalies in the monitored parameters, it immediately notifies the authority with the exact parameter values and coordinates of the affected transformer. This real-time data transmission allows for proactive maintenance and reduces downtime.

### *Simulation and Prototyping*

A simulation of Mlinzi-Volt was conducted using Proteus Design Suite to analyze system behavior. During the simulation, the system successfully established a connection with the monitoring device of the authority, sending alerts in response to anomalies or unauthorized access. Figure 1 illustrates the system inside the simulation and its connection

to the monitoring cell phone of the authority. After a successful simulation, a prototype of Mlinzi-Volt was built using key components such as processing units, sensor stacks, and a communication module.

***Implementation Steps***

To achieve the study objectives, the following steps were followed:

**Step 1:** Identifying Key Parameters Selection and integration of suitable sensors for monitoring transformer health and security. Determining the most efficient method for data transmission and component sourcing.

**Step 2:** Designing the Real-Time Monitoring System

Development of a circuit diagram for Mlinzi-Volt. Interfacing the microcontroller, sensors, and anti-theft measures.

**Step 3:** Developing Core Functions

Writing code for each sensor and the GPS module. Integrating individual component functions into a unified system, ensuring smooth data flow. Simulating various theft and fault scenarios to validate system response.

**Step 4:** Testing System Effectiveness Deploying the integrated Mlinzi-Volt system in a real-world power distribution network to evaluate performance.

***Testing and Validation Procedures***

Simulated Environment Testing: Initial testing in a controlled environment to verify sensor accuracy and data transmission reliability. Use of Arduino IDE and Proteus software for programming and simulation.

Field Testing: Deployment of Mlinzi-Volt in real-world conditions to assess its functionality under various scenarios. Designing and testing a prototype for practical implementation.

Performance Metrics: Evaluating system accuracy, response time, reliability, and effectiveness in theft prevention.

The software components of Mlinzi-Volt include Arduino IDE for microcontroller programming and Proteus for simulation. Sensor data is transmitted to a cloud-based server, where it is processed and visualized through a web-based dashboard. This enables utility operators to monitor transformer health in real time, ensuring improved efficiency and security in power distribution.

## RESULTS

After careful simulation of the system in Proteus, a prototype was built using the specified elements of processing units, sensors, and the communication unit. The results obtained from the simulation and testing of the system were promising.

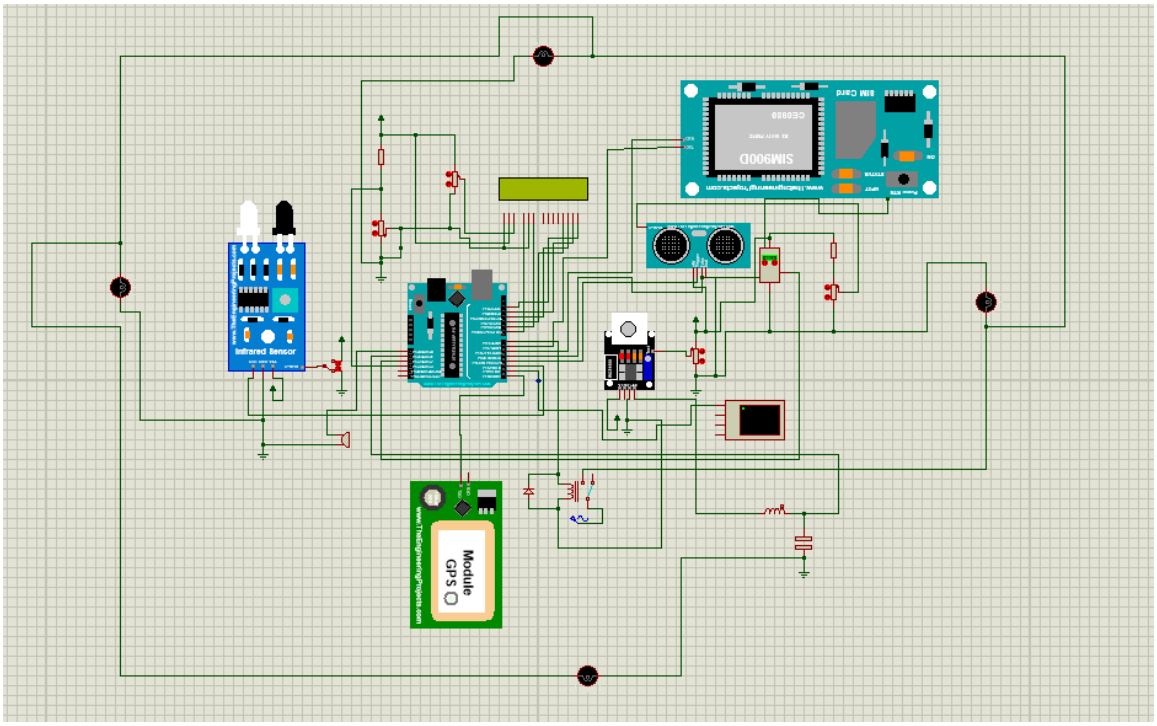



*Figure 1: Circuit diagram of the monitoring and anti-theft system for distribution transformer portrayed in Proteus Simulation Software*

The system successfully monitored the transformer's current, voltage, oil level, and temperature in real time. Additionally, the anti-theft mechanisms were tested in various scenarios.

After successful simulation, the system provided the following results:

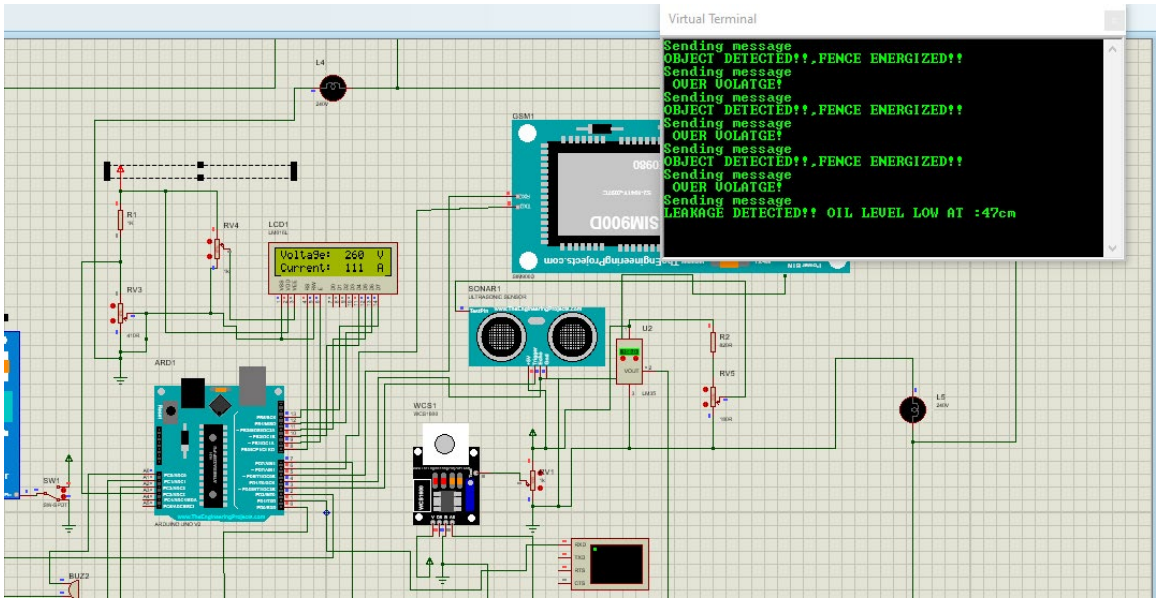



*Figure 2: Simulation results*

- Real-Time Monitoring: The system monitored and recorded transformer parameters such as current, voltage, oil level, and temperature in real time.
- Anti-Theft Mechanism: Unauthorized access or movement of the transformer triggered alerts and activated the anti-theft mechanism, including electric fencing.
- Data Visualization: The user-friendly web interface allows operators to visualize real-time data and track transformer health. Historical data trends will assist in predictive maintenance.

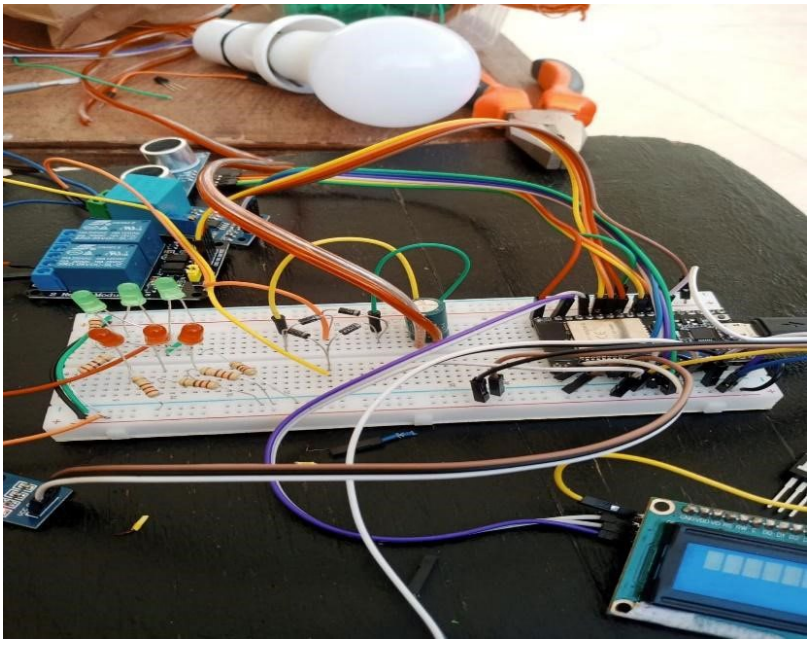


*Figure 3: The anti-theft subsystem system during construction stage*

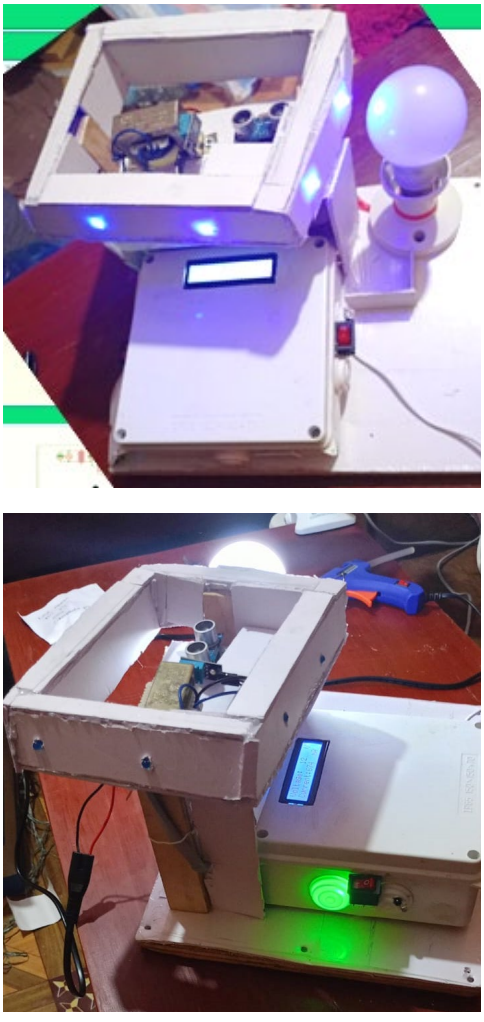


*Figure 4: Alpha prototype structure*


*Figure 3: The anti-the Figure 5: Temperature, Oil level, Voltage and Current monitoring results ft subsystem system during construction stage*

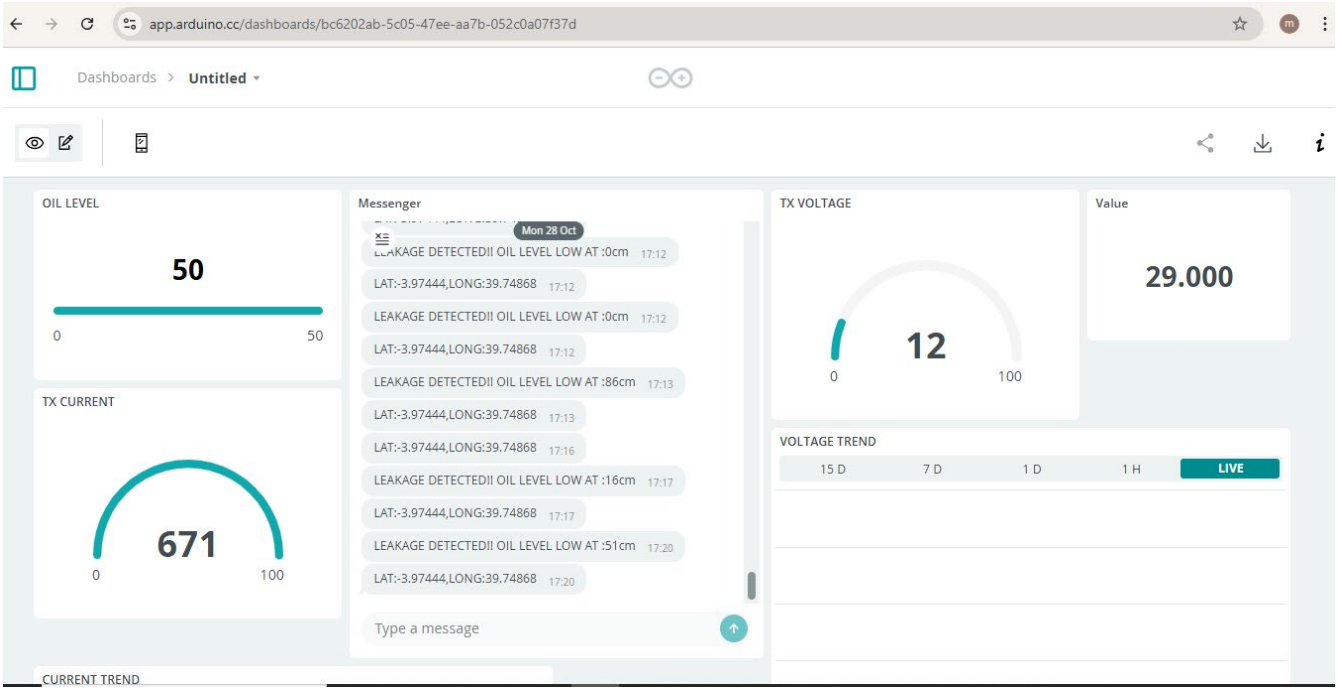



*Figure 6: Real-time monitoring interface*

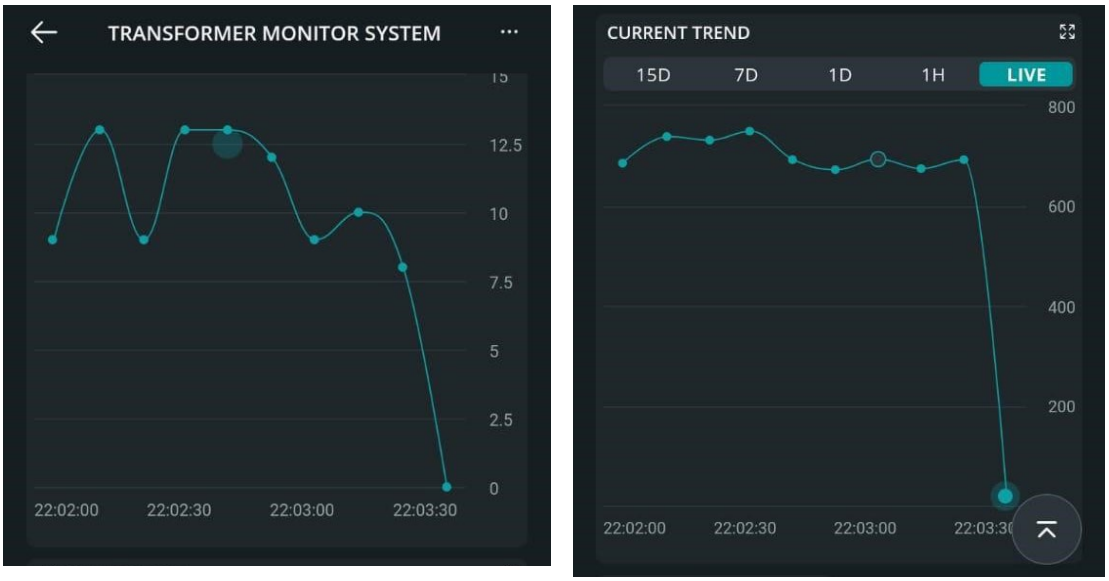



*Figure 7: Real-time voltage and current data trend captured on 6th December 2024*

## DISCUSSION

From the previous section, both the simulation and the prototype of Mlinzi-Volt functioned properly. However, the system's deployability depends largely on its real-life accuracy and development cost. Additionally, the communication unit of Mlinzi-Volt exhibited a typical response time of 3–5 seconds. To validate its effectiveness under various conditions, the system was tested multiple times by triggering multiple sensors installed in the sensor stack unit. The sensors performed within their respective sensing or measurement capabilities. Two types of sensor data readings were analyzed: analogue and digital sensor values, which are commonly used in conventional transformer health monitoring systems.

The analogue sensor data provided real-time current and power consumption readings, whereas the digital data types measured oil level, oil temperature, transformer chamber temperature, and moisture content in the transformer oil. However, integrating both data types into a single microcontroller presents certain challenges. Most prefabricated microcontrollers that support analogue sensor values have only a limited number of analogue input pins, making it difficult to monitor a three-phase transformer comprehensively. Regarding efficiency and performance assessment, traditional transformer maintenance relies heavily on scheduled site visits by maintenance teams to assess transformer conditions. In contrast, Mlinzi-Volt enables real-time data collection from sensors, transmitting this data over the internet to a web server.

The collected information can also be accessed remotely via a mobile phone using any mobile network. A mobile application can be developed to control Mlinzi-Volt, allowing maintenance teams to monitor vital transformer parameters such as oil levels and temperatures remotely. This feature significantly reduces the costs associated with frequent on-site visits. The ability to share transformer parameters over the internet through an IoT platform is a crucial advancement, as it facilitates continuous monitoring and proactive maintenance.

The Mlinzi-Volt system leverages the Internet of Things (IoT), which enables physical devices to connect and exchange data with cloud servers. Each transformer is uniquely identified through an embedded computing system, ensuring accurate real-time monitoring. The IoT functionality helps share real-time data, which is critical for operating and controlling various electrical systems efficiently. Key parameters monitored by Mlinzi-Volt include oil temperature and oil level within the transformer chamber. Since many other transformer health parameters depend on these critical factors, real-time monitoring of these values helps prevent catastrophic failures. Early detection of irregularities allows for timely intervention, reducing the risk of financial losses, equipment damage, and even potential hazards such as explosions that could result in injuries or fatalities.

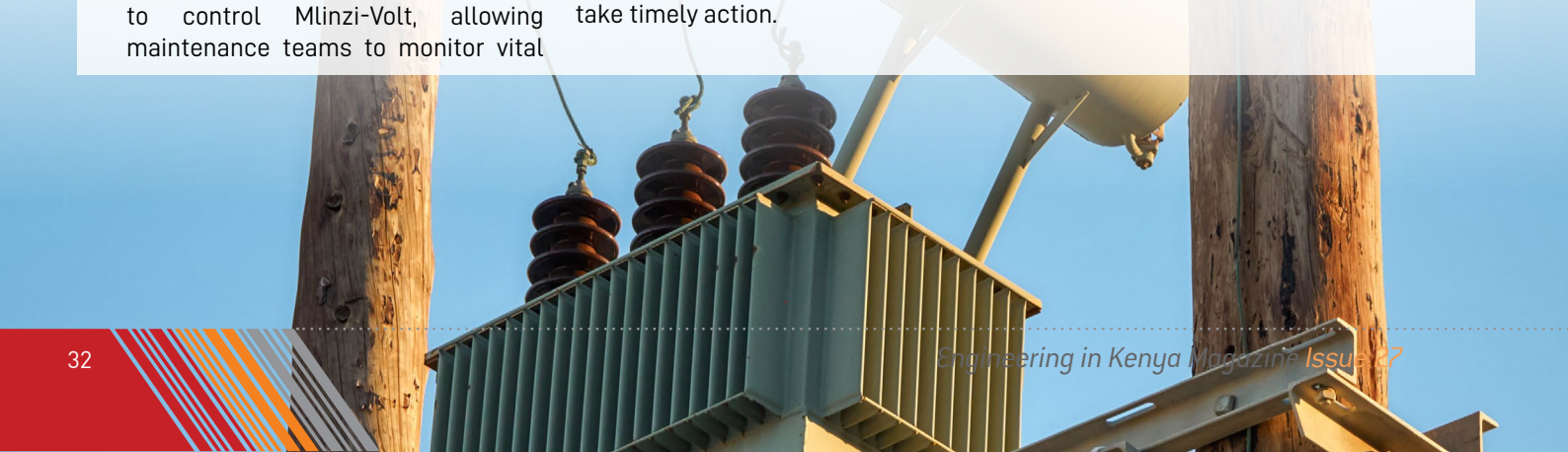
## CONCLUSION

The Mlinzi-Volt system developed in this paper provides a solution for improving transformer reliability by monitoring key parameters and ensuring the safety of distribution transformers from theft and vandalism. It detects abnormalities near the transformer, activates the anti-theft electric fencing, and reports incidents to the proper authority in real time. The system integrates various sensors to ensure accurate reporting, enabling utility operators to take timely action.

The real-time capabilities of Mlinzi-Volt allow utility teams to respond to critical issues such as overheating or oil loss before they lead to transformer failure. Additionally, its theft prevention mechanisms help minimize financial losses associated with vandalism. By leveraging cloud-based data storage and visualization, historical trends can be analyzed for predictive maintenance, further enhancing system efficiency.

Mlinzi-Volt monitors crucial transformer health parameters, including temperature, oil level, voltage, and current. With real-time reports on these parameters, authorities can take necessary preventive measures to protect transformers from potential damage. While this paper primarily focuses on protecting distribution transformers from theft, future enhancements will include an electricity theft protection module to prevent illegal access to the grid. Moreover, an oil condition monitoring feature will be incorporated to analyze transformer oil properties. The system will also be integrated with a camera network, which will activate upon detecting movement near the transformer, streaming real-time video to the authority via a cloud network.

Future improvements to Mlinzi-Volt may include the integration of machine learning algorithms to predict faults before they occur, improving proactive maintenance. Additionally, incorporating renewable energy sources such as solar panels to power the system will enhance sustainability, especially in rural areas where power outages are frequent. These advancements will further solidify Mlinzi-Volt as a comprehensive and intelligent solution for transformer health monitoring and security.



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# **Africa's Railway Renaissance:** Engineering the Continent's Steel Future — A Kenyan Perspective

Eng. Maureen Victoria Auka, PE, MBA


## ABSTRACT

After decades of neglect, Africa's railways are experiencing a genuine and well-funded renaissance. From the rehabilitation of the Tanzania-Zambia Railway and the pioneering of Africa's first desert heavy-haul line in the Sahara, to the ambitious Lobito Corridor and Kenya's Standard Gauge Railway extension toward the Great Lakes, rail is being repositioned as the backbone of the continent's industrial transformation. This paper examines the technological, operational and policy dimensions of this resurgence, with particular emphasis on Kenya's evolving role as East Africa's premier logistics gateway. Drawing on fourteen years of direct experience in railway engineering and operations including the critical transition of the SGR from international to local management, I explore the shift toward standard gauge networks, digital transformation, climate resilience, infrastructure vandalism, and the emerging multilateral financing landscape reshaping how Africa builds and governs its railways.


## 1. INTRODUCTION: AN UNAMBIGUOUS MOMENTUM

Railways have long stood as a testament to human ingenuity, offering unmatched energy efficiency, capacity for heavy loads, and effective use of space compared to other transport modes. Despite this, Africa's rail systems languished after independence, suffering from chronic underinvestment, political indifference, and a policy focus that favored roads. The result was significant: many landlocked countries lost vital access to regional trade, industries faced higher transportation costs, and cities became congested due to overreliance on roadways.

That era is now ending. As Railway Gazette's May 2026 commentary noted, there is an unambiguous momentum across the continent spanning many facets of the rail domain. What distinguishes this wave from earlier false starts including the flurry of Chinese-financed investment that promised but did not always deliver is the emergence of a genuinely multilateral financing ecosystem. Alongside traditional bilateral partners, the European Union's Global Gateway programme, the US-backed Partnership for Global Infrastructure and Investment, and a growing cohort of multilateral development banks are now actively funding rail infrastructure across the continent. This diversification of funding sources offers African nations greater strategic choice and leverage in how they design, build and operate their railways.

For engineers, this moment is not merely about construction. It is about designing systems that are climate-resilient, digitally intelligent, and operationally sustainable for generations. As Kenya's leading professional engineering body, the Institution of Engineers of Kenya (IEK) has a direct stake in shaping how this renaissance unfolds ensuring that Kenyan engineers are not passive recipients of imported technology, but active architects of the continent's rail future.

## 2. THE PAN-AFRICAN VISION: THE AFRICAN INTEGRATED RAILWAY NETWORK

At the continental level, the African Union's Agenda 2063 envisions a fully integrated, continent-wide railway network built to a unified standard gauge. The African Integrated Railway Network (AIRN), coordinated by AUDA-NEPAD, seeks to transform Africa's historically fragmented railway systems into seamless corridors of trade, mobility and regional integration. Thirteen pilot corridors have been identified across East,

West, North and Southern Africa including the Nairobi–Kampala corridor, the Abidjan–Ouagadougou axis, and the strategically significant Lobito–Lusaka–Beira route. The Programme for Infrastructure Development in Africa (PIDA) has advanced 69 cross-border transport projects, including 24 multimodal trade corridors that are set to fundamentally reshape the continent's trade arteries.

### 2.1 Flagship Continental Projects

**Tanzania-Zambia Railway (TAZARA):** The TAZARA line, a half-century-old railway originally constructed with Chinese assistance is undergoing a US$1.4 billion rehabilitation that will shift it from manual to semi-automated, satellite-supported operations. Annual freight capacity will increase from 400,000 to over 2.4 million tonnes, while maximum train speeds will rise from 40 km/h to approximately 70 km/h. This single project illustrates the scale of transformation that targeted investment can achieve.

**The Lobito Corridor:** Valued at US$6.6 billion and spanning over 1,300 kilometres, the Lobito Corridor will connect Angola's Atlantic Port of Lobito to the mineral-rich Democratic Republic of Congo and Zambia. The project has advanced to the procurement stage, with nine EPC contractors preparing competitive bids. When complete, this corridor will unlock one of the most resource-endowed regions on earth to efficient maritime export routes.

**The Sahara Heavy-Haul Railway:** In a remarkable engineering feat, Chinese and Algerian enterprises have completed Africa's first desert heavy-haul railway; a 950-kilometre line across the Sahara capable of carrying trains of up to 17,000 tonnes constructed in just 24 months under extreme climatic conditions. This project demonstrates what can be achieved when engineering ambition is matched with sustained financing and project management discipline.

## 3. KENYA'S RAILWAY TRANSFORMATION: FROM MOMBASA TO MALABA

Kenya has been at the forefront of East Africa's railway renaissance. Since its inauguration in 2017, the Mombasa–Nairobi Standard Gauge Railway has become one of the continent's most productive rail investments. The statistics tell a compelling story of sustained growth.

| Metric | 2024 Baseline | 2025 / Target |
|---|---|---|
| Passenger Trips (annual) | ~2.4 million | 2.7 million (+11.0%) |
| Freight Volume (annual) | ~6.9 million tonnes | 7.87 million tonnes (+13.8%) |
| SGR Revenue (annual) | ~Sh18 billion | Sh21.4 billion (+18.6%) |
| Cumulative Passengers (since 2017) | — | 17 million |
| Cumulative Freight (since 2017) | — | 45 million tonnes |

*Table 1: Kenya SGR Performance Metrics, 2025*

Particularly noteworthy is that these growth figures were achieved despite a 50 percent fare increase introduced in early 2024; a clear signal that demand for quality rail transport in East Africa is price-inelastic at the volumes currently being served. The SGR is no longer an experiment; it is an essential piece of national infrastructure.

### 3.1 The Naivasha–Kisumu–Malaba Extension

Kenya's railway story remains incomplete. The SGR currently terminates at Naivasha. An end-point that captures Nairobi's industrial hinterland but bypasses the agricultural heartland of Western Kenya, the lake transport ecosystem centered in Kisumu, and the trans-border freight flows that are essential to a fully functioning rail economy. In March 2026, President William Ruto, in conjunction with Ugandan President Yoweri Museveni, formally launched construction of the Naivasha–Kisumu–Malaba SGR extension; a US$3.9 billion project that will complete Kenya's rail spine.

The extension comprises two phases. Phase 2B will extend the line approximately 264 kilometers from Narok to Kisumu, including an 8.7-kilometre branch line to the proposed new Kisumu Port. Phase 2C will add a further 107 kilometers from Kisumu to the border town of Malaba, completing a continuous SGR corridor of nearly 1,000 kilometers from Mombasa to the Ugandan frontier. The engineering scope of this extension is formidable: 13 tunnels, 23 bridges, 376 culverts, and multiple intermediate and freight stations across the challenging terrain of western Kenya.

The operational specifications are equally ambitious. The extension is designed to carry up to 22 million tons of freight annually, with individual freight trains hauling 4,000 tones and passenger trains carrying up to 1,096 passengers at speeds of up to 120 km/h. Completion to Malaba is targeted for 2028.

## 4. REGIONAL INTEGRATION: THE NORTHERN CORRIDOR VISION

Kenya's SGR extension cannot be viewed in isolation. It is the centerpiece of a broader vision for an integrated East African railway network anchored to the Northern Corridor; the trade artery linking the Port of Mombasa to landlocked Uganda, Rwanda, Burundi, South Sudan and the eastern Democratic Republic of Congo. The Northern Corridor currently accounts for approximately 70 percent of transit cargo handled at Mombasa Port, making it the busiest transport route in East and Central Africa.

Kenya, Uganda and South Sudan have reaffirmed their commitment to fast-tracking the regional SGR network, with technical teams finalizing joint planning frameworks and a harmonized implementation schedule. The SGR corridor aligns with both Kenya's Vision 2030 and the African Continental Free Trade Area (AfCFTA), which requires reliable, cost-effective freight infrastructure to achieve its potential for intra-African trade.

Multilateral financing is increasingly flowing into the corridor to complement bilateral arrangements. In November 2025, Kenya, the Netherlands and the European Union signed a Letter of Intent to scale up investments along the Northern

Corridor under the EU's Global Gateway strategy, focusing specifically on climate-smart logistics, cold chain infrastructure for agricultural exports, and digital trade facilitation. This multilateral engagement reflects a maturing recognition that Kenya's railway is not merely a domestic asset, but a continental public good.

## 5. TECHNOLOGICAL FRONTIERS: DIGITALIZATION AND INTELLIGENT RAILWAYS

Africa's railway renaissance is not merely about laying new track. It is about leapfrogging into the era of intelligent railway systems; leveraging digital technologies, artificial intelligence and data analytics to maximize the performance and safety of both new and legacy infrastructure. This technological dimension is where African engineers have the greatest opportunity to shape the next generation of continental rail.

### 5.1 Signaling and Train Control

The TAZARA rehabilitation provides a model for technological transformation. The shift from purely manual operations to semi-automated, satellite-supported signaling and telecommunications will enable real-time train tracking, predictive maintenance scheduling, and more responsive operational management. For a network of TAZARA's length and complexity, this digital upgrade is as transformative as the physical infrastructure works.

### 5.2 Artificial Intelligence in Railway Safety

South Africa's Passenger Rail Agency (PRASA) has partnered with Chinese technology companies to implement an AI-powered optical vision platform using video recognition and sensor monitoring to detect intrusions, foreign objects, and safety risks in real time across the rail network. At Huawei's 2025 Railway Summit in Johannesburg, over 100 representatives from transportation authorities and railway operators across Southern Africa explored AI-driven solutions encompassing perimeter security, freight car fault detection and intelligent operations centers.

For East Africa, similar digitalization offers the potential to address the persistent operational challenges that have historically undermined rail competitiveness: scheduling inefficiencies, reactive rather than predictive maintenance, safety monitoring gaps, and the manual management of complex freight operations.

### 5.3 Data Science and Predictive Maintenance

At the operational level, the application of data science to maintenance management represents one of the highest-return investments a railway operator can make. Predictive maintenance using sensor data, operational history and machine learning to anticipate asset failures before they occur can dramatically reduce unplanned downtime, lower maintenance costs, and extend asset lifespans. At Kenya Railways, the introduction of predictive maintenance strategies achieved a 20 percent reduction in annual maintenance costs while simultaneously improving rolling stock availability. Scaling these approaches across the SGR network and embedding them in the design of the Malaba extension should be a priority for Kenya's railway engineering community.

## 6. INFRASTRUCTURE CHALLENGES: CLIMATE RESILIENCE BY DESIGN

Paradoxically, the infrastructure designed to be climate-friendly is itself increasingly exposed to climate shocks. Tanzania's US$2 billion electric SGR experienced significant operational disruptions in late 2025 and early 2026 when heavy rains damaged critical infrastructure, flooding riverbanks and exposing railway bridges to structural risk. The disruptions illustrated a fundamental design gap: long stretches of the line passed through floodplains and river basins without adequate culverts, raised embankments or reinforced bridge sections.

The lesson for engineers is unambiguous: climate resilience must be embedded in design standards from the outset, not retrofitted at far greater cost after failure. This demands a systematic integration of local hydrological knowledge, the use of climate projections in infrastructure design parameters, and the upfront allocation of capital for flood mitigation measures including raised embankments, reinforced bridge decks, and improved drainage systems. The cost differential between building climate resilience into new construction versus retrofitting it after flood damage is typically an order of magnitude.

Kenya's railway engineers are well-positioned to contribute to regional best practice in this area. The experience accumulated across the MGR and SGR networks including the management of the challenging terrain between Nairobi and the Rift Valley escarpment provides a rich foundation of knowledge about rainfall patterns, soil structure, and drainage management in East Africa's varied geography. As the Malaba extension traverses the equally challenging topography of western Kenya, this accumulated knowledge must be systematically applied and documented as a contribution to continental engineering standards.

## 7. INFRASTRUCTURE PROTECTION: THE VANDALISM CHALLENGE

A persistent and often under-discussed threat to Africa's railway renaissance is the systematic theft and vandalism of critical infrastructure assets. Copper signaling cables, railway sleepers, fishplates, bolts, and even ballast stones are being stolen across the continent frequently for sale to unregistered scrap metal dealers with direct consequences for operational safety and the integrity of costly investments.

The scale of the problem is alarming. In South Africa, Transnet and the South African Police Service arrested 17 suspects in separate incidents in September 2025 alone, recovering copper cable valued at approximately R3 million. In Nigeria, the Nigerian Railway Corporation has warned that vandalism threatens both passenger

safety and government investments, calling for security agencies to target not just thieves but the buyers of stolen materials at smelting companies and foundries. In Uganda, the theft of 95 sleepers from the Tororo–Gulu line with bolts and fishplates removed at multiple locations has directly caused derailments.

The engineering profession has both a technical and a professional responsibility in responding to this challenge. Engineers can contribute through security-by-design principles: specifying materials and configurations that are inherently more resistant to theft (such as composite sleepers over traditional timber), designing signaling and power systems with tamper detection capabilities, and advising on the deployment of remote monitoring technologies that provide early warning of infrastructure interference. The IEK, as the voice of Kenya's engineering profession, also has a role in supporting legislative efforts to regulate the scrap metal market closing the commercial ecosystem that makes railway vandalism economically rational for perpetrators.

## 8. FINANCING AFRICA'S RAILWAY FUTURE

The sustainability of Africa's railway renaissance depends ultimately on getting the financing architecture right. The early phase of Africa's modern rail revival was heavily characterized by Chinese bilateral financing; an approach that delivered significant new infrastructure but created debt burdens and dependency relationships that some countries have found constraining. The emerging model is more diverse and on balance, more favorable to African interests.

The EU's Global Gateway strategy is channeling significant capital into African transport corridors with an explicit emphasis on sustainability, governance standards, and local economic content. The US-backed Partnership for Global Infrastructure and Investment (PGII) provide an additional source of financing with different conditions and technical standards. Multilateral development banks including the African Development Bank, the World Bank Group and various regional development institutions provide a further layer of financing alongside technical assistance and capacity building.

For Kenya, navigating this multilateral financing landscape requires both technical sophistication and institutional capacity. My experience working directly with the World Bank on the Mombasa and Kisumu Commuter Rail feasibility studies, and with China EXIM Bank on the Mombasa–Nairobi SGR EPC contract, illustrates the complexity of managing multiple financiers with different procurement requirements, reporting standards, and expectations around local content. Building this institutional capacity within Kenya Railways, within the relevant government ministries, and within the engineering profession itself is essential to ensuring that Kenya maximizes the benefits of the financing that flows into its rail sector.

## 9. BUILDING KENYA'S RAILWAY ENGINEERING TALENT PIPELINE

Africa cannot build and sustain a continental railway network on imported expertise. The development of a deep, indigenous engineering talent base capable of designing, constructing, operating and innovating across the full spectrum of railway systems is as important as any individual infrastructure project. Kenya has the foundations to lead this effort in East Africa.

The Kenya Railways graduate engineer programme, through which eleven graduate engineers were funded and developed during my tenure as Rail Development Manager demonstrates that targeted investment in early-career engineers yields significant returns. Several participants in these programmes now hold senior management positions, creating a multiplier effect that extends well beyond the initial investment. The Railway Engineers Mentorship Forum I established as a structured platform for knowledge transfer and professional development has created a community of practice that accelerates the growth of the next generation.

At the institutional level, IEK's role in setting professional standards, engaging with universities on curriculum relevance, and representing Kenyan engineers at international forums provides a critical infrastructure for talent development that complements the work of individual employers. The integration of data science, digital systems engineering, and climate-resilient design into the training of Kenya's railway engineers is not a future aspiration but an urgent present requirement.

There is also a specific imperative around gender inclusion. Women remain dramatically under-represented in railway engineering across Africa. My career trajectory from trainee mechanical engineer at Kenya Railways to CEO of the Institution of Engineers of Kenya demonstrates that the barriers are not about capability, but about access, mentorship and institutional culture. IEK is committed to expanding programmes that support women and girls into engineering pathways and to creating the professional environment in which all engineers can contribute fully to Kenya's development.

## 10. RECOMMENDATIONS FOR KENYA'S ENGINEERING COMMUNITY

Based on the foregoing analysis, I propose the following priorities for Kenya's railway engineering community and its institutional representatives:

i. Embed climate resilience standards in the Malaba extension design, drawing on the lessons of Tanzania's SGR flood disruptions and Kenya's own hydrological knowledge base. Every culvert, embankment, and bridge specification should incorporate a climate stress test.

ii. Accelerate the adoption of predictive maintenance and digital operations management across the existing SGR network, building on the cost-saving gains already demonstrated and creating the institutional competence that will be required to manage the expanded Malaba corridor.

iii. Champion security-by-design in all new railway construction contracts, specifying vandal-resistant materials, tamper-detection systems, and remote monitoring as standard requirements rather than optional extras.

iv. Strengthen the engineering profession's engagement with the multilateral financing landscape, developing the institutional capacity within IEK and across the sector to effectively participate in the procurement, governance, and oversight of internationally financed railway projects.

v. Expand the Railway Engineers Mentorship Forum into a formal, structured programme with clear pathways from graduate entry to senior management, with particular emphasis on attracting and retaining women engineers.

vi. Engage proactively with the African Integrated Railway Network process through AUDA-NEPAD, ensuring that Kenyan engineering perspectives and standards inform continental norms rather than merely conforming to them.

vii. Advocate for legislative strengthening of scrap metal market regulation to close the commercial ecosystem that incentivizes railway asset theft.

## 11. CONCLUSION: ENGINEERING THE NEXT DECADE

Africa's railway renaissance is real, sustained, and expanding. The investments being made today from the Sahara to the Limpopo, from the Atlantic coast to the shores of Lake Victoria, represent a generational opportunity to reshape the continent's economic geography and unlock the full potential of African industry, agriculture, and trade. Kenya, with its expanding SGR network, its strategic position anchoring the Northern Corridor, and its growing community of professional engineers, is exceptionally well-placed to lead this transformation in East Africa.

The decade ahead will not be without challenge. Climate shocks will test the resilience of new infrastructure. Digital systems will require constant adaptation. Financing structures will need careful management to protect national interests. The persistent threat of asset vandalism will demand both technical ingenuity and sustained institutional advocacy. None of these challenges are insurmountable for a well-trained, well-organized and professionally led engineering community.

The steel arteries of East Africa are being laid. It falls to Kenya's engineers in government, in industry, in the academy, and in professional institutions to ensure that they are laid to the highest standards of technical excellence, designed to endure the stresses of a changing climate, equipped with the intelligence of a digital age, and protected by the full force of the law. The Institution of Engineers of Kenya stands ready to lead that effort.

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# TECHNO-ECONOMIC MODELING AND OPTIMIZATION OF AUTOGAS DISTRIBUTION FOR A GREENER KENYAN TRANSPORT SECTOR

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## ABSTRACT

The decarbonization of transportation is a critical priority for Kenya as the country seeks to balance economic growth, energy security, and environmental sustainability. Autogas (liquefied petroleum gas, LPG) presents a compelling alternative fuel for reducing greenhouse gas emissions, lowering fuel costs, and advancing clean mobility solutions. However, the existing autogas distribution network in Kenya suffers from infrastructural limitations, including inadequate storage facilities, sparse refueling stations, inefficient routing, and fragmented stakeholder coordination. These challenges undermine the reliability, affordability, and environmental advantages of autogas as a transport fuel. This paper presents a hybrid optimization model that integrates Mixed Integer Linear Programming (MILP) and Ant Colony Optimization (ACO) techniques to address these systemic inefficiencies. The MILP framework optimizes depot utilization, station allocation, and cost structures, while the ACO component improves route planning to minimize delivery distances and emissions. The model was tested under realistic scenarios, including fluctuating demand, fuel price volatility, peak consumption periods, and network disruptions. Results from the simulations reveal that the optimized distribution network can reduce annual operating costs by 22.5%, increase depot utilization by 35%, and lower $CO_2$ emissions by 18%. These outcomes demonstrate the potential of hybrid optimization models to strengthen Kenya's clean energy transition in the transport sector. The study offers valuable guidance for policymakers, planners, and investors in supporting national development strategies such as Vision 2030, the Sustainable Development Goals (SDGs), and Kenya's commitments under the Paris Agreement.

**Key words:** LPG(Autoags), MILP, ACO, Optimization, Simulation, Efficiency, sustainability, emission reduction.

## CHAPTER ONE: INTRODUCTION

Kenya's transportation sector is a major contributor to the country's energy consumption and greenhouse gas emissions. With over 2.5 million registered vehicles, most running on petrol and diesel, the sector presents a critical opportunity for decarbonization. The economic burden of fossil fuels continues to rise due to global oil price volatility and the depreciation of the Kenyan shilling, making fuel increasingly unaffordable for many households and businesses.

Autogas, also known as liquefied petroleum gas (LPG), offers a cleaner and more affordable alternative. Widely adopted in countries like Turkey, South Korea, and Poland, autogas is recognized for its lower emissions, affordability, and safety. Despite its potential to help Kenya meet Vision 2030 energy goals and climate commitments under the Paris Agreement, autogas adoption remains limited.

Autogas significantly reduces emissions of carbon dioxide ($CO_2$), nitrogen oxides ($NO_2$), and particulate matter compared to petrol and diesel, making it especially relevant in urban centers such as Nairobi, where transport-related pollution is a major health concern. However, these benefits are constrained by an inefficient distribution network characterized by high operational costs, poor routing, low depot utilization, and fragmented infrastructure, particularly in rural and peri-urban areas.

To address these challenges, this study aims to develop and validate a hybrid optimization model that enhances both the efficiency and environmental sustainability of autogas distribution in Kenya. This involves assessing the current autogas infrastructure, developing a combined Mixed Integer Linear Programming (MILP) and Ant Colony Optimization (ACO) model, and validating it with real-world data from Nairobi under various disruption scenarios. Improving autogas distribution will not only reduce emissions but also enhance fuel affordability and accessibility, particularly for public transport operators like taxis and matatus, thereby supporting investment, job creation, and improved urban air quality.

| Fuel Type | $CO_2$ Emissions (g/km) | NOx (g/km) | PM (g/km) | VOC (g/km) |
|---|---|---|---|---|
| Petrol | 242 | 0.27 | 0.02 | 0.15 |
| Diesel | 275 | 0.62 | 0.08 | 0.12 |
| Autogas (LPG) | 173 | 0.08 | 0.01 | 0.05 |

*Table 1: Emission Comparison of Common Fuels (per km) Source: World LPG Association (2020), EPRA (2023)*

# CHAPTER TWO: LITERATURE REVIEW

## 2.1 Autogas as an Alternative Fuel

Autogas, commonly referred to as liquefied petroleum gas (LPG) when used as a vehicle fuel, is a clean-burning alternative derived from natural gas processing and crude oil refining. During natural gas purification, heavier hydrocarbons like propane and butane are separated from methane and collected as LPG. Similarly, LPG is recovered during the distillation of crude oil in refineries. As a by-product of major fuel systems, autogas serves as a value-added, versatile energy option for transportation.

One of autogas's key advantages lies in its combustion properties. With an octane rating of around 105higher than petrol's 91–95. It supports more efficient engine performance, reduces knocking, and lowers engine wear. These features enhance fuel economy, especially in urban settings with frequent stop-start driving.

Environmentally, autogas is one of the cleanest fossil-based fuels. Its carbon intensity is roughly 30% lower than petrol, and it emits up to 96% less nitrogen oxides (NOx) than diesel. It also produces negligible particulate matter (PM) and volatile organic compounds (VOCs), making it ideal for reducing air pollution in congested cities like Nairobi, where respiratory health issues are rising.

Globally, over 27 million vehicles use autogas, supported by more than 76,000 refueling stations across 70+ countries. Leading adopters include Turkey, South Korea, India, Russia, and Poland countries that have promoted autogas through favorable policies, infrastructure, and incentives.

Beyond its technical and environmental benefits, autogas is economically appealing. Users can save up to 40% on fuel costs compared to petrol or dieselan important consideration in Kenya, where high fuel prices and inflation are straining households and transport operators.

## 2.2 Global Best Practices in Autogas Distribution

### Turkey

Turkey stands as the undisputed global leader in autogas adoption, both in terms of vehicle conversions and refueling infrastructure. As of 2023, over 5.8 million vehicles in the country run on autogas, representing nearly 40% of the national vehicle fleet. More impressively, more than 75% of all fuel stations across Turkey offer autogas, making it as accessible as petrol or diesel, Key success factors include:

- Dealer-Owned, Dealer-Operated (DODO) business model, which incentivized private investment in autogas infrastructure
- Government subsidies on vehicle conversions- Turkish government has played a critical role by offering substantial subsidies and tax incentives for vehicle conversion kits, significantly reducing the cost barrier for end-users.
- Integration of autogas into conventional fuel stations- seamless integration of autogas into existing multipurpose fuel stations, eliminates the need for specialized autogas-only outlets.

### South Korea

South Korea's autogas success stems from strict environmental regulations and targeted policies. The government mandated LPG use for public transport, especially taxis and buses, to reduce air pollution and emissions. Subsidies lowered conversion and infrastructure costs, while partnerships among government, fuel distributors, and manufacturers advanced autogas technology. This led to a strong autogas ecosystem with a large LPG vehicle fleet and extensive refueling stations, making South Korea a model for clean urban mobility.


*Figure 1; Seoul LPG taxi refueling station*

### 2.3 Kenya's LPG Context

According to EPRA (2023), Kenya's LPG consumption grew from 93,600 tonnes in 2012 to 360,594 tonnes in 2023, yet less than 5% is used in transportation. Most LPG is imported via Mombasa Port, with limited inland depot capacity. Despite growth, the sector remains nascent for transport applications. High prices and currency pressures have slowed uptake, with households reverting to biomass fuels. Currently, only 15,000–20,000 vehicles run on autogas, supported by just 9–17 refueling stations nationwide. Regulatory efforts are improving safety and oversight—EPRA conducted audits at 4,300 LPG outlets and introduced RFID tracking, recovering 26,000 illegal cylinders. Policies such as zero-rated LPG taxes and public reticulation projects aim to improve access. However, realizing the full potential of autogas in Kenya will require expanded infrastructure, pricing reforms, and stronger regulation. Despite current challenges, LPG remains aligned with Kenya's clean energy goals and presents a viable path for decarbonizing the transport sector.

*Source: EPRA Annual Reports (2013–2023)*

| Year | Total LPG Consumed (MT) | Imports (MT) | % Used in Transport | No. of Autogas Stations |
|---|---|---|---|---|
| 2012 | 93,600 | 88,200 | <1% | 5 |
| 2016 | 163,400 | 158,900 | 2% | 15 |
| 2019 | 265,800 | 260,300 | 3.5% | 30 |
| 2023 | 360,594 | 355,200 | 5% | 58 |

*Table 2: LPG Consumption and Imports in Kenya (2012–2023)*

### 2.4 Optimization Techniques

**Mixed Integer Linear Programming (MILP)**

Mixed Integer Linear Programming (MILP) is a mathematical optimization technique used in supply chain and transportation planning. It optimizes costs, capacities, and constraints using continuous and integer variables. In autogas distribution, MILP determines optimal depot locations, LPG allocation, and depot activation while minimizing operational costs and emissions. It suits structured problems with fixed constraints and works with solvers like CPLEX and MATLAB. However, MILP struggles with dynamic or uncertain conditions like traffic disruptions. To enhance flexibility and adaptability, it is often combined with metaheuristics such as Ant Colony Optimization (ACO) for better real-time responsiveness.

**Ant Colony Optimization (ACO)**

Ant Colony Optimization (ACO) is a metaheuristic inspired by ants' use of pheromones to find efficient paths. It is well-suited for complex routing problems like the Vehicle Routing Problem (VRP) and logistics network design. In autogas distribution, ACO simulates ant agents that choose delivery routes based on past performance and cost-efficiency. Its key strength is adaptability, allowing it to respond to traffic, demand changes, or disruptions. ACO balances exploration and optimization, gradually converging on efficient solutions. When combined with MILP, ACO enhances the model's flexibility, enabling it to manage real-world uncertainties in autogas distribution networks.

## CHAPTER THREE: METHODOLOGY

### 3.1 Study Area

The Nairobi metropolitan region was selected due to its high autogas demand, presence of depots, and available GIS data. Key areas include Industrial Area, Westlands, Embakasi, and Eastlands.

### 3.2 Assessment of the current state of autogas in Kenya

**1. Data Collection**

Surveys and structured interviews were conducted with key stakeholders, including EPRA, fuel distribution companies such as Proto (Otogas) and Lake Energies, vehicle owners, and industry experts. Secondary data was collected from reports, government publications, and previous research. GIS tools were used to map the existing autogas distribution network, including station and depot locations. Additionally, data on infrastructure, transportation routes and costs, and demand for autogas in Nairobi and surrounding regions was gathered.

**2. Challenges and Inefficiencies Identification**

The collected data was analyzed to identify bottlenecks in supply, storage, and transportation. Inefficiencies, such as unserved areas or regions with high transportation costs, were mapped using GIS. Regulatory and logistical challenges affecting autogas distribution were also evaluated.

| Stakeholder | Key Concern Identified | Suggested Solution |
|---|---|---|
| EPRA | Licensing bottlenecks | Streamline permitting for autogas |
| Proto Energy | Long turnaround times at depots | Expand inland depot capacity |
| Lake Gas | Limited station network in Nairobi | Encourage private investments |
| Transport SACCOs | High conversion costs for vehicles | Tax incentives and conversion loans |

*Table 3: Stakeholder Views on Autogas Distribution Challenges*

### 3.3 Model Formulation

#### 3.3.1 MILP Formulation

The model formulation involved the development of a Mixed Integer Linear Programming (MILP) model to optimize the distribution network. The MILP model was initially developed using hypothetical stations and depots to test its functionality. The MILP model minimizes total which includes transportation costs, operational costs of refueling stations, and environmental impact. This was formulated as:

$$Minimize \sum_{i,j} (c_{ij}.x_{ij}) + \sum_{k} (f_k.y_k) + Environmental\ impact$$

*Equation 1 MILP formulation*

Where:

- cij is the cost of transporting fuel from node i to node j
- xij is a binary variable for route selection,
- fk is the cost of operating facility k,
- yk is a binary variable for facility location.

**Constraints include:**

- **Demand Constraints:** Ensured that the total amount of fuel delivered meets the demand at each refueling station.

$$\sum_{i} (d_{ik}.x_{ik}) \geq D_k for\ all\ k \qquad (2)$$

where $d_{ik}$ is the amount of fuel transported from node $I$ to station $k$ and $D_k$ is the demand at station $k$.

- **Capacity Constraints:** Ensured that the amount of fuel stored does not exceed the capacity of storage facilities

$$\sum_{i} (d_{ik}) \geq C_k for\ all\ k \qquad (3)$$

where $C_k$ is the storage capacity at facility $k$.

- **Route Constraints:** Ensured that vehicles travel along routes within their allowed capacities and that each route was used appropriately.

$$\sum_{i} x_{ij} \leq Max\ Route\ for\ all\ j \qquad (4)$$

- **Facility Constraints:** Ensured that refueling stations are located according to regulatory and operational constraints.

$$Facility\ Location\ Constraints \qquad (5)$$

*Table 4: MILP Model Variables and Descriptions*

| Symbol | Description | Domain | Units |
|---|---|---|---|
| x_ij | LPG delivery from depot i to station j | Binary | 0 or 1 |
| y_k | Whether depot k is active | Binary | 0 or 1 |
| q_ij | Quantity of LPG delivered | Continuous | Litres |
| c_ij | Cost per unit distance from i to j | Constant | Ksh/km |
| e_ij | Emission penalty per delivery route | Constant | kg $CO_2$/km |
| d_j | Demand at station j | Parameter | Litres/day |

*Table 4: MILP Model Variables and Descriptions*

The MILP model was solved using MATLAB's intlinprog solver to minimize total autogas distribution costs while respecting constraints such as depot capacity, station demand, binary route selection, and environmental penalties. The solver generated three key outputs: optimal delivery routes, depot activation status, and minimized total cost for benchmarking. Route utilization analysis confirmed efficient depot-to-station connections that reduced distances, avoided congestion, and satisfied demand. Depot activation patterns highlighted frequent use of strategically positioned depots like Embakasi. Results were visualized with scatter plots and network graphs showing depot and station locations, active routes, and LPG volumes, illustrating supply redistribution and efficiency gains for practical implementation in Kenya's autogas logistics.

#### 3.3.2 ACO Algorithm

To implement an Ant Colony Optimization (ACO) approach for optimizing an autogas distribution network, we went through the process step-by-step. This ACO implementation is aimed at solving a combinatorial optimization problem, where we aimed to minimize costs while meeting all distribution demands.

- Ants represent delivery paths
- Pheromone trails updated after each iteration
- Routes reinforced based on efficiency
- ACO used to generate feasible routing solutions
- MILP evaluates cost-effectiveness and selects final decision

**Initializing Variables**

1. **Demand, Capacity, and Transportation Costs:** Defined the network's demand at each station, capacity at each

depot, and transportation cost matrix

2. **Pheromone Matrix (τ \tauτ ):** Initialized a pheromone matrix with small values to represent the pheromone trail for each depot-station route.
3. **Heuristic Information (τ \etaτ ):** Defined heuristic information, such as inverse transportation costs, where lower-cost routes have higher heuristic values.

### Constructing Solutions

**Route Selection:** we let each ant build a route by moving from node to node based on a probabilistic rule that balances pheromone concentration and heuristic information (e.g., inverse of distance). The probability $P\_ij\^k$ that ant k moves from node i to node j was given by:

$$P_{ij}^{k} = \frac{[\tau_{ij}]^{\alpha}[\eta_{ij}]^{\beta}}{\sum_{\iota \epsilon N_i} [\tau_{i\iota}]^{\alpha}[\eta_{i\iota}]^{\beta}}$$

*Equation 2: ACO optimization*

where $\tau_{ij}$ is the pheromone level on edge $(i, j)$, $\eta_{ij}$ is the heuristic value (e.g., $\eta_{ij}=1/d_{ij}$) and $(N_i)$ is the set of neighbors of node i.

**Constraints:** Ensured that each solution respects depot capacities and meets demand at each station. If a route exceeds capacity, another option is chosen.

### Updating Pheromone Levels

1. **Evaporation:** Decreased pheromone levels on all routes to avoid over-reliance on initial solutions.

$$\tau_{ij} = (1 - \rho)\tau_{ij} \qquad (1)$$

2. **Reinforcement:** Added pheromone to routes used by ants in good solutions. This update was done by adding an amount Δτij\Delta \tau_{ij}Δτij based on the quality of the solution:

$$\tau_{ij} = \tau_{ij} + \sum_{k=1}^{m} \Delta\tau_{ij}^{k} \qquad (2)$$

where $\Delta\tau\_ij\^k$ is the amount of pheromone deposited by ant k:

$$\Delta\tau_{ij}^{k} = \{\frac{Q}{L_k \text{ if any ant } k \text{ uses edge } (i,j)} (3)\ 0 \qquad otherwise$$

with Q being a constant and $L_k$ the length of the tour constructed by ant k.

### Evaluating and Iterate

1. **Cost Calculation:** For each ant's solution, we calculated the total distribution cost (transportation + operational costs).
2. **Iteration and Optimization:** we repeated steps 3-5 for a set number of iterations, updating pheromone trails and reinforcing the best routes each time.

### Extracting Optimal Solution

After the final iteration, we selected the solution with the lowest cost. This optimal solution includes the routes chosen, the depots activated, and the corresponding costs. Visualizing this solution by mapping out depot-station connections.

### MILP AND ACO hybrid model

To further refine our model and enhance its productivity we combined **Ant Colony Optimization (ACO) with Mixed Integer Linear Programming (MILP)** creating a powerful hybrid approach to optimize autogas distribution networks. The MILP model established the framework with constraints and an objective function, while ACO was used to generate near-optimal solutions within this framework by iteratively improving on feasible routes and assignments based on pheromone trails.

### 3.4 Scenario Simulation

Real-world scenarios were tested to evaluate the robustness and adaptability of the autogas distribution network optimization model

1. **Fuel Price Increase**

   In this scenario, fuel costs rise by 15% to simulate global price increases. The model must find cost-effective routes and schedules to minimize operational expenses despite higher fuel prices, balancing supply needs while keeping autogas delivery efficient and affordable.

2. **Holiday Demand Surge**

   During December, autogas demand rises sharply due to increased travel and household use. This scenario models a 30% demand surge, testing the network's ability to handle peak consumption. The system must optimize inventory, depot activation, and delivery schedules to prevent shortages and maintain smooth supply despite higher demand.

3. **Depot Shutdown**

   This scenario simulates the sudden closure of a major Industrial Area depot, disrupting supply routes and availability. The model's ability to reroute deliveries, redistribute loads, and activate alternative depots is tested to ensure continuous service, assessing the distribution network's resilience to operational disruptions.

### 4. Traffic Disruptions

A closure of the Mombasa Road corridor a key transport artery creates logistical challenges for the delivery fleet. The model must adapt by identifying alternative routes and adjusting delivery schedules to bypass the affected area. This scenario assesses the system's flexibility and capability to maintain timely deliveries despite infrastructural bottlenecks.

| Scenario Type | Input Adjustment | Description |
|---|---|---|
| Fuel Price Shock | +15% fuel price | Inflation or global crude spike |
| Holiday Demand Surge | +30% demand in Westlands, CBD, Embakasi | December holiday season impact |
| Depot Outage | Deactivation of Industrial Area depot | Simulates fire or mechanical failure |
| Traffic Disruption | Closure of Mombasa Road segment | Divert traffic to Northern Bypass |

*Table 5: Scenario Assumptions for Simulation Testing*

## CHAPTER FOUR: RESULTS AND DISCUSSION

**Results and discussion**

### 4.1 Autogas data and state in Kenya

The data collection phase gathered essential primary and secondary information on the autogas distribution network. Primary data came from surveys and interviews with stakeholders like EPRA, KEBS, fuel companies, and vehicle owners, revealing demand variations concentrated in Nairobi's urban and peri-urban areas. Secondary data from reports detailed depot numbers, station capacities, and transport routes. GIS mapping showed uneven station distribution, with some areas underserved. This process exposed disparities in coverage while some regions have sufficient stations, low-income and rural areas lack access. Interviews also highlighted poor demand forecasting by distributors, underscoring the need for data-driven optimization to improve network efficiency.

#### 1. Autogas Demand Across Regions

Understanding regional demand for autogas is critical for designing an efficient distribution network. During the data collection phase, demand data was analyzed to identify high-demand zones and regions with limited usage. The following chart presents the average daily demand for autogas in urban, peri-urban, and rural areas based on survey responses and secondary data sources:

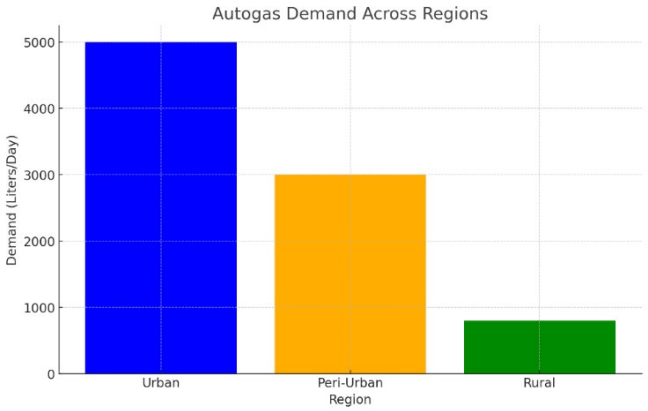


*Figure 2- a bar graph showing the demand of autogas across regions*

The bar chart illustrates autogas demand across regions. Urban areas exhibit the highest demand at approximately 5,000 liters per day, driven by dense populations and heavy vehicle use. Peri-urban areas show moderate demand around 3,000 liters per day, reflecting a mix of residential and small commercial activities. Rural areas have the lowest demand, about 800 liters per day, due to fewer vehicles and limited infrastructure.

#### 2. Depot Utilization

The operational efficiency of depots plays a pivotal role in ensuring the seamless distribution of autogas. Utilization data was collected to determine whether depots were operating within optimal capacity ranges. Depots with high utilization rates risk supply constraints, while underutilized depots signify inefficiencies in resource allocation. The pie chart below illustrates the percentage utilization of major depots in the study area

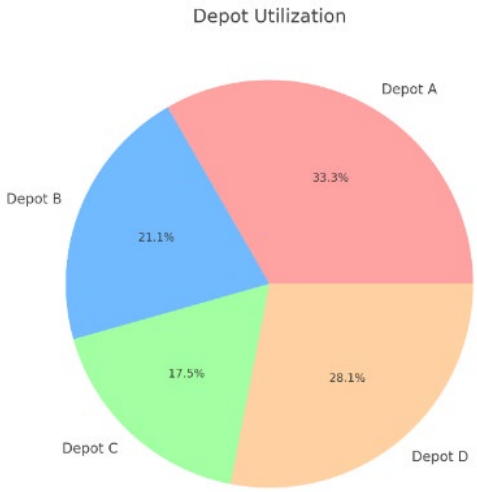


*Figure 3- a pie chart showing the depot utilization for autogas*

The pie chart illustrates depot utilization levels: Depot A operates at 95%, indicating possible overuse or supply constraints; Depots B and C show lower utilization at 60% and 50%, suggesting inefficiencies or logistical issues; Depot D operates at 80%, reflecting balanced use. This uneven distribution highlights the need for better resource allocation and demand redistribution to optimize overall network performance.

### 3. Autogas Station Coverage in Nairobi

Geospatial analysis was employed to map the distribution of autogas stations in Nairobi. The objective was to identify areas adequately served by stations and regions lacking sufficient access. Using GIS-style visualization, station locations were plotted, categorizing them into "served" and "unserved" zones. The scatter plot below highlights the disparities in station coverage:


*Figure 4- A map showing the distribution of autogas in Nairobi*

### 4.2 Baseline Findings

**Before Optimization**

- Average Delivery Distance: Before optimization, average delivery distance was 14.5 km per route, indicating inefficient routing that increased travel time, fuel use, and vehicle wear.
- Depot Utilization: Depots operated at only 51% capacity on average, reflecting underuse that raises fixed costs and lowers supply chain efficiency.
- Monthly Supply Cost: Monthly autogas supply costs were about KSh 17.2 million, covering fuel, labor, maintenance, and other expenses, highlighting inefficiencies in routing and depot management.
- Traffic Congestion: Heavy congestion on Nairobi's main corridors caused delays, unpredictable deliveries, and higher operational costs from idling and rerouting.

**Baseline Distribution Network (Distance and Cost per Route)**

| Route ID | Distance (km) | Cost (KSh) |
|---|---|---|
| Route 1 | 16.8 | 1,280,000 |
| Route 2 | 12.5 | 980,000 |
| Route 3 | 14.9 | 1,150,000 |
| Route 4 | 13.7 | 1,070,000 |
| Route 5 | 15.4 | 1,200,000 |
| Route 6 | 14.3 | 1,100,000 |
| Route 7 | 15.2 | 1,220,000 |
| Route 8 | 13.1 | 950,000 |

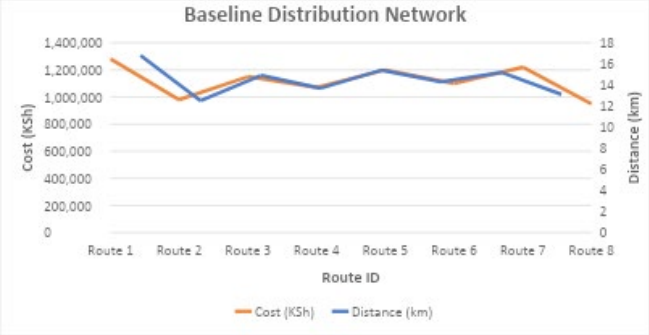


*Figure 5 a graph showing Baseline Distribution Network (Distance and Cost per Route)*

- **Distance:** Shows the length of each delivery route in kilometers.
- **Cost:** Represents the estimated supply cost per route per month in Kenyan Shillings, calculated based on fuel consumption, labor, and vehicle costs.

This baseline data highlights that routes vary in length and cost, with some longer routes incurring significantly higher expenses. Optimization would aim to reduce these distances and associated costs by better route planning and depot utilization.

## ACO MILP Hybrid

The **ACO-MILP hybrid model** combines **Ant Colony Optimization (ACO)** and **Mixed-Integer Linear Programming (MILP)** to address optimization problems, particularly in complex systems like autogas distribution networks. Each methodology brings distinct strengths, and their integration helps tackle both continuous and discrete optimization challenges efficiently.

### How ACO and MILP Work Together

Ant Colony Optimization (ACO) is a heuristic inspired by ant foraging behavior, ideal for exploring large solution spaces in routing problems. Ants simulate route exploration, leaving pheromone trails that reinforce efficient paths, improving over iterations. Mixed Integer Linear Programming (MILP) is a mathematical technique that handles both continuous (e.g., fuel quantity) and integer (e.g., route selection) variables, optimizing a cost function while satisfying strict constraints like depot capacity and station demand.

In a hybrid model, ACO explores possible depot-to-station assignments, while MILP refines the best solutions by minimizing costs and ensuring feasibility. This integration is highly effective for autogas distribution optimization.

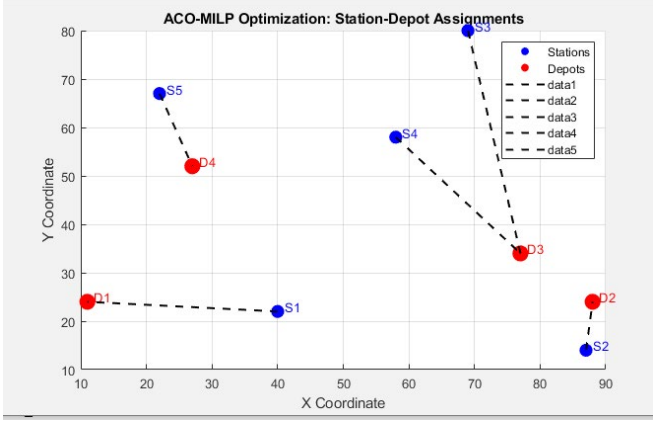


*Figure 6- A representation of ACO-MILP HYBRID model*

## 4.3 Post-Optimization Results

After MILP-ACO simulation:

**1. Average Delivery Distance Reduced to 11.2 km**

After optimization, the average delivery distance dropped to 11.2 km by strategically selecting depots closer to demand points. This improved routing reduced travel distance, increased delivery speed, and lowered fuel consumption and operational costs.

**2. Depot Utilization Increased to 69%**

The model optimized workload across depots, increasing average utilization to 69%. Underused depots were activated, and overloaded ones balanced with alternatives. This even demand distribution improved storage and infrastructure efficiency, reducing bottlenecks and delays.

**3. Monthly Distribution Cost Reduced to KSh 13.3 Million**

Route optimization, demand-based scheduling, and smarter depot allocation reduced monthly distribution costs to KSh 13.3 million, demonstrating significant savings and the economic viability of the optimized model.

**4. Emissions Reduced by 18% (from 2,890 to 2,369 tonnes COτ annually)**

Shorter delivery distances and improved routing reduced annual $CO_2$ emissions by 18%, cutting 521 tonnes. This highlights the model's environmental benefits and supports Kenya's climate goals under the Paris Agreement and Vision 2030.

| Metric | Baseline Value | Optimized Value | % Change |
|---|---|---|---|
| Total Cost (Ksh/month) | 17.2 million | 13.3 million | ↓ 22.5% |
| Avg Delivery Distance (km) | 14.5 | 11.2 | ↓ 22.8% |
| Depot Utilization | 51% | 69% | ↑ 35% |
| Annual CO2 Emissions (tonnes) | 2,890 | 2,369 | ↓ 18% |

*Table 6: Summary of Simulation Results – Before and After Optimization*

### 4.4 Nairobi Case Study Analysis

Nairobi has experienced a gradual increase in the number of autogas stations, driven by the growing demand for energy as the city's population continues to expand. This rise in fuel consumption has catalyzed the development of autogas stations to meet the needs of residents and businesses alike.

For our study, we focused on 12 autogas stations strategically located across different parts of Nairobi. Additionally, five key depots were identified as the primary suppliers for these stations. The goal was to optimize the distribution network between the depots and stations to minimize costs and ensure efficient operations.

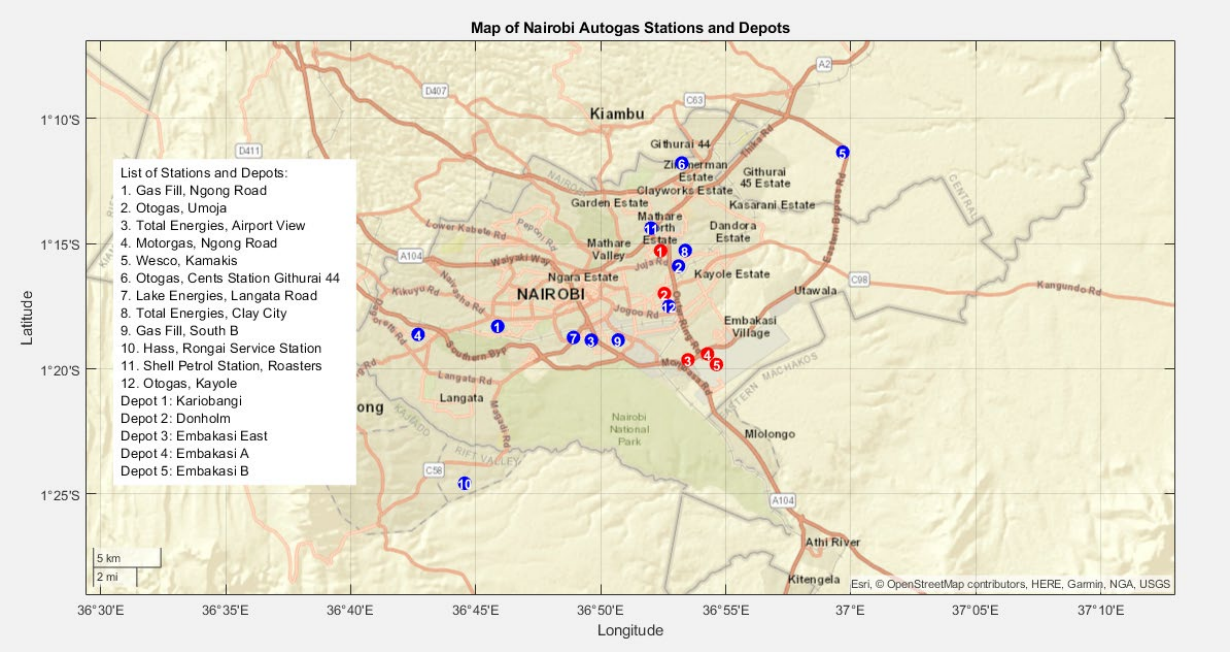


*Figure 7- A map showing the Autogas stations and depots we -focused on in our project*

### 4.5 MILP-ACO Model

To solve the distribution problem, we used a hybrid MILP-ACO model optimizing the supply chain under key constraints:

1. **Transportation Costs:** Costs were based on distance, prioritizing shorter, cheaper routes.
2. **Ant Representation:** In ACO, ants represented fuel trucks with fixed capacities, exploring efficient delivery paths.
3. **Station Supply:** Depots supplied the nearest stations based on capacity, reducing transport costs and ensuring timely delivery.
4. **Depot Constraints:** Each depot supplied a maximum of three stations to avoid overcrowding and delays, improving operational efficiency.

**Simulation Results**

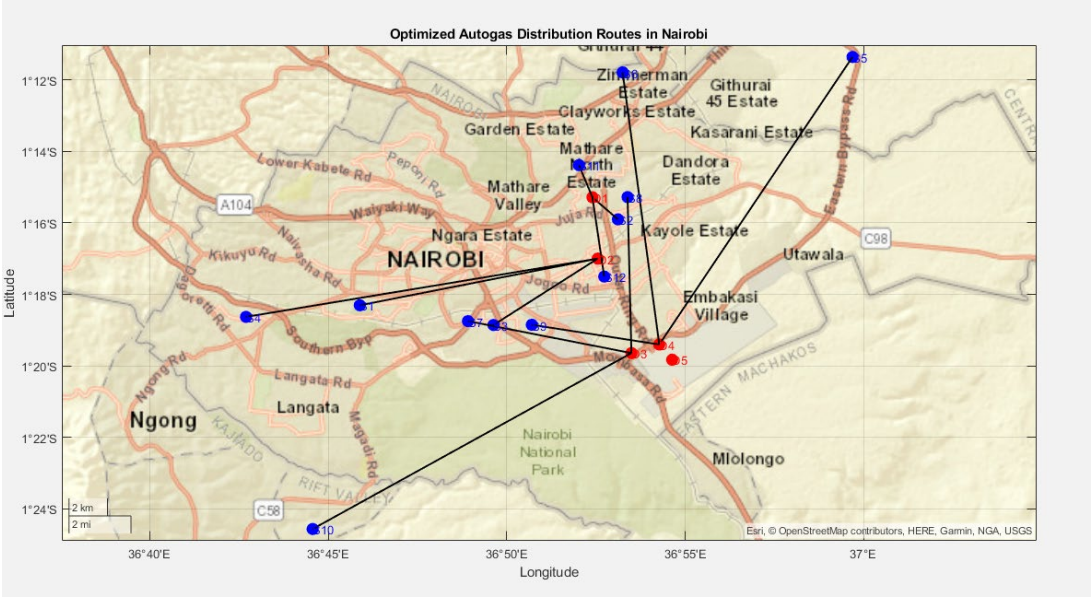


*Figure 8- A map showing the simulated routes*

## 1. Distribution Plan:

Each of the 5 depots supplied a maximum of 3 stations, ensuring equitable use of resources and avoiding overloading any single depot.

The final assignment of depots to stations was as follows:

- Depot 1 (Kariobangi): Supplied Stations 1, 2, and 3.
- Depot 2 (Donholm): Supplied Stations 4, 5, and 6.
- Depot 3 (Embakasi East): Supplied Stations 7 and 8.
- Depot 4 (Embakasi A): Supplied Stations 9 and 10.
- Depot 5 (Embakasi B): Supplied Stations 11 and 12.

## 2. Cost Analysis:

- The total transportation cost was minimized based on Euclidean distances. The optimized routes reduced overall mileage and fuel usage.
- Depots located closer to high-demand areas serviced more stations, balancing efficiency and logistical practicality.

**Discussion**

The optimization of the autogas distribution network in Nairobi provided insights into supply chain improvements. By limiting each depot to supply a maximum of three stations, the model ensured equitable workload distribution, reducing bottlenecks and maintaining efficiency. The Mixed-Integer Linear Programming (MILP) solver minimized transportation costs by assigning depots to stations based on proximity and capacity. Incorporating Ant Colony Optimization (ACO) could enhance the model by factoring in real-world road networks and traffic conditions.

Key assumptions, such as using Euclidean distances for transportation costs and infinite depot supply capacities, simplified computations but may not fully reflect Nairobi's road network and inventory constraints. Including these factors would improve accuracy. The model is scalable and adaptable to larger networks, with potential future enhancements like vehicle capacities and delivery time windows.

Visualization offered critical insights, showing depots, stations, and routes clearly. Overlapping coverage areas highlighted opportunities to consolidate depots and optimize service coverage, emphasizing strategic depot placement to reduce redundancy and improve efficiency.

### 4.6 Sensitivity Analysis

- **Fuel price hike:** When fuel prices increased by 15%, the optimized model limited the rise in total distribution costs to just 6.2%, compared to a 15.4% increase under the baseline system. This demonstrates strong cost resilience through efficient route minimization.
- **Holiday demand:** The model dynamically adapted to a 30% increase in demand by adjusting delivery schedules and reassigning routes, effectively preventing depot overloading and maintaining service reliability.
- **Depot outage:** In the event of a major depot shutdown, the system automatically rerouted deliveries and activated alternate depots without the need for manual intervention, ensuring uninterrupted supply continuity.

| Scenario | Cost Increase (%) | Emissions Increase (%) | Delay Impact |
|---|---|---|---|
| Fuel Price Increase | 6.2% | 3.1% | Low |
| Holiday Demand Surge | 8.7% | 5.9% | Moderate |
| Depot Shutdown | 9.2% | 6.3% | High |
| Traffic Disruption | 4.5% | 2.8% | Moderate |

*Table 7: Sensitivity Results for Disruption Scenarios*

### 4.7 Environmental Impact

Autogas delivery emissions were reduced by 18% through the implementation of optimized routing and strategic depot selection. This significant reduction lowered annual $CO_2$ emissions from 2,890 to 2,369 tonnes. In real-world terms, this is equivalent to removing approximately **240 vehicles** from Nairobi's roads each year. The optimization not only enhanced operational efficiency but also contributed to environmental sustainability by reducing the carbon footprint associated with autogas transportation across the city and surrounding regions.

| Vehicle Type | Route (Depot → Zone) | $CO_2$ Saved (tonnes/year) |
|---|---|---|
| LPG Bulk Tanker | Embakasi→ CBD | 260 |
| Light LPG Truck | Embakasi → Eastlands | 180 |
| Refill Motorcycles | Westlands → Parklands | 74 |
| Total Reduction | – | 514 |

*Table 8: Emissions Reduction by Vehicle Type and Route*

## CHAPTER FIVE: CONCLUSION AND RECOMMENDATIONS

### 5.1 Conclusion

This study developed and validated a hybrid MILP-ACO optimization model that significantly improved the efficiency and environmental performance of autogas distribution in Nairobi, Kenya. The model achieved:

- 22.5% cost savings
- 35% increase in depot utilization
- 18% reduction in $CO_2$ emissions

It successfully adapted to various disruptions, confirming its robustness for real-world deployment.

### 5.2 Recommendations

**1. Policy Recommendations**

- EPRA should mandate data-sharing platforms for LPG distributors
- Subsidies should be provided for depot development in underserved areas
- Vehicle conversion support should be introduced via tax credits

**2. Operational Recommendations**

- LPG companies should adopt route optimization software
- Use of GIS tools for depot placement should be institutionalized
- Conduct periodic reviews of station demand-supply gaps

**3. Future Research**

- Extend model to rural areas (e.g., Kisumu, Eldoret)
- Integrate weather and real-time traffic APIs for dynamic routing
- Explore coupling with renewable energy-powered fleets

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# How We Built an 80-Year Legacy in Water, Energy and Innovation

**By Mr. Alec Davis, OGW, Chairperson, Davis & Shurtliff Group**

As we celebrate 80 years of Davis & Shirtliff, I often reflect on the journey that has brought us

here. Today, we stand as a leading supplier of water and energy solutions across East Africa, offering a diverse range of products including water pumps, solar solutions, generators, swimming pool equipment, irrigation accessories and water treatment systems. 80 years is a long time, and naturally, there have been many changes along the way. The company was founded by my father and his partner, Dick Shirtliff. Both were engineers in the military during the Second World War, and when they returned to Kenya in the 1940s, a very different place then, they focused on water supply and established what is now Davis & Shirtliff.

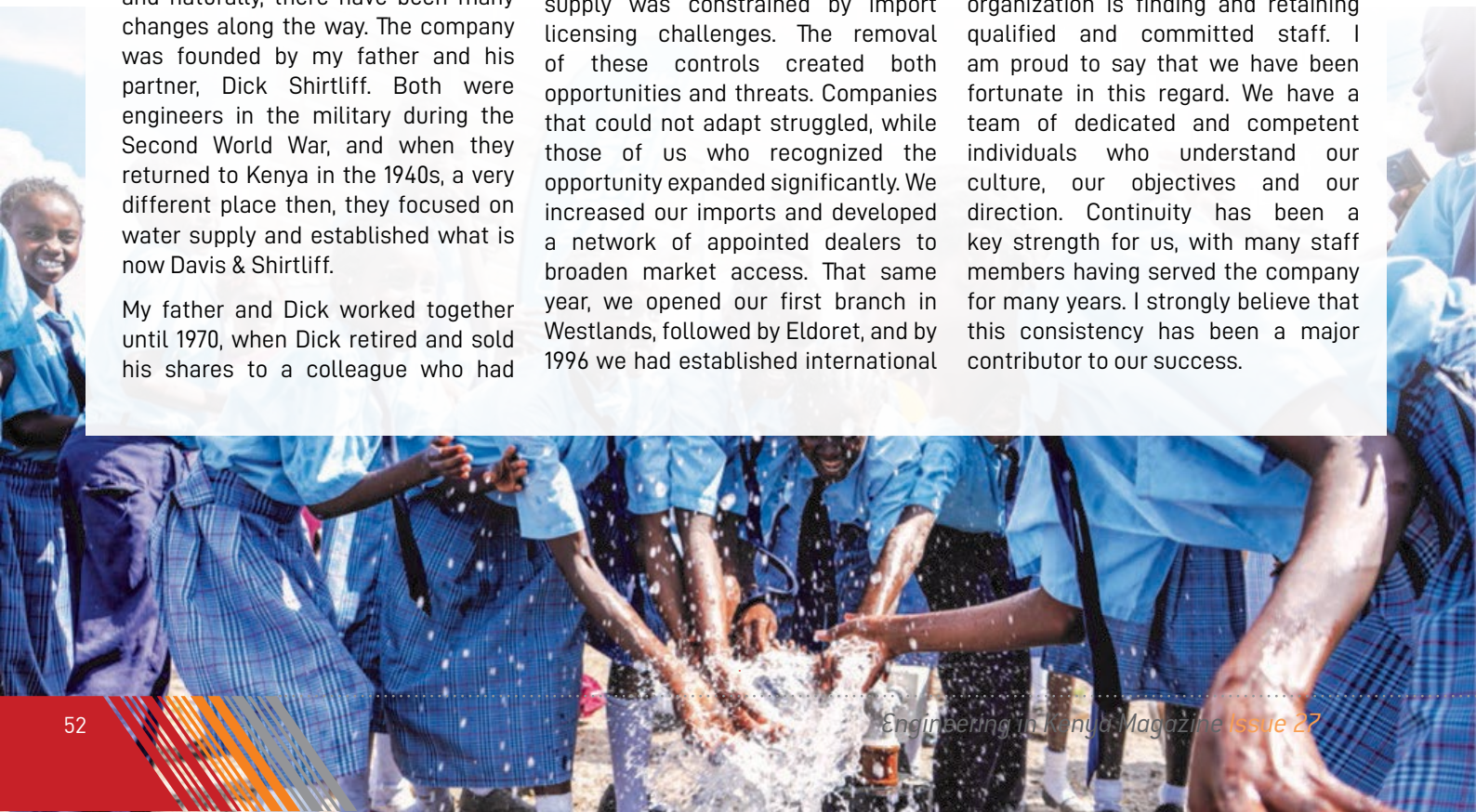
My father and Dick worked together until 1970, when Dick retired and sold his shares to a colleague who had been with the company for some years. Shortly after independence, the economy was relatively flat, but in the 1970s it began to pick up strongly. During that time, we expanded significantly, particularly in project work. Notable projects included building the original water treatment plants at the Tana River power stations. We also constructed many swimming pools, though our core business remained borehole equipping.

I joined the business in 1976 as a field engineer. When my father passed away in 1982, I took over the family shareholding, and a few years later I bought out my partner when he chose to retire. Our growth has always been evolutionary rather than sudden. A key growth driver in the 1970s and 1980s was our pump business. We represented international brands such as Grundfos from Denmark, which played a major role in shaping our development.

One of the most defining moments, not just for us but for the entire country, came in 1993 when the economy was liberalized and foreign exchange controls were removed. Prior to that, supply was constrained by import licensing challenges. The removal of these controls created both opportunities and threats. Companies that could not adapt struggled, while those of us who recognized the opportunity expanded significantly. We increased our imports and developed a network of appointed dealers to broaden market access. That same year, we opened our first branch in Westlands, followed by Eldoret, and by 1996 we had established international subsidiaries in Tanzania and Uganda. From there, our branch network continued to grow. Today, we have 120 branches in Kenya and a presence in 10 regional markets, including Zambia, Uganda and Tanzania.

We continued to expand our product portfolio. In 1993, we introduced Pedrollo pumps from Italy, which remain our largest supplier today. We strengthened our water treatment business and, in 2003, entered the solar sector as early adopters. Solar has since become one of our largest product areas, driven by growth in solar pumping and power systems. Our expansion has always been driven by two factors: increasing our product range and expanding our footprint. The more products we offer and the more branches we establish, the greater the market opportunities we create. This has been fundamental to our growth and the strong position we enjoy today.

Of course, the journey has not been without challenges. We have had to navigate changing fiscal policies, fluctuating market demand and increasing competition. However, one of the biggest challenges for any organization is finding and retaining qualified and committed staff. I am proud to say that we have been fortunate in this regard. We have a team of dedicated and competent individuals who understand our culture, our objectives and our direction. Continuity has been a key strength for us, with many staff members having served the company for many years. I strongly believe that this consistency has been a major contributor to our success.



In recent years, we have made significant investments to position ourselves for future growth. In 2021, we established a new Distribution Centre, and this year we launched an Engineering Centre at Tatu City. This facility is designed to enhance our technical engineering capabilities, featuring assembly and manufacturing areas, a certified water testing laboratory, an electrical panel assembly unit, research and development facilities, offices and a training centre. We are also bringing in engineers with strong digital capabilities to drive product development. Technology has transformed the pumping industry, and we are particularly focused on water treatment, where we design and manufacture specialized systems using technologies such as Reverse Osmosis and Ultra Filtration.

Beyond business, one of the aspects I am most proud of is our impact on communities. Through our 'Improving Lives' initiative, which represents our CSR activities, we have completed over 800 projects focused on water supply for disadvantaged communities, including schools and healthcare centres. These initiatives have benefited over one million people, which we consider a meaningful contribution to society. We often collaborate with partners and welcome others to participate in these programmes. Looking ahead, the greatest opportunities for growth will come from enhanced technology and digital solutions, areas in which we are investing heavily. We operate in the critical sectors of water and energy, both of which are essential for regional development. Our objective is to build a world-class indigenous organization capable of delivering local solutions to challenges that were previously unmet.

Over the years, I have learned several important leadership lessons. The first is the importance of having a clearly defined strategy. You must know where you are going and remain disciplined in executing that vision. Avoid distractions and stay focused on your core competencies. Secondly, consistency is key. Strategy must be applied continuously and with discipline. Continuity and consistency are essential for long-term success. Finally, people are the most critical factor in any organization. You need a capable and committed team, guided by strong leadership and a clear culture. At Davis & Shirtliff, our values of Integrity, Quality and Altiora Peto -meaning "I seek higher things" -define our commitment to continuous improvement and progress.

Ultimately, every organization must keep investing, innovating and evolving. If you are not moving forward, you are moving backwards. This philosophy has driven Davis & Shirtliff to where we are today and will continue to guide us into the future.

## PICTORIALS

*CSR: Thika School for the Visually Impaired*

*Solar Pumping System installation in Ngaremara Primary School - 1*

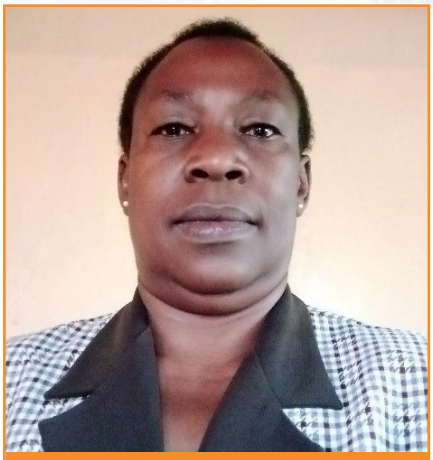
*Ngaremare Primary School - 2*

*Inside Tatu Warehouse*

*Service Centre*

*Davis & Shirtliff Group Chairman, Alec Davis, General Manager for Branches Margaret Kuchio, Ambassador Bitange Ndemo and Group's CEO George Mbugua during the commemoration of Davis & Shirtliff's 80 years of operations as leading provider of sustainable water and energy solutions*

# Breaking Barriers in Academia: Women Engineers Shaping Research, Innovation, and Higher Education Leadership



By Eng. Prof. Bernedette Sabuni

Eng. Prof. Bernedette Sabuni is a registered civil engineer and currently an Associate Professor in Structural and Materials Engineering and the Dean of the School of Engineering and the Built Environment at Masinde Muliro University of Science and Technology (MMUST).

## From humble beginnings to Engineering

I come from a very humble background. I went to school in remote areas at a time when girls rarely progressed beyond secondary school. As I looked at my surroundings, I kept asking myself, "Why can't I make a difference? How can I make a difference?" I did not look at myself as a girl limited by circumstance; instead, I saw myself as somebody who could make a difference.

As I progressed through secondary school and later university, I discovered that I enjoyed making things and understanding how they worked. Whenever I saw something that had been created, I would ask myself, "Why is it like this? Why is it behaving like this?" That curiosity naturally led me into engineering.

## Rising through the ranks

When I joined academia after completing my master's degree, I carried one principle with me: *Aways do your best.* I have never lobbied for an administrative position. Instead, opportunities came because people recognized my work. Whenever a task needed to be done, my colleagues would often say, "Prof. Sabuni is there. She can do it." When I joined MMUST, I was appointed Chair of the Department of Civil and Structural Engineering. After completing my term, I was appointed to serve as the Director of Quality Assurance. Later, I was appointed Dean of the School of Engineering and the Built Environment. Over the years, I have also served in acting capacities as Deputy Vice-Chancellor. People often ask how I rose through the ranks. My answer is always the same: "Just do your best and somebody will identify you. They will not look at you as a woman but as a performer." Once people recognize that you can deliver results, they begin to trust you with greater responsibilities.

## Learning to work in male-dominated spaces

Throughout my career, I have often found myself working in environments where I was the only woman. At the Housing and Building Research Institute, for example, we would go out on projects and I would often be the only lady among many men. What I learned is that you can work with men just like any other colleague. In fact, many of them were very supportive. These experiences taught me resilience and confidence. They showed me that competence and professionalism are what matter most.

## Balancing leadership, family and personal life

As a woman, balancing life can be difficult. During the early years, when you are raising children while building a career, there is a lot to manage. Sometimes I pose and ask myself: "Have I forgotten myself? Have I forgotten my family? Have I forgotten other enjoyments that other ladies go through?"

These are real feelings that come with leadership responsibilities and the demands of professional life. Even today, balancing teaching, mentorship, leadership, consulting, and social life requires careful planning. Sometimes I set aside specific days for office work and others for mentoring students or attending to personal matters. It is not easy, but somehow you try to balance. You have to keep it in mind that as a woman, you have to work much extra.

### Researching sustainable construction solutions

My research interests have focused on alternative construction materials and sustainable building technologies. I believe in using what is available around us. If we can utilise locally available materials while reducing waste and protecting the environment, then we are doing the right thing. That is why I advocate for sustainable building technologies. We must ask ourselves whether the materials we use are suitable for our environment and whether they can be implemented by ordinary people. Nature has provided us with many resources. As engineers, we must find the best ways to use them without compromising the good environment that God has given us.

The satisfaction of seeing research in practice

One of the most rewarding aspects of research is seeing it translated into practical solutions. When you see something that started as your idea being used in practice, you feel a deep sense of satisfaction. You feel connected to it because you know you have contributed something valuable. That connection between research and real-world application is what makes academic work worthwhile.

### The reality of women in leadership

Leadership presents unique challenges, particularly for women. Challenges have been a constant feature throughout my career journey. Men often thrive in competitive environments and are willing to take risks. Women, on the other hand, tend to be more cautious because they want to do things well and avoid mistakes. Yet leadership is highly competitive, and everybody wants to be at the top. Women still carry many other responsibilities, yet are expected to perform at the same level. One thing I do not like is when people want to include women merely to satisfy gender requirements. I always remind them not to pick on me because they want to balance gender, but because I can do it. That distinction is important. Women should be recognised for their competence and performance.

### A changing landscape for Women Engineers

Looking back, I can confidently say that the landscape has vividly changed.

Today, there are far more women engineers than there were when I started my career. Women are taking bold steps and entering spaces that were once considered inaccessible. Who would have imagined women flying airplanes, leading major infrastructure projects, or heading important institutions? We are seeing women command major responsibilities, and we are very proud of them.

### Lessons from the first Women Engineers Convention

One experience that stood out for me was attending the First Women Engineers Convention. I saw bold women with confidence and power. For me, the biggest lesson was that the issue of a woman feeling self-pity is now over. It was so encouraging to see women standing out in the profession and demonstrating what they can achieve. I returned home with one message for women, "Come out from your shell. Sometimes all you need is to take a step into a new space. Then you discover that you can actually do it." The convention reminded many of us that women are capable of far more than they sometimes believe.

### Professionalism above all else

As engineers, we have a responsibility to society. We have undergone the training. We have passed the examinations. We know the right thing to do. The question is whether we are willing to act professionally regardless of the environment around us. If we all acted professionally, we would not see many of the problems we complain about today, including unsafe buildings and poor planning. Engineers must remain committed to their principles even when doing so is difficult.

### My Vision for Kenya

After more than 20 years in the profession, my dream is simple. I would like to see more Kenyan innovations. I want to see products made by Kenyans in Kenya, and I want us to be proud of Kenyan-made products. We conduct research and generate good ideas, yet people sometimes look down on locally developed solutions. I believe we should support our own innovations, improve them where necessary, and continue building on them. That is how development happens. As I often say: "I want people to envy Kenya because we should be proud of what we produce."

### Universities as centers of solutions

Academic institutions have a critical role to play in national development. We need to teach what is relevant and ensure that learners can apply what they have been taught. Universities should be recognized as centers of knowledge, innovation, and practical solutions. Industry should know that when it comes to our universities, it will find answers to real-world challenges. That is the future I would like to see: a Kenya that believes in its own innovations, supports its own researchers, values its institutions of learning, and takes pride in what it creates.

# PICTORIALS


*Eng. Prof. Bernedette Sabuni joins members of the IEK Western Branch in a tree-planting activity to mark World Engineering Day.*

*Eng. Prof. Bernedette Sabuni engages with learners at Approved School, Kakamega, during a mentorship and community outreach programme, inspiring and empowering the next generation through guidance on personal growth, education, career development, and leadership.*

*Eng. Prof. Bernedette Sabuni and fellow women engineers during a photo session at the 1st Women Engineers Convention, a landmark event showcasing excellence, leadership, and the contributions of women in engineering.*

*Eng. Prof. Bernedette Sabuni with stakeholders at the Engineering Dinner, MMUST, fostering collaboration and innovation in engineering excellence.*

# The Future of Consulting Engineering in Kenya: Opportunities, Challenges, and Women's Growing Influence

By Eng. Barbara A. Adhoch, PE, MIEK, CEO, Association of Consulting Engineers of Kenya

Eng. Barbara Adhoch, CEO of the Association of Consulting Engineers of Kenya (ACEK), believes that Engineering is not only about technical expertise but also about shaping policy, mentoring future professionals, and ensuring infrastructure serves society equitably. She shares how her journey through engineering, leadership, and advocacy has shaped the evolving role of women in the profession and the future of consulting engineering in Kenya.

**Finding purpose through Engineering**

Reflecting on her journey into civil engineering, she explained that she entered the profession during a period when engineering was viewed as a key driver of national transformation. For her, the appeal was not only the promise of career growth but also the opportunity to solve real-world problems and see tangible results. She noted that engineering provided a platform through which she could contribute to national development while building a meaningful career. "What has motivated me over the years is the fact that you can see the tangible impact that engineering has on transforming communities and the country itself," she said. According to Eng. Barbara, the profession's ability to create lasting change continues to be one of her greatest sources of motivation.

**Leadership beyond personal achievement**

As CEO of ACEK, she views leadership as a responsibility that extends far beyond personal success. She explained that every engagement, decision, and public appearance represents not only the consulting engineering fraternity but also countless young women aspiring to join the profession. She observed that many people still find the idea of a woman leading in male dominated spaces underscoring the importance of visible female leadership in engineering. "We need to normalize the idea that women can be senior in engineering and in leadership," she remarked. According to her, leadership creates an opportunity to influence policies, programmes, and partnerships that create more inclusive pathways within the profession.

**The value of early leadership exposure**

Before assuming the CEO position, Eng. Barbara was actively involved in the ACEK Future Leaders Chapter, first as a member and later in Vice Chair of the Future Leaders. She believes this experience played a significant role in preparing her for executive leadership. She explained that participation in the chapter gave her a deeper understanding of the Association, institutional advocacy, and professional leadership. By the time she rose to senior leadership, she already understood how the ACEK operated, allowing her to transition seamlessly into her current role.

**Engineering is about people, not just projects**

While Eng. Barbara has worked on numerous engineering assignments, she says some of her most valuable lessons came from projects that required direct interaction with communities. She recalled working on feasibility studies and water supply projects where technically sound solutions faced resistance because communities had not been adequately engaged. "You may have a very perfect design on paper, but if you are not willing to sit down and listen to the community, then the whole design can fail," she explained. These experiences reinforced the importance of communication, stakeholder engagement, and empathy in engineering practice. In her view, technical competence alone is not enough; engineers must also understand the people they serve.

**Why Transportation Engineering matters**

The CEO of ACEK's passion for transportation engineering stems from her belief that transport systems form the backbone of economic and social development. Having worked extensively on road design and highway engineering projects, pursuing a master's degree in transportation engineering felt like a natural progression. She described transportation infrastructure as the circulatory system of the economy because it determines how people, goods, and services move. "Transport determines whether farmers reach markets, children reach schools, and patients access hospitals," she noted. She aspires to contribute towards building transport systems that are safer, more efficient, and more equitable for all users.

**Are women becoming more visible in Consulting Engineering?**

Although consulting engineering remains male-dominated, Eng. Barbara believes the landscape is gradually changing. She acknowledged that the number of women in consulting engineering is still lower than desired but pointed out that visibility, mentorship, and professional support systems are helping to accelerate

progress. According to her, one of the most powerful motivators for young women is seeing other women succeed. "When you see other women thriving in these spaces, it should help you believe in yourself even more," she said. She cited initiatives such as ACEK's Women in Consulting Engineering and Leadership Mentorship Programme as important platforms for nurturing future female leaders in the profession.

**Moving beyond the Imposter Syndrome**

Eng. Barbara believes that many of the barriers facing women today are less about competence and more about confidence. She noted that women graduate from engineering schools with the same qualifications and technical capabilities as their male counterparts. However, self-doubt and imposter syndrome sometimes discourage them from pursuing leadership opportunities. Mentorship and visibility, she explained, help address these challenges by providing guidance, encouragement, and examples of women who have successfully navigated similar journeys. In her view, creating supportive professional networks is essential for increasing women's participation in consulting engineering.

**Consulting Engineers as advisors and change-makers**

Eng. Barbara emphasized that consulting engineers have a role that goes far beyond project implementation. She believes consultants should serve as trusted advisors to governments, communities, and clients by helping shape decisions that are technically sound, economically viable, and environmentally sustainable. "Consulting engineers should actively participate in policy discussions rather than waiting until projects reach the implementation stage. We should sit at the tables where national development plans are being drafted, not simply wait for projects to be handed to us for implementation," she stated. This proactive engagement, she believes, is necessary for creating infrastructure that truly meets society's needs.

**The importance of continuous learning**

Throughout her career, Eng. Barbara has witnessed the growing importance of continuous professional development. She commended ACEK's training programmes, webinars, conferences, and technical sessions for helping engineers stay current with emerging technologies, industry trends, and global best practices. According to her, university education provides a strong foundation, but professional growth requires ongoing learning. She also highlighted mentorship as a critical component of professional development because it creates opportunities for networking, knowledge-sharing, and career guidance.

**Balancing leadership, career, and family**

Like many women in leadership, the CEO of ACEK has had to navigate the demands of professional responsibilities, family commitments, and personal growth. She explained that achieving balance is not about perfection but about intentional decision-making and adapting to different seasons of life. Strong support systems, including family, colleagues, mentors, and trusted caregivers, have played a vital role in helping her manage competing responsibilities.

"Some seasons will demand more of you professionally, while others will demand more personally. I encourage women to adjust their priorities as circumstances change while remaining true to their personal identity," she observed.

**Building a more inclusive Engineering future**

Looking ahead, Eng. Barbara hopes to see an engineering sector where leadership reflects the diversity of society. She believes that greater inclusion will result in better decision-making because diverse perspectives lead to more responsive and effective solutions. Drawing from personal experience, she noted that individuals often understand challenges best when they have encountered them firsthand. As such, she advocates for greater representation across gender, age, ability, and community backgrounds within engineering leadership.

**Creating African solutions for African challenges**

"Beyond diversity, I would like to see more locally generated engineering knowledge and innovation. I believe African engineers possess the expertise needed to solve many of the continent's challenges and should be empowered to develop solutions tailored to local realities. We have the knowledge," she said. "I would like to see our own people spending their energy solving our own problems."

In her view, strengthening local innovation will not only address development challenges but also position African engineers as global contributors to knowledge and practice.

**A message to the next generation**

As the conversation came to a close, Eng. Barbara shared a message for young women aspiring to careers in engineering and leadership. She encouraged them to be confident, embrace opportunities, and pursue excellence in everything they do. Rather than focusing on barriers, she urged them to focus on competence, professionalism, and continuous growth.

Her parting words captured the essence of her own journey and leadership philosophy:

> **Be so good at what you do that they cannot ignore you.**

# PICTORIALS

*ACEK's presence at the What Women Want Summit 4.0, March 2026, fostering dialogue and collaboration.*


*The 7th EPC Convention, Mombasa, Kenya*


*The 7th Engineering Partnership Convention, April 2026*

*The 32nd IEK International Convention, November 2025*

*Participants during the ACEK STEM Mentorship Outreach and CSR Programme, fostering innovation, career awareness, and academic excellence among young learners, reflecting ACEK's commitment to empowering youth through education, mentorship, and community engagement.*

# Women Transforming Transportation Infrastructure: Engineering Sustainable and Inclusive Futures in Kenya



**By Eng. Monica Abonyo,**
**Director Highway Design and Survey,**
**Kenya National Highways Authority**

The transformation of transportation infrastructure is ultimately a transformation of society itself. Roads, bridges, and mobility systems determine how economies function, how communities access opportunity, and how nations respond to effects of climate change, population, and development pressures. For me, engineering has never been, abstract it has always been deeply connected to lived experience, particularly growing up in a rural environment where infrastructure directly shaped daily life.

In my early years growing up in the rural countryside, ease of access to schools, markets, and essential services depended heavily on prevailing weather conditions. During rainy seasons, roads would become impassable, cutting off communities from economic activity and social services. These early realities shaped my understanding of infrastructure not as a technical construct alone, but as a critical enabler of inclusion, mobility, and life opportunities. It is from this foundation that my journey into engineering began.

My academic path in civil engineering at the University of Nairobi was both formatives, marked by a period of rapid growth and adaptation. Transitioning from a background that had limited exposure to technical subjects at the secondary school level, I quickly embraced the need to build new competencies and strengthen my foundation. Courses such as engineering drawing, structural analysis, and design demanded not only academic effort but also continuous self-learning to bridge foundational gaps. This period shaped my engineering mindset rooted in resilience, precision, and continuous improvement.

A defining moment in my professional direction came through early exposure to highway engineering practice during industrial attachments and early career assignments. Observing senior engineers leading multidisciplinary teams on major road design projects made the profession come to life in in a new way. It provided clarity on the practical impact of engineering and strengthened my interest in contributing to transformative infrastructure development. Seeing women in technical leadership roles within infrastructure projects was particularly influential, as it demonstrated that engineering leadership was not limited by gender, but defined by competence, vision, and delivery.

This exposure naturally led me to specialize in highway and transportation engineering. Transport infrastructure, more than many other engineering disciplines, has a direct and immediate impact on economic development and social inclusion. Roads determine access to markets, education, healthcare, and regional trade. In rural economies especially, transport infrastructure is the backbone of opportunity creation and poverty reduction.

Over the course of my career, I have worked across consultancy, construction, and public sector institutions, gaining end-to-end exposure over the full road infrastructure lifecycle from; feasibility studies and detailed engineering design; to construction supervision and maintenance planning. This breadth of experience has reinforced the importance of systems thinking in infrastructure development. Engineering decisions are interconnected, and outcomes

depend on how effectively technical, environmental, financial, and social components are integrated.

I currently serve as Director - Highway Design and Survey. My responsibilities include leading and coordinating highway engineering project planning; engineering design and surveys; as well as the design, construction, maintenance, and management of bridges, and related structures. I also oversee highway safety management, environmental and social safeguards, resource mobilization, policy formulation and implementation, performance management, and strengthening of regional collaboration and institutional partnerships. Each of these functions plays a critical role in ensuring that infrastructure is not only technically sound, but also sustainable, safe, and socially responsible.

Highway design extends beyond geometry and materials. It involves traffic forecasting, land use analysis, environmental assessment, and long-term economic alignment. Survey systems ensure spatial accuracy and support land acquisition processes, while structural engineering ensures durability and resilience of bridges and key infrastructure. Road safety engineering introduces a preventive approach to reducing fatalities and improving user protection across transport networks.

A critical dimension of modern infrastructure engineering is environmental and social integration. Infrastructure development inevitably interacts with ecosystems and human settlements. As a result, engineering today must incorporate safeguards such as environmental impact mitigation, resettlement frameworks, and sustainability planning. This ensures that infrastructure development contributes positively to long-term ecological and social outcomes.

My professional experience has also included involvement in major transport infrastructure development and management projects across Kenya's national and regional corridors. These include key sections of the Northern Corridor connecting the Port of Mombasa to inland East African countries, as well as major highways linking urban and agricultural regions. Such corridors are not just national infrastructure they are regional economic lifelines that support trade, mobility, and integration across East Africa.

Working on these projects has reinforced the strategic importance of infrastructure planning and design. Upgrading road networks improves safety, reduces transport costs, enhances trade efficiency, and strengthens regional competitiveness. Conversely, inadequate infrastructure planning can result in long-term inefficiencies and economic bottlenecks that are costly to reverse.

Beyond project delivery, a significant part of my work has focused on institutional strengthening and policy development, particularly in road safety engineering. Establishing structured road safety systems required coordination across multiple agencies, including transport authorities, law enforcement bodies, and regional organizations. This work included developing crash data systems, black spot management frameworks, and road safety guidelines that support evidence-based decision-making.

The introduction of centralized digital crash data systems marked a major shift from fragmented reporting to integrated national data platforms. This has enabled better analysis of accident trends, improved identification of high-risk corridors, and more targeted interventions to reduce road fatalities. It represents a broader transition toward data-driven infrastructure management.

Leadership in engineering requires a balance between technical depth and strategic oversight. Technical credibility is essential, but equally important are communication, stakeholder engagement, and team coordination skills. Over time, I have learned that effective leadership is built on continuous learning, adaptability, and the ability to translate complex technical systems into actionable decisions for diverse teams.

Mentorship has also been a consistent

part of my professional journey. Supporting young engineers particularly women entering the field has been both a responsibility and a commitment. While the engineering profession has historically been male-dominated, the landscape is gradually changing. Increasing numbers of women are entering engineering education and progressing into professional practice, though representation in senior technical and leadership roles still requires significant improvement.

From experience, career progression in engineering is influenced not only by technical capability but also by visibility and sponsorship. Mentorship, advocacy, and institutional support play a critical role in enabling professionals to access leadership opportunities. It is equally important for young engineers to actively participate, speak up in technical spaces, and take on responsibilities even before they feel fully ready.

Encouragingly, progress is visible. More women are entering engineering programs, contributing to infrastructure projects, and participating in professional institutions. However, achieving true equity requires sustained effort through education, mentorship, institutional reform, and cultural change within the profession.

Looking ahead, the future of transportation and infrastructure engineering in Kenya is highly promising. Rapid urbanization, population growth, and economic expansion are driving increased demand for efficient, resilient, and integrated transport systems. At the same time, climate change requires infrastructure that is adaptable and environmentally responsible.

Future transport systems will increasingly integrate multimodal networks, smart mobility solutions, and digital infrastructure management. The focus will extend beyond road construction to include system-wide mobility planning that integrates public transport, non-motorized transport, logistics optimization, and climate resilience strategies.

Ultimately, engineering plays a central role in shaping sustainable development outcomes. Infrastructure is not only about physical construction it is about enabling opportunity, improving equity, and strengthening economies. When applied with systems thinking and long-term vision, engineering becomes a powerful tool for transformation.

My journey has reinforced a simple but important principle: transportation infrastructure is most impactful when it is designed with people in mind, informed by systems thinking, and guided by a commitment to sustainability and inclusion.

# **Women in Technical Leadership:** Advancing Innovation in Building and Mobility Systems

**By Ms. Diana Masila**
**General Manager, KONE East Africa**

*BIO Data: Diana Masila is the Branch Manager of KONE East Africa, leading strategic growth and operations across the region. With over 17 years of experience in the vertical transportation and building solutions industry, she brings deep expertise in sales leadership, customer engagement, and operational excellence.*

*She has advanced through several key roles at KONE, demonstrating a strong track record in driving performance and expanding market presence. Her leadership is rooted in innovation, collaboration, and a commitment to customer satisfaction.*

*Diana holds an MBA and a bachelor's degree in communication and Sociology from the University of Nairobi. She is also a passionate advocate for mentorship, women's empowerment, and community development.*

We spoke to Diana Masila, one of the few women in leadership and at the core of ensuring that cities grow taller, smarter, and more connected. She tells of her leadership journey, demonstrating that technical leadership is way beyond engineering expertise. It is about vision, people, innovation, and impact.

## Inspired by the power of infrastructure

I have always been fascinated by how engineering and technology can transform the way people live, work, and move. The infrastructure and mobility systems industry provides a unique opportunity to create solutions that directly impact millions of people every day. What inspired me most was the ability to contribute to the development of safer, more efficient, and more sustainable urban environments. Being part of an industry that shapes cities and improves accessibility for people from all walks of life has been both professionally rewarding and personally fulfilling.

## Leading in a highly technical industry

My experience has been both challenging and rewarding. While I do not come from a traditional engineering background, my education in Communication and Sociology provided a strong foundation in stakeholder engagement, relationship management, and understanding organizational dynamics. My MBA further equipped me with the strategic and commercial skills required to lead in a complex business environment.

Over the years, I have learned that technical leadership is not solely about technical expertise; it is also about building high-performing teams, driving innovation, solving customer challenges, and creating a culture of excellence. The industry is evolving, and organizations increasingly recognize that diverse perspectives strengthen decision-making and innovation. I am encouraged by the progress being made to create more inclusive opportunities for women across all leadership levels.

## Leadership shaped by people and purpose

Several experiences have shaped my leadership philosophy. Leading diverse teams and managing complex customer relationships taught me the importance of empathy, communication, and collaboration. My background in Sociology helped me appreciate the human side of organizational success, while my MBA reinforced the importance of aligning people, strategy, and performance.

One key lesson I have learned is that leadership is not about authority; it is about influence, trust, and empowering others to succeed. Working in a highly technical environment has shown me that the best outcomes occur when technical excellence is combined with strong interpersonal leadership and a shared sense of purpose.

## Driving innovation in smart buildings

KONE is at the forefront of transforming urban mobility through digitalization and smart technologies. We continue to invest in intelligent solutions that improve the flow of people within buildings while enhancing safety, efficiency, and user experience. Through predictive maintenance, connected services, data analytics, and smart building integrations, we are helping customers optimize building performance and future-proof their assets. These innovations enable building owners and facility managers to make informed decisions while creating seamless experiences for building users. As cities become increasingly connected, KONE remains focused on developing technologies that support smarter and

more sustainable urban environments.

KONE's technologies contributing towards smarter, safer, and more sustainable cities

Sustainability is deeply embedded in KONE's innovation strategy. Our solutions are designed to improve energy efficiency, reduce environmental impact, and support responsible urban development. From energy-efficient elevators and escalators to regenerative technologies and intelligent maintenance solutions, we help customers reduce operational costs and carbon emissions while maintaining the highest standards of safety and reliability. As urbanization continues across Africa and globally, sustainable mobility solutions will be essential in supporting smart cities that are environmentally responsible, accessible, and resilient.

## The changing face of technical leadership

The progress has been remarkable. More women are stepping into technical and leadership roles, and organizations are increasingly recognizing that diverse perspectives drive stronger innovation and business outcomes.My own journey has reinforced that leadership is built through more than academic qualifications. While my degree in Communication and Sociology and MBA provided a strong foundation, I have found the 70-20-10 learning principle to be true in practice—70% of growth comes from real-world experiences, 20% from mentors and professional networks, and 10% from formal education. As more women gain access to these opportunities, we are seeing a new generation of confident, capable leaders shaping the future of technical industries.

**Projects that leave a lasting impact**

What stands out most are projects that have delivered a lasting impact on customers and communities. Throughout my career, I have had the opportunity to contribute to initiatives involving modernization, digital transformation, customer experience enhancement, and operational excellence. I am particularly proud of projects where cross-functional teams came together to solve complex challenges and create measurable value for customers. These experiences reinforced my belief that successful infrastructure projects are built not only on technical expertise but also on effective collaboration, stakeholder engagement, and strong leadership.

## Creating opportunities for women

Honestly, there has been significant progress. More organizations are recognizing the value that diverse leadership teams bring to innovation, business performance, and organizational culture. Women are increasingly occupying leadership positions across technical, operational, and executive functions. While there is still work to be done, particularly in increasing representation at senior leadership levels, today's environment offers more mentorship opportunities, professional networks, and development programs than ever before. This progress is encouraging and is helping to create a stronger pipeline of future female leaders.

Initiatives that can be adopted to encourage more women to pursue careers in engineering, automation, and technical leadership

Organizations must be intentional about creating opportunities for women to enter and advance in technical careers. Policies such as the one-third representation principal help ensure women have a meaningful presence in recruitment, development, and leadership pipelines. At KONE, we are committed to building an inclusive culture where women are encouraged to explore technical roles, grow their expertise, and lead with confidence. Through mentorship, development opportunities, and equitable career pathways, we are helping shape the next generation of female technical leaders.

My message to young women is simple: engineering is not only about machines and technology but also about solving real-world problems, driving innovation, and shaping the future. The industry needs your ideas, your perspective, and your leadership.

## The future of women in engineering and technical leadership

I am extremely optimistic. Africa's rapid urbanization, infrastructure investments, and digital transformation initiatives present enormous opportunities for women to contribute and lead. As smart cities continue to emerge across the continent, there will be growing demand for leaders who can combine technical innovation with strategic thinking, stakeholder engagement, and sustainable development. I believe women will play an increasingly influential role in shaping Africa's infrastructure future, not only as engineers and technical specialists but also as business leaders, innovators, and decision-makers. By fostering inclusive workplaces and investing in talent development, we can ensure that the next generation of women leaders helps drive Africa's growth and transformation.

## Parting shot

My career has shown me that leadership in technical industries is about more than technology. It is about understanding people, communicating a vision, driving innovation, and creating lasting value. As Africa builds the smart cities and infrastructure of tomorrow, women have a vital role to play in shaping a future that is more connected, sustainable, and inclusive for all.

# 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, 548th council accepted the following members under various membership categories as shown below;

| MEMBERSHIP CLASS | NUMBER ACCEPTED- 548th COUNCIL | TOTAL |
|---|---|---|
| FELLOW | 2 | 2 |
| CORPORATE | 2 | 2 |
| GRADUATE | 51 | 51 |
| GRADUATE ENGINEERING TECHNOLOGIST | 5 | 5 |
| GRADUATE ENGINEERING TECHNICIAN | 5 | 5 |
| STUDENT | 13 | 13 |
| **TOTAL** | **78** | **78** |

During the period, we had 2 members who transferred from the class Corporate to Fellow member 2 from Graduate to Corporate member. In addition, we had 51 graduates, 5 graduate engineering technologists, 5 graduate engineering technicians and 13 students were accepted as members.

## Gender Data

| Class | Male | Female | Percentage (Male) | Percentage (Female) |
|---|---|---|---|---|
| Fellow | 2 | | 100% | 0% |
| Corporate | 1 | 1 | 50% | 50% |
| Graduate | 42 | 9 | 82% | 18% |
| Graduate Engineering Technologist | 4 | 1 | 80% | 20% |
| Graduate Engineering Technician | 5 | | 100% | 0% |
| Student | 7 | 6 | 54% | 46% |
| **TOTAL** | **61** | **17** | **78%** | **22%** |

## Summary

| Gender | No. | Percentage |
|---|---|---|
| Male | 61 | 78% |
| Female | 17 | 22% |
| | 78 | 100% |

## 548th APPROVAL

### FELLOW

| S/N | Name | Member No |
|---|---|---|
| 1 | Ahmed Shee Mukhtar | F.4705 |
| 2 | Martin Kidali Lumasia | F.3216 |

### CORPORATE

| S/N | Name | Member No |
|---|---|---|
| 1 | Dickson Lerionka Paul | M.6901 |
| 2 | Rosaline Wangari Muhia | M.9786 |

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;

# Student Voices

**Margaret Muthoni Kiiru,**
The Technical University of Kenya , 5th year
Bachelor of Engineering in Geospatial Engineering (B. Eng)

**Women in Engineering:** Building Inclusive Infrastructure Through Geospatial Engineering

Engineering is more than designing structures and systems; it is about solving real human problems. My passion for Geospatial Engineering grew from the desire to understand the world through mapping, spatial data, and technology that improves people's lives. Geospatial engineering combines surveying, Geographic Information Systems (GIS), remote sensing, and satellite technology to support land management, urban planning, disaster response, and infrastructure development.

One fascinating aspect of the field is how modern GIS tools can create digital maps that help governments and engineers make accurate decisions about roads, utilities, housing, and environmental conservation. In rapidly growing communities, these technologies are essential for planning sustainable and efficient infrastructure.

As a woman in engineering, I believe diversity is critical in technical decision-making. Inclusive infrastructure can only be achieved when people from different backgrounds, genders, and experiences contribute ideas. Women often bring unique perspectives on accessibility, safety, community needs, and social impact, helping engineers design solutions that serve everyone fairly. Engineering should reflect the divers

## The Challenges Women Face in Engineering Projects

My interest in engineering started in a simple way. I used to watch roadside workers in helmets and overalls and feel quietly drawn to what they were doing. I did not fully understand it then, but I knew I wanted to be part of that world.

Now being in engineering, I see both the passion and the pressure behind it.

One major challenge is the **authority gap on site**. Even when qualified, women engineers are sometimes met with doubt from contractors or workers, and have to repeatedly prove their competence before being taken seriously in decision-making spaces.

There is also the issue of **limited access to meaningful project roles**. Being present on a project does not always translate into being trusted with critical tasks that build real experience and confidence.

On top of that, field environments are not always designed with women in mind. **Lack of appropriate PPE fit and basic facilities** like proper sanitation can make some sites uncomfortable and even unsafe to fully operate in.

Another challenge is the **internal pressure** that builds over time. Constant evaluation and subtle exclusion can lead to self-doubt, hesitation, and over-thinking even when you are capable.

Still, engineering remains powerful and worth it. Every challenge also shapes resilience, and slowly, women are not just participating in engineering projects, they are reshaping them.

**Shigel Mary Donald,** 20yrs
Technical University of Kenya (Tu-K), 3rd year
Bachelor Of Technology in Civil Engineering

**Brenda Chepkirui Towett, 22**
The Technical University of Kenya, 4th year
B.Tech. Electrical and Electronics Engineering

## The Evolving Identity of Women in Electrical Engineering

Growing up in a family of male engineers, my early years were surrounded by blueprints, circuit boards, and technical discussions that naturally shaped my curiosity toward electrical and electronics engineering. This environment fostered a strong interest in understanding how invisible electrical currents power and sustain modern civilization.

However, as a fourth-year student, I have come to appreciate that the identity of women in engineering must go beyond simply entering spaces that have traditionally been male-dominated. Today, the role of a woman engineer is rapidly evolving into that of a versatile, global problem-solver who integrates traditional hardware expertise with emerging digital technologies.

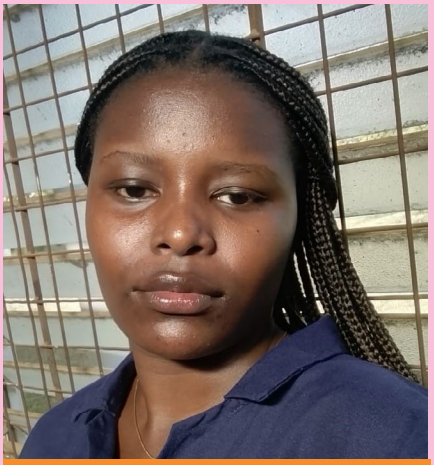
What makes this field particularly exciting is its increasingly borderless nature. The analytical and adaptive skills we develop enable us to transition into diverse global roles, ranging from smart grid systems to automated and intelligent technologies. Despite this progress, challenges still exist, especially the limited access to inclusive leadership pathways within the profession.

Addressing these challenges requires expanding our skill sets beyond core circuit design to include agile management, systems thinking, and digital competencies. By broadening our capabilities, young African women engineers are not only following in the footsteps of those who came before us but are actively reshaping global technical leadership. In doing so, we are helping to build future infrastructure that is more innovative, inclusive, and sustainable.

## The Challenges Women Face in Engineering Projects

Women in engineering projects continue to face several challenges despite increasing participation in the profession. These challenges include gender stereotypes, limited representation in leadership positions, unequal access to mentorship opportunities, workplace discrimination, and difficulties balancing demanding project schedules with family responsibilities.

In some cases, women may also experience bias in technical decision-making processes, where their ideas and expertise are undervalued compared to those of their male counterparts. However, through professional support networks, inclusive workplace policies, and increased awareness of gender equality, many organizations are creating environments where women engineers can thrive, contribute innovative solutions, and take on leadership roles in engineering projects across the world.



**Carolyne Zighe Mwalasha, 20yrs**
Jomo Kenyatta University of Agriculture and Technology , 2nd year
BSc Mining and Mineral Processing Engineering

**Mibei Naomi**
Kenyatta University, 4th year
BSc. Electrical and Electronics Engineering

## Engineering Institutions and Gender Inclusion: How Professional Bodies in Kenya Are Supporting Women Leaders

For generations, engineering in Kenya has been a field shaped predominantly by men. Today, however, a determined transformation is taking root, led by professional bodies that recognize gender inclusion as central to the country's development agenda.

The Engineers Board of Kenya (EBK) and the Institution of Engineers of Kenya (IEK) have emerged as key drivers of this change. IEK, through its Women in Engineering (WEC) chapter, runs structured mentor-ship programme that pair female engineering students with established women professionals, fostering both technical growth and leadership confidence. The EBK, on its part, has incorporated gender equity considerations into its registration and continuing professional development frameworks, encouraging more women to formalize their engineering credentials.

Kenya's engineering institutions have also partnered with universities such as the University of Nairobi and Jomo Kenyatta University of Agriculture and Technology to fund scholarships targeting women in undergraduate engineering programme. These initiatives directly address enrolment disparities that have persisted for decades.

At the professional level, IEK has made deliberate efforts to place women in visible leadership roles within its branch committees and national executive, ensuring female voices shape institutional policy.

These steps are promising, yet sustained commitment remains essential. Kenya's engineering future will only reach its full potential when women lead not at the margins, but at the centre.

## Women Engineers in the Diaspora: Navigating Global Engineering Practice, Opportunities, and Leadership Experiences

There is something quietly remarkable about a woman who leaves her home country, earns an engineering degree, and then rebuilds her professional identity in a place that did not always expect to see her.

For women engineers in the diaspora, the journey is rarely just technical. It is cultural negotiation. You learn to code-switch between boardrooms and site visits, between your accent and theirs, between who you are and who the room assumed you would be. And yet, within that friction, something powerful emerges.

Diaspora engineers bring a dual literacy; the rigor of their training and the adaptability of their lived experience. Those qualities are not soft skills. They are strategic assets in a globalized industry that increasingly demands engineers who can work across borders, systems, and communities.

The leadership gap for women in engineering is well-documented. For women of color in the diaspora, that gap is compounded. But the tide is shifting. Mentorship networks, professional organizations, and visibility platforms are slowly closing what credentials alone cannot.

The most urgent conversation is not whether these women belong in global engineering they do, and they always have. The real conversation is about building structures worthy of the talent already in the room.

**Angela Wangui Waithaka, 21yrs**
Kenyatta University , 4th year
Bachelors of Science in Biomedical Engineering

## Integrating Direct Air Carbon Capture with Airport Carbon Utilization Systems for Sustainable Aviation in Kenya: A Phased Engineering Framework for Climate Change Mitigation

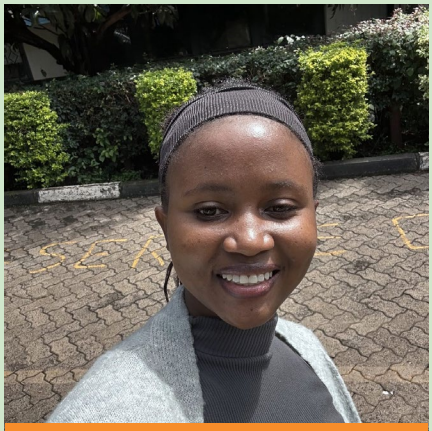
The aviation industry continues to be one of the most challenging sectors in terms of decarbonization efforts due to its dependence on hydrocarbon-based fuels as well as the delayed rollout of lower emission fuel alternatives, including hydrogen technology and Sustainable Aviation Fuels (SAFs). Although DACCS solutions have started being recognized more widely as useful climate mitigation technologies, they still have not been fully integrated within the aviation sector, especially in developing countries. As a recent entrant into the DACCS space via projects initiated by companies like Octavia Carbon, Kenya is yet to find ways to apply DACCS engineering in aviation sustainability contexts.

This study puts forth the concept of the Airport-Coupled Carbon Circularity Framework (ACCCF), which is a complementing engineering framework that aims at integrating Direct Air Carbon Capture systems into airport carbon utilization systems for promoting sustainable aviation in Kenya. Unlike the concept of developing massive infrastructure in isolation, this framework is based on a phased approach to engineering, which would be ideal in resource-limited contexts. The framework considers the possibilities of incorporating modular DAC systems into airport ecosystems using various carbon pathways such as renewable energy systems, carbon accounting, and carbon valorization into Sustainable Aviation Fuel (SAF) feedstocks.

The research uses a systems engineering and sustainability lifecycle assessment methodology to examine the technical viability, environmental effect, and scale-up capability of the project in the Kenyan aviation environment, considering large airports as deployment centers conceptually. Specific consideration is given to resolving challenges associated with DACCS, namely high cost and non-scalability, by presenting carbon capture as an economic complementarity system capable of scale-up deployment.

This paper makes a contribution to the conversation on climate change mitigation by reconceptualizing airports as functioning carbon ecosystems that can support circular carbon economies. The insights gained from this study are envisaged to offer an engineering solution for harnessing the potential of carbon capture technologies within the African aviation sector.

**Kimberly Nyawira**
Technical University of Kenya
Petroleum Engineering, 4th yr
B. Eng in Aeronautical Engineering



**Grace Tsadza**
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Engineering decisions influence every aspect of society, making diversity in technical decision-making essential. For many years, engineering solutions were designed from limited perspectives, often overlooking the needs of diverse users. The inclusion of women in engineering brings different experiences, ideas, and approaches to problem-solving, leading to more innovative, inclusive, and effective solutions that benefit everyone.

Professional institutions have played an important role in supporting this transformation. While many engineering spaces were once perceived as male-dominated, initiatives such as mentorship programs, scholarships, leadership development opportunities, and women-in-engineering chapters are helping to create a more inclusive profession. These platforms have enabled many women, including myself, to grow professionally and gain confidence in pursuing leadership roles within engineering.

Despite the progress made, significant challenges remain. Women engineers still face stereotypes, dismissive attitudes, and workplace systems that are often designed with men in mind. The pressure to constantly prove competence and earn equal recognition can be demanding. Recognizing and discussing these challenges openly is necessary if the profession is to create meaningful and lasting change.

For African women engineers working internationally, the journey often involves overcoming additional barriers. However, the ability to innovate and solve problems in resource-constrained environments is a valuable strength. These experiences equip African women engineers with unique perspectives that contribute positively to the global engineering community.

My identity as a woman engineer has evolved beyond a passion for calculations and technical systems. I have come to understand that engineering is also about shaping the future and ensuring that all communities are represented in the solutions we create. Each challenge I overcome strengthens my commitment to building sustainable systems and creating opportunities for others. The future of engineering depends on diverse voices, and women have a vital role to play in designing a more inclusive and innovative world.

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### The Challenges Women Face in Engineering Projects

Every woman pushed out of engineering is not just a personal loss, it is an economic catastrophe. Research estimates that increased female participation could unlock billions in untapped value, yet the industry continues to bleed the very talent it cannot afford to lose.

The barriers women face is not accidental. They are structural, cultural and deeply embedded in how projects are built and teams are run.

Underrepresentation remains stark with women accounting for barely 16% of the engineering workforce. When young women see no one who looks like them, the message is clear: this space was not built for you. Engineering culture confirms it; from project sites layout and equipment designs to the mindsets that greet her when she walks in. With their every judgment second-guessed and mistakes remembered longer, women have to work twice as hard for half the recognition. This pressure erodes ambition from the inside out; and where ambition survives, blocked pathways finish the job.

Yet despite everything, women show up, outperform expectations, push through unfriendly environments and still deliver. That resilience deserves more than admiration. It deserves action.

Diversity in engineering is not a favor extended to women. It is an investment the industry makes in itself. The blueprints for change exist. The only missing material is the will to build.

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