# FEDERAL UNIVERSITY OF TECHNOLOGY, AKURE

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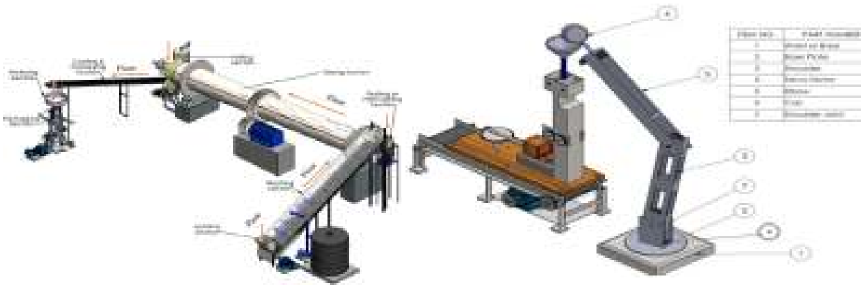
# HUMAN FACTOR, MANUFACTURING, AND TECHNOLOGY: THE TRIPLE HELIX DRIVING OUR JOURNEY INTO THE FUTURE

**Inaugural Lecture Series 197**



**Delivered By**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***(FNSE, MMSN, MIAENG, MNiMechE, NIEM)***

B.Eng., M.Eng., Ph.D (Akure)

**PROFESSOR OF MACHINE AND PROCESS DESIGN, AND APPLIED ERGONOMICS**


**TUESDAY, 28TH APRIL 2026**

School of Infrastructure, Minerals, and Manufacturing Engineering (SIMME)

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# PROTOCOL

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Gentlemen of the Press
Ladies and Gentlemen
Great FUTARIANS!!!

# 1.0 INTRODUCTION

An inaugural lecture is a lecture formally inducting a person into a new office. Such lectures are delivered after assuming the status of a professor, provide the community with the opportunity to know what the Professor is professing, and provide a platform to showcase and celebrate the Professor's landmark achievements. It is with great gratitude to the Almighty God, the father of my Lord and Saviour Jesus Christ, that I stand here with great joy before this great gathering of eminent scholars and distinguished elites with a deep sense of humility, and honour to deliver the 197th Inaugural Lecture of this great University, the Federal University of Technology, Akure, Nigeria titled "Human Factor, Manufacturing, and Technology: The Triple Helix Driving Our Journey into the Future" today, 28th day of April, 2026. This inaugural lecture chronicles my research of over twenty-five years, which essentially focused on ergonomics principles application to machine and process design, and manufacturing and the use of appropriate technology for optimal performance in a dynamic world.

This lecture is historically the 27th in the defunct School of Engineering and Engineering Technology (SEET), the 8th for those of us of Department of Mechanical Engineering origin since the first one was delivered on October 10, 2002 by Professor Adeyemi Adegbemisipo Aderoba titled "Strategies for Engineering Development in Nigeria", the 3rd in the recently created Department of Industrial and Production Engineering (IPE) where I was the Pioneering Head of Department, and the 3rd in the School of Infrastructure, Minerals and Manufacturing Engineering (SIMME), an offshoot of SEET.

Today is a landmark in the journey of my life, which can only happen because I am a product of God's grace if not, how can a son of two people (My father and Mother) who never attended any school for one day in their lives become a professor! Truely it's from the dark pot that white pap comes out (*'ninu ikoko dudu ni eko funfun ti n jade')*. It has been only God all the way. Let everything that has breath praise the Lord.

## 1.1 The beginning of my journey into Mechanical Engineering

Madam Vice-Chancellor, I would like to share my personal experience that led to my studying mechanical engineering. When I was in Primary three, I was staying with my maternal grandmother, who on one fateful evening, sent me to grind soup ingredients. While the person attending to me was busy with the grinding, I was focused on the moving parts (pulley and belt) of the grinding machine. I got carried away, and I stretched forth my right hand to see if I could stop it from rotating, which led to two of my fingers being cut off. I started crying only when I sawpart of my finger jumping on the floor because the cutting was so fast that I did not feel any pain. Thank God I did not lose my life in the process, because it took a long time before it healed up. Thereafter, I decided to take revenge on the mechanism that moved so fast to cut off my finger, and the only course that can help me in this mission is mechanical engineering. I had deficiencies in some subjects in my O level result, most especially in English language, where I had F9, Don't blame me for this, because throughout my secondary school education, I never had a qualified English language teacher. Thanks to Mr Bolarinwa from Ijesa-Isu in Ekiti State, who studied Yoruba language at NCE level, who was the one who taught us the little he could. My mission is clear: to study Mechanical Engineering, and nothing could stop me. So, I registered for General Certificate Examination (GCE) in 1991 and passed all my subjects. I also registered for my first and the only Joint Admission Matriculation Board (JAMB) examination I wrote in my life with my first choice being FUTA and my second choice being FUT Minna. FUTA delayed her admission process during the year, so FUT Minna considered me first for admission. When FUTA eventually considered me, it was turned down by JAMB, because I had been admitted by FUT Minna. It took the intervention of Mrs Adebayo (the wife of former Registrar, FUTA) and Late Dr Mrs Oyebade (former Registrar, FUTA), who was the Admission Officer then, to change my admission to FUTA, my preferred university to study the course of my dream, mechanical engineering. This sounds like a dream come true, but not without a big challenge: finance. My benefactor, the late Mr. Moses Akinyemi, who brought me to Akure with a promise to help me with my studies to any level in life, did not even live to pay for my GCE to make up for the deficiencies in my O-level result. I was faced with challenges of core mechanical engineering courses like: engineering mathematics, thermodynamics, fluid mechanics, theory of machines, mechanical engineering designs, engineering drawing, strength and science of materials, manufacturing technology, mass and heat transfer, electromechanical devices, control engineering among others in one hand and the challenge of taking care of myself and my younger brother staying with me who needed transportation fare to school every morning. Since there is no financial backing anywhere and I must survive, I had to take up a home teaching and coaching centre job. I was a home teacher to the children of so many staff during this period. Glory be to God, I graduated in mechanical engineering with Second Class Honour Upper Division in 1998. After the one-year compulsory National Youth Service Corps (NYSC), I responded to FUTA advertisement for employment and was shortlisted for an interview which I was considered and offered employment in the Department of Mechanical Engineering as a Graduate Assistant and I assumed duty on the 18$^{th}$ September, 2000. This employment afforded me the opportunity of registering for my Master of Engineering in Mechanical

Engineering, which I completed in 2003 and subsequently, my PhD in 2009 in the same course, same department, and in the same University of Technology that is second to none in Nigeria and making waves across the globe, FUTA. So, if you had seen me being highly passionate about the well-being of FUTA, now you should understand why.

Madam Vice-Chancellor, I can say boldly that I am a complete academic who has passed through all the ranks in academia, from Graduate Assistant to Assistant Lecturer, Lecturer II, Lecturer I, Senior Lecturer, Reader and to full Professor on 1st October, 2019. I have been trained and work with the best, professionally sound and outstanding scholars that one can find around in the field of mechanical engineering. This sound training has allowed me to meet and interact with different people in this field across the globe. I can only say, it has been a jolly good ride in the world of mechanical engineering with particular focus on machine and process design, and applied ergonomics.

## 1.2 The global manufacturing reality

Around the world, manufacturing firms face intense pressure to remain competitive on cost, quality, and speed. Customer expectations have escalated – consumers now demand defect-free products delivered faster and customised to their needs, all while expecting companies to uphold sustainable practices (Nahil, 2024). It means manufacturers must juggle multiple challenges: improving quality and eliminating defects, shortening lead times to respond to market shifts, and adopting greener processes to meet environmental standards. Today's manufacturing environment is unforgiving – only those who can consistently deliver high-quality products quickly and sustainably will thrive. The triple helix of human factor, manufacturing, and technology is crucial here because it directly addresses these pillars of competitiveness:

a well-trained, well-supported workforce (human factor), efficient processes (manufacturing), and appropriate tools (technology). This is the proven formula for excelling in quality, speed, and innovation.

## 1.3 The Emerging Economic Reality

In developing and emerging economies, the manufacturing landscape faces contextual challenges that make the triple helix especially pertinent. Small and medium-sized enterprises (SMEs) dominate production in many of these countries, accounting for over 90% of industrial firms and the majority of employment. These SMEs often operate with severe resource constraints. Maintenance limitations and skills gaps mean that simply importing advanced technology can backfire – without local capability to maintain and operate it, the investment is wasted. Moreover, SMEs in these contexts face short product life cycles and fickle consumer demand, just like their global counterparts (Adeyeri *et al*., 2019). They must somehow become agile and innovative, despite scarce resources. This is why a holistic triple helix approach is so vital for emerging economies: only by concurrently upgrading human skills, rethinking process design, and introducing right-fit technologies can SMEs overcome their resource constraints and improve quality and throughput.

## 1.4 Definitions

### *1.4.1 Human Factor/Ergonomics*

A classic definition adopted by the International Ergonomics Association is that ergonomics is *the scientific discipline concerned with understanding interactions among humans and other elements of a system, and the profession that applies theory, principles, data, and methods to design to optimise human well-being and overall system* *performance* (Bridger, 2018). In simpler terms, it is about designing work *to fit human capabilities and limitations*. Ergonomists often say it is fitting the job to the person, not the person to the job. This involves knowledge of anatomy, physiology, psychology, and engineering – everything from arranging a workstation to suit a worker's body measurements, to scheduling tasks in a way that accommodates human cognitive limits. In the context of this lecture, the human factor refers to human-centred considerations in engineering, specifically, ergonomics and human factors engineering.

### *1.4.2 Manufacturing*

In this lecture, manufacturing is not just the act of making things, but a systems view of production. Manufacturing is *the process of converting raw materials into finished products using tools, machines, people, and processes* (Kenton, 2024). However, beyond that basic description, we treat manufacturing as a *complex system* that must be managed. It encompasses planning and coordinating workflows, controlling quality and variability, maintaining equipment, and continuously improving processes. Therefore, when this lecture refers to the manufacturing strand of the helix, it implies a disciplined, systems-oriented approach to operations: understanding the end-to-end production flow, reducing non-value-added activities, controlling variation to ensure high quality, and ensuring that equipment and processes are reliable and efficient. It is the foundation that ensures technology and human work can be effective.

### *1.4.3 Technology*

In this lecture, technology refers to the tools, machines, and digital systems used to enhance manufacturing. These range from traditional machinery to advanced automation and computing. In recent years, manufacturing technology has increasingly meant *digitalisation* and *smart automation*. We refer to elements of Industry 4.0, such as robotics on the factory floor, sensor networks that monitor equipment and product conditions, computer systems for planning and scheduling, and artificial intelligence (AI) for decision support or quality inspection (Oostveen *et al*., 2025).

Crucially, technology is not just about cutting-edge inventions; it is also about appropriateness and maintainability. Appropriate technology means choosing solutions that fit the local context and the user's needs. E.F. Schumacher, the economist who championed the concept of appropriate technology, argued that in developing markets, the best technologies are often *small-scale, labour-intensive, easy to use and maintain, and adapted to the local environment* (Adeyeri *et al*., 2019). This is a pertinent point for our environment: if we import extremely complex, state-of-the-art equipment that our technicians cannot maintain or that our power grid cannot reliably support, that technology will not drive progress. In fact, it could become a burden (sitting idle when it breaks, waiting for expensive foreign experts to fix it). So, maintainability is a key aspect of technology selection: we should ask: *Can we keep it running? Do we have the skills and spare parts to service it?* A highly advanced machine that is frequently down for repairs will perform worse than a simpler machine that runs consistently (Smith, 2025).

## 1.5 The Hidden Cost of Ignoring Human Factors

Madam Vice-Chancellor, my personal experience I shared in section 1.1 of this lecture speaks directly to the hidden cost of ignoring human factors principles in design and manufacturing. If principles of ergonomics have been considered in the design of the grinding machine, I would not have been exposed to this danger that permanently took part of one of my fingers away (Figure 1). So many people were not as lucky to survive their own avoidable accident to tell the story like me. It is unfortunate that we still have most of these machines in use till today (Figure 2).

***Figure 1: My Cut-Off Finger***

Importantly, human error is viewed as a signal rather than merely a personal failing. Modern safety science indicates that when an error repeatedly occurs, it points to a design flaw in the system that requires remediation. For example, if operators consistently press the wrong button, the controls may be poorly labelled or placed. If workers frequently drop a part, the provided tools may be too awkward to grip. By treating errors and accidents as valuable feedback, we improve the system for everyone. The ultimate goal of focusing on the human factor is to design systems in which humans can perform work *safely, efficiently, and comfortably.*

*Figure 2: Machines Without Ergonomics Considerations*

It is tempting in fast-paced industrial environments to focus on machines and output and to view human factors and ergonomics as secondary concerns. That approach is costly. When human considerations are neglected, fatigue, errors, and injuries inevitably rise – bringing serious direct and indirect costs. For example, a 2021 workplace safety index found that the ten most disabling work injuries (many due to poor ergonomics, like heavy lifting and repetitive strain) cost employers over $1 billion per week in compensation and medical bills (Smith, 2025).

Studies confirm that investing in human-centred design pays off. In one compilation of ergonomics interventions, companies reported a 67% reduction in scrap and errors and a 25% increase in productivity after improving operators' workstations and tools (Smith, 2025). Ignoring these human factors is, in effect, ignoring a root cause of unstable quality and inefficiency. There is also the challenge of poor adoption: if a new technology or process is introduced without considering human usability, workers may resist using it or use it incorrectly. The triple helix framework forces us to heed those signals and redesign work to fit humans, rather than expecting humans to suffer and fail.

## 1.6 The Common Implementation Gap

If the problems are so well-known, why do they persist? A significant reason is the gap between technology-first implementation and other approaches. Under competitive strain, firms often grasp at the latest technology as a silver bullet – automating processes, installing advanced robots or software – without making equal investments in *human* and *process* redesign. The result, all too frequently, is disappointment. The new technology might work in principle, but the organisation around it remains misaligned: processes are poorly defined or overly complex, and employees are unprepared to integrate the tool into their routines. Thus, simply layering technology onto a broken process multiplies the dysfunction. Technology must be appropriate, which does not only involve technical specifics but also *human factors and process fit*. Ultimately, the technology component of the triple helix is the force multiplier – it can exponentially increase capability, but only when applied wisely. Toyama's Law of Amplification succinctly states that applying technology to an ineffective operation will amplify its ineffectiveness (Malavasi & Schenetti, 2023). In essence, many firms overemphasise hardware and underemphasise people and processes.

This lecture argues that closing this gap requires a socio-technical approach: before investing in high-tech equipment, an enterprise must ensure processes are simplified and robust, and that workers are engaged, trained, and involved in the change. Technology should be the last puzzle piece we fit in place, once the human and process elements are ready. Otherwise, we risk automating waste or creating high-tech systems that people find ways to work around. The triple helix model is a direct response to this pattern – it insists that any technological change be accompanied by commensurate human factors engineering and process improvements to deliver truly better performance.

# 2.0 CONCEPTUAL FOUNDATIONS

## 2.1 Socio-Technical Systems Thinking

A recurring theme so far is the interplay between humans, technology, and process. Sociotechnical systems thinking is the formal way to analyse and design for that interplay. Originating from studies in the mid-20th century (notably in British coal mines), this approach posits that every organisational system has both a social subsystem (people, roles, culture) and a technical subsystem (tools, tasks, procedures), and performance emerges from the interactions between the two. Neither humans nor machines alone determine outcomes; it is how they work together. One core principle is *joint optimisation*, meaning we should design the social and technical aspects in tandem, rather than optimising one at the expense of the other (Kleiner *et al*., 2015).

Research in this field has shown that systems are safer and more effective when workers are given a degree of autonomy and input (the social side) and when technology is designed to complement human strengths and compensate for human weaknesses (the technical side), Kleiner *et al*., (2015). In practice, sociotechnical thinking leads us to examine interaction effects: Does introducing a new software change communication pattern on the shop floor (and with what effect)? If we speed up a production line with automation, do we inadvertently create an excessive cognitive workload for the human overseers? How does error feedback flow – do workers have the authority to stop a machine when they sense something wrong; technical process interacting with social authority structure? By asking such questions, we aim to avoid unintended consequences and to design systems in which humans and technology support each other. In the triple helix, sociotechnical theory explains why we must treat the three strands as inseparable. It reminds us that optimising one strand in isolation can undermine the system.

## 2.2 Technology as an Amplifier: The Need for Socio-Technical Alignment

The central thesis of this inaugural lecture is that technology is an amplifier, not a magician. It magnifies the capabilities of a well-designed system – or the cracks of a flawed one. A factory with skilled workers and lean processes will find that new technology accelerates productivity; conversely, in a disorganised setting, technology merely helps create chaos faster (Malavasi & Schenetti, 2023). Thus, the impact of any manufacturing technology depends entirely on how well it is aligned with human and process factors. This is why we speak of a triple helix driving performance. Just as a biological triple helix would lose strength if one strand were weak, an industrial system falters if any of the three strands – human factor, process, or technology – is out of alignment.

## 2.3 The Triple-Helix Thesis: Where Manufacturing Performance is Won or Lost

Human factors and manufacturing performance are fundamentally interdependent and cannot be separated in practice. Human Factors and Ergonomics (HFE) is a science of designing systems that optimise both human well-being and overall system performance (Bridger, 2018). In a production setting, people are an integral part of the system – they operate, maintain, and improve the processes. Studies show that the *human element is a key driver of manufacturing outcomes*: workers provide flexibility and problem-solving that enhance productivity, but if their needs and limitations are ignored, they can introduce variability, errors, or safety hazards (Dantan *et al.*, 2019).

In fact, focusing only on technical aspects while neglecting human factors often leads to unrealistic performance expectations and sub-optimal results. One analysis found that when human capabilities and ergonomics were not properly accounted for, the designed production capacity was overestimated, resulting in the system failing to achieve its expected output (Dantan *et al.*, 2019). This underscores that manufacturing systems must be designed *with* humans in mind from the start.

Overworked or ergonomically strained operators are more likely to commit errors and have accidents. Thus, *ignoring the people side of manufacturing leads to errors, fatigue, unsafe work, and variability* in output. On the other hand, integrating human factors improves not only worker well-being but also productivity and quality, reinforcing that people and processes cannot be separated (Bridger, 2018).

Advanced technology and automation can certainly *enhance* manufacturing, but they are not magic fixes for underlying process problems. In practice, technology amplifies the strengths or weaknesses of a workflow; it cannot inherently compensate for a flawed process or a poor user experience. A well-known principle is that automating an inefficient operation will simply allow you to produce inefficiency faster. For instance, if a workflow is poorly designed (with redundant steps, bottlenecks, or unclear procedures), introducing automation or IT systems on top of it tends to exacerbate the problem rather than eliminate it. Industry experts and case studies echo this concept: automating or digitising a broken process often exacerbates issues such as errors and delays because fundamental workflow problems remain (Quixy, 2026). In lean manufacturing terms, adding technology to a process full of waste (non-value-added activities) will automate the waste rather than remove it. Automation should reinforce good process design, not compensate for a poor one.

Moreover, technology cannot rescue *poor usability or workflow from a human perspective.* If a new software system or machine has a complicated interface, slows users down, or does not fit smoothly into the operational sequence, workers will find ways to avoid or work around it. Research on digital manufacturing adoption finds that many failures occur not because of the technological capabilities, but because of low usability and misalignment with real-world work practices. For example, a survey of manufacturing employees in the UK found that workforce readiness and acceptance are often overlooked when new technology is rolled out, leading to underutilisation of expensive systems that make *the job harder* rather than easier (Oostveen *et al.,* 2025).

A new Enterprise Resource Planning (ERP) or automation system might promise efficiency, but if it requires extra steps, disrupts established workflows, or is unreliable, operators will revert to familiar manual methods (e.g., paper checklists or whiteboards). In essence, no amount of cutting-edge technology will deliver benefits if the process logic and user experience are deficient. Effective manufacturing improvement should *first fix the workflow* (simplify, streamline, and error-proof it) and ensure usability, then apply technology as a force multiplier. Technology is an enabler, not a substitute, for sound process design. As one ergonomics-integrated lean study put it, lean methods focus on minimising waste in processes. At the same time, ergonomics ensures the system fits human operators; only together do they yield sustainable efficiency gains (Hizam *et al.*, 2024). High-Tech cannot be used in place of fundamental design flaws or a lack of human-centred design; those issues must be addressed at the root.

## 2.4 The Triple Helix: A Practical Engineering Model, not a Metaphor

Human factor, manufacturing and technology have been the triple helix driving the world since God created heaven and the earth, as seen clearly in the making of the first man in the garden of Eden (Gen.1:1; 26-28). From the body dimensions and positioning of body parts (anthropometry which is a branch of human factor), the central nervous system, sense organs, different body mechanism (technology), and to the production and assembly of all body parts - both internal and external organs (manufacturing), God, in creation, considered these three very important aspects of making progress. The wise nations of the world, from generation to generation, and from one kingdom to another, have been ruled by these three agents of progress. Every nation that has neglected them has always been relegated to the back seat. The much-talked-about slave trade was made possible by advances in manufacturing and technology, sophisticated weapons and war strategies. Nothing has really changed; the future of the world, in every aspect of life, is still driven by this triple helix.

The term triple helix has been used in other contexts (notably to describe innovation ecosystems involving universities, industry, and government). Here, we repurpose it to encapsulate the interplay among human factors, manufacturing processes, and technology in successful industrial systems. It is not meant as a vague metaphor but as a practical model to guide analysis and design.

In the same way, an engineering solution or business strategy should be evaluated based on how well it integrates these three elements. For example, if someone proposes to implement a new advanced manufacturing technology, the triple helix model prompts us to ask: *Have the workers (human factor) been considered – do they have the skills, is the change acceptable to them, will it improve their work condi-*

*tions? Have the current processes been analysed? Will this technology simplify flow or create new bottlenecks? Does it require process re-engineering?* If the answer to any of those is no, then the solution is incomplete. The triple helix is our way of ensuring *socio-technical alignment* in a tangible checklist form. It is also an advocacy: in engineering education and industry practice, we often have silos. I emphasise that our future advances will not come from technology alone, nor from process tweaks in isolation, nor from human initiatives like training programs on their own – but from innovations that deliberately connect these domains.

This is a model borne of my experience in both research and industrial projects over the years, and again, I have seen that neglecting one strand leads to sub-optimal results. By treating the triple helix as a concrete model, we can develop methodologies and checklists. The ultimate aim is for this thinking to become second nature in our institution and industries – that when we think about innovation or productivity improvement, we naturally consider training needs, ergonomic impacts, process workflow changes, maintenance implications, and so on as part of a single package.

# 3.0 SCHOLARLY JOURNEY AND RESEARCH PHILOSOPHY

The Vice-Chancellor, ladies and gentlemen, my research journey did not begin in a laboratory or on a factory floor. It began with a question that has echoed through every stage of my academic and professional path, as depicted in Figure 3: *How do we design systems that work for our people, our industries, and our future?* That question has led me to work at the confluence of three essential streams: human factors, manufacturing systems, and appropriate technology, which I now call the Triple Helix of performance.

My early exposure to industrial realities during my undergraduate years at the Federal University of Technology, Akure (FUTA), and later through graduate training in mechanical engineering, sharpened my awareness of a deep problem in our national manufacturing landscape. Too often, we import technologies, replicate foreign design templates, and apply textbook solutions without aligning them to our context, our people, our environment, and our industries. This was not just a technical mismatch; it was a human one.

## 3.1 From Anthropometry to Engineering Design

My first scholarly focus was to bridge this mismatch through ergonomics and anthropometry. I asked: How do we design products and systems that actually fit the Nigerian workers and users? This led to extensive research on the collection of anthropometric data, especially among special populations, such as mobility-impaired users, older adults, and healthcare workers. This work has helped produce validated anthropometric datasets and design frameworks that ensure assistive devices, medical carts, and workstations that meet the needs of the people who use them, not as an afterthought, but as a design imperative. Nevertheless, I did not stop at the analysis. My philos-

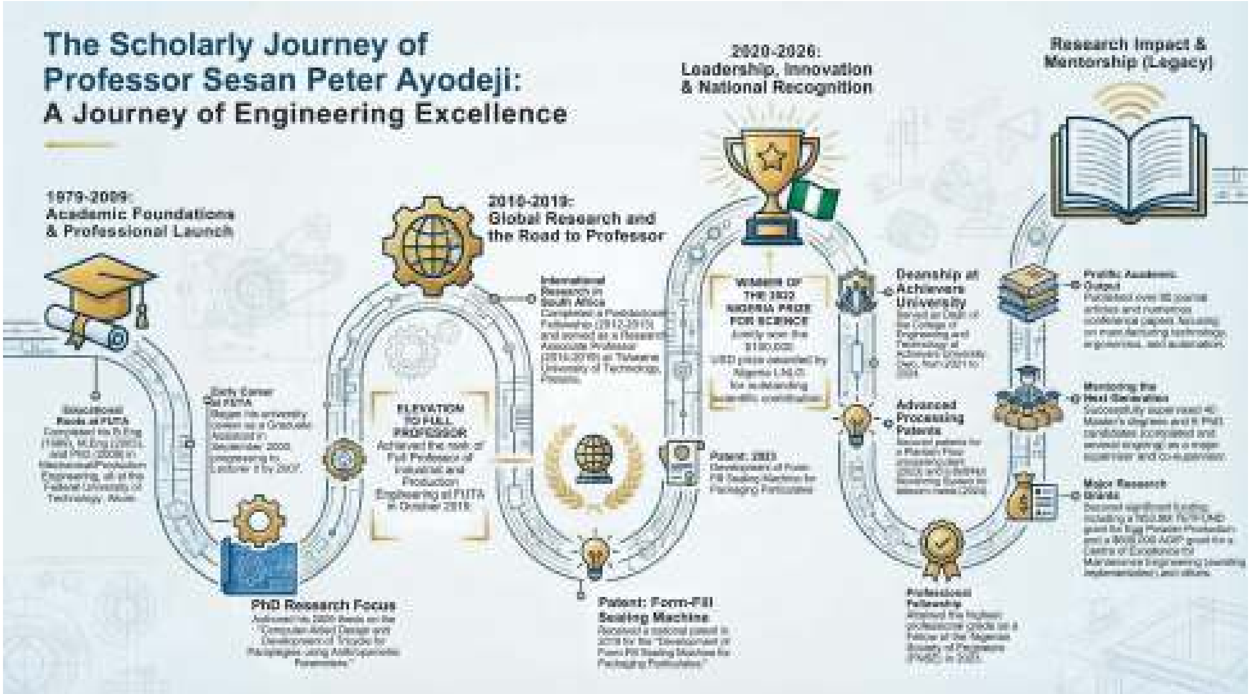



*Figure 3: My Scholarly Journey*

ophy has always been that design must lead to creation. As such, I transitioned from anthropometric research into practical mechanical design, developing mobility aids, evaluating wheelchair ergonomics, and constructing work environments where safety and dignity of labour were embedded by design.

### 3.2 Expanding into Manufacturing and Agro-Processing Systems

As my research matured, it became clearer that human-centred design alone was not enough. We also need to engage with the manufacturing systems that drive productivity and national development. Nigeria's agro-processing sector presented itself as a critical site of both opportunity and challenge. I began designing and developing mechanised and semi-automated process lines for staple crops such as plantain, yam, and cassava. I supervised the design and construction of process plants, from washing and drying to slicing and packaging. Each machine represented not just a technical artefact, but a carefully reasoned response to the needs of small and medium-scale producers operating under constraints of space, cost, and maintainability.

### 3.3 Engineering Automation with Meaning

The third strand of my research journey, technology, entered more fully as I began to explore how automation could improve efficiency and consistency in our local production systems. However, I approached this not from the usual "high-tech-first" standpoint; I asked, "How do we judiciously apply automation?" How do we integrate sensors, controls, and software in a way that empowers rather than replace the worker?

This led to work on PLC-controlled processing plants, the integration of safety sensors and digital interfaces, and simulation-based design verification using CAD/CAE platforms. Each intervention aimed to strike a balance between technological capability, affordability, and operational simplicity. To me, technology is not an end in itself; it is an enabler. Its true value is measured by how it amplifies human performance and stabilises process reliability.

## 3.4 A Collaborative and Capacity-Building Ecosystem

Throughout this journey, I have been privileged to walk alongside brilliant students, engineers, and academic colleagues. Our laboratory (Advanced Manufacturing and Applied Ergonomics Research Team) has trained over 200 undergraduate and well over 75 postgraduate students, many of whom have gone on to significantly contribute in academia, industry, and public service. We have actively fostered interdisciplinary collaborations, working with specialists in biomedical engineering, food science, technology, materials science, and project management. Beyond academia, our research group has engaged directly with local manufacturers, rural cooperatives, and industrial partners, translating scholarly ideas into deployable technologies. As the leader of the research group, I have served in technical advisory roles, contributed to curriculum development, made presentations at many academic and engineering gatherings, and participated in various engineering forums.

## 3.5 Research Grants, Patents, Awards, and Recognition

This journey has been greatly enriched by competitive research funding and recognitions, both national and international. I was privileged to be one of the joint winners of the prestigious 2022 Nigeria Prize for Science, awarded by Nigeria LNG Limited, which came with a $100,000 prize in recognition of innovation in science and technology.

Several other grants have provided the bedrock for our developmental efforts:

**TETFund National Research Grant (2022):** ₦53.9 million for the *Diversification of Egg Marketing and Egg Powder Production (DEMEPP)* project.

**TETFund Institution-Based Research Grant (2025):** ₦3.481 million for optimising plantain flour production and quality.

**TETFund Research Grant (2017):** ₦1.9 million to develop an automated plantain-flour production line.

**FUTA Research Grant (2007):** ₦192,200 for anthropometric design of a motorised wheelchair.

**World Bank Supported STEP-B Grant (2008):** ₦800,000 for CAD development of tricycles for people with paraplegia.

**AGIP Research Grant:** $600,000 (awaiting implementation) for the establishment of a Centre of Excellence in Maintenance Engineering. These grants have not only supported equipment design and testing but have also enabled capacity building through postgraduate supervision, staff training, and cross-border collaborations.

Madam Vice-Chancellor, in addition to these grants, five inventions have been patented in our laboratory and by other members of the research team. These are:

Development of a Monitoring System for the Torqueing of Bolts and Nuts on a Telecommunication Mast, Federal Ministry of Industry, Trade and Investment, Abuja, Nigeria, with Patent Number NG/PT/NC/O/2024/14194.

Development of a Plant for Processing Unripe Plantain into Bagged Flour, Federal Ministry of Industry, Trade and Investment, Abuja, Nigeria, with patent certificate number: 013249 and Patent Number NG/PT/NC/2023/9211.

A Hip-Waist Circumference Ratio and Body Mass Index Measuring Device Deplorable on Android Application for Determining Some Health Status. Federal Ministry of Industry, Trade and Investment, Abuja, Nigeria, with patent certificate number: 013251 and Patent Number F/PT/NC/2023/9210.

Development of Form-Fill Sealing Machine for Packaging Particulates, *National Office for Technology Acquisition and Promotion (NOTAP),* Abuja, Nigeria, with patent certificate number: 010936 and Registration of Patent number RP: NG/P/2018/381.

Development of an Automated Trio-Packaging Machine for Packaging Food Particulates (awaiting certificate).

I have also been honoured to receive various awards that reflect both scientific contributions and service to the profession, society, and most recently FUTA's Excellence and Productivity Award as the Best Inventor of the Year (2025). I have received multiple letters of commendation for my impactful leadership roles as Editor-in-Chief, Conference Organiser, and Sub-Dean at FUTA, and as Dean at Achievers University. These affirm the institutional value and cross-generational impact of my work.

### 3.6 FUTA and the Engineering Mandate

Madam Vice-Chancellor, this journey is not mine alone; it reflects the mission and mandate of our institution, FUTA, as a driver of applied innovation, industrial relevance, and national capacity-building. Every machine we design, every process we optimise, every human factor we embed into our systems, they are expressions of this mandate.

As I reflect on this journey today, I see a single thread woven through all my work: the pursuit of alignment between man and machine, process and purpose, context and innovation. That pursuit has shaped my research philosophy, guided my mentorship, and defined what I now call the Triple Helix, Human Factor, Manufacturing, and Technology, as the foundation for our engineering future.

# 4.0 MY CONTRIBUTIONS TO THE TRIPLE HELIX

What began as a solitary pursuit to improve machines and workplace ergonomics has matured into a cohesive body of work, a systems-level approach that integrates human factors, manufacturing excellence, and technological enablement. Over the years, our laboratory has evolved from producing stand-alone solutions to developing full-fledged production ecosystems, from post-harvest processing units to complete factory automation solutions. This evolution has made it possible to tackle complex challenges such as energy optimisation, production waste reduction, and product quality assurance in integrated ways.

## 4.1 The Human Factor: Engineering Designs for Ergonomics, Safety, and Social Inclusion - Helix One

Madam Vice-Chancellor, distinguished colleagues, and guests, I stand before you to articulate the strategic axis upon which all sustainable mechanical advancement must rotate: "Helix One - the human factor". My team and I have maintained a steadfast conviction that the accurate measure of engineering success is not in the cold complexity of a gear train or the ephemeral speed of a processor, but in the comfort and dignity these solutions afford the living, breathing user. Engineering is, at its most fundamental level, the moral art of problem-solving to make life comfortable. This mandate is amplified into a social imperative when we design for people with physical disabilities, for whom a well-engineered device is not merely a convenience but a bridge to social inclusion and personal autonomy. The "Human Factor" is the primary axis of our work, ensuring that our indigenous engineering solutions are not merely functional but are perfectly synthesised with the biological and psychological realities of the African context. We do not simply build machines; we restore the human spirit through technical precision.

### 4.1.1 Anthropometry: The Bedrock of Ergonomics

Anthropometry, the study of human body measurements, is the foundation of ergonomics. By understanding human physical characteristics, ergonomists design spaces, products, and systems that fit users' needs, enhancing comfort, safety, and performance. Why it matters: reduces injury risk; boosts productivity, and improves user experience. Ergonomics applies anthropometric data to create user-friendly environments, making it a crucial aspect of design, engineering, and healthcare. Because anthropometric data vary by region, there is a lack of trusted, documented Nigerian anthropometric data up to 2007. Ayodeji *et al.* (2008) conducted an anthropometric survey of Nigerian Paraplegics, and in 2012, Anthropometric data on Nigerian infants were documented (Ayodeji, 2012). The results of this survey have been used to develop numerous ergonomically compliant machines, as highlighted in the following sub-sections.

### 4.1.2 Engineering for Inclusivity: Assistive Technologies for Mobility and Independence

Engineering for inclusivity is not merely a technical exercise; it is a moral and economic imperative for national development. Marginalising people with disabilities through poor design is to sideline a reservoir of human potential voluntarily. Assistive technology, within the Helix One framework, serves as a bridge to economic participation and personal dignity, restoring the autonomy necessary for a productive life.

### *4.1.3 Breaking Barriers in Personal Mobility: The Paraplegic Tricycle and Hydraulic Height Adjustable Paraplegic Wheelchair*

In 2009, I worked on "Computer-Aided Design and Development of Tricycle for Paraplegics" (Figure 4) and subsequently, my team's inquiry into personal mobility has focused on the height-adjustable wheelchair research (Figure 5) (Ayodeji, 2009; Ayodeji & Adeyeri, 2011; Ayodeji *et al.*, 2015a; Ayodeji *et al.*, 2016b). By utilising Solid-Works and advanced Computer-Aided Design (CAD) methodologies, we have successfully developed systems that enable paraplegic users to perform tasks at an average adult's standing height, such as accessing high shelves or wardrobes. The impact of utilising indigenous anthropometric data instead of imported standards is quantifiable.

***Figure 4: The 3-D Tricycle for Paraplegics (Ayodeji, 2009)***

We furthered the quest for independence by modifying the standard paraplegic wheelchair. By replacing complex, expensive electrical propulsion with a robust, locally maintainable hydraulic jack mechanism, we have empowered "poor disabled persons" who were previously priced out of the economy. Using low-cost, readily available materials, this design enhances the user's domestic capacity, allowing them to independently retrieve items from shelves at 2 meters (Figure 5). In our performance evaluation of a modified hydraulic wheelchair, the modified system reached the target height in 28 seconds, whereas the existing model required 36 seconds. Physiological strain was markedly lower: the modified wheelchair recorded a heart rate of 79 beats/minute, consistent with healthy, unstressed breathing, compared with the 95 beats/minute recorded by the existing model (Ayodeji *et al.*, 2015a). In my quest to bring comfort to wheelchair-bound individuals, an off-road push-crank wheelchair was developed to help them navigate difficult terrain that common wheelchairs cannot access (Figure 6) (Ayodeji & Adeyeri, 2013). Also, Ayodeji & Adejuyigbe (2008) developed a CAD model for designing wheelchairs for Nigerian Paraplegics (Figure 7).

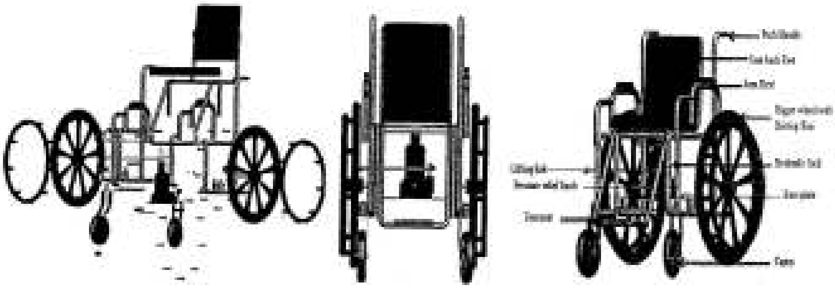


***Figure 5: Height Adjustable Wheelchair***

During the COVID-19 pandemic, people who use wheelchairs were at risk of not receiving the usual assistance from those around them due to social distancing rules. My team decided to help by developing a Dual-purpose wheelchair for COVID-19 patients with paraplegia, using Nigerian

***Figure 6: Off-road push-crank wheelchair***

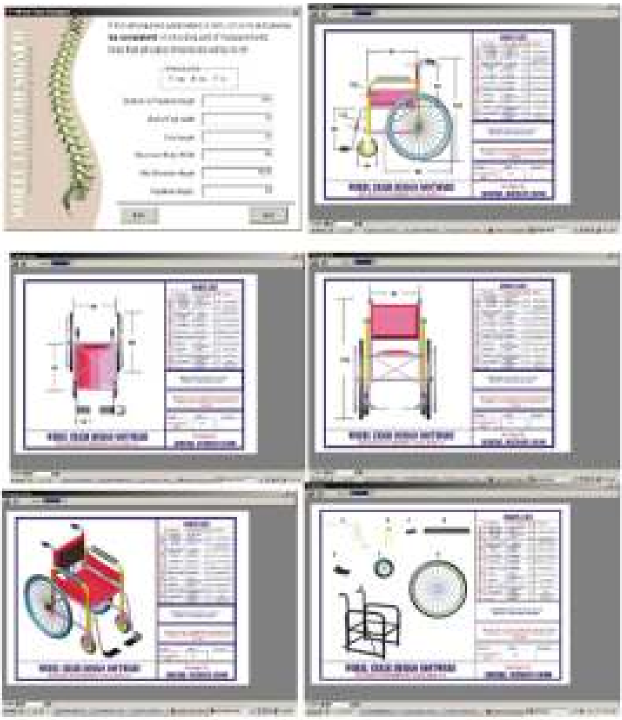


*Figure 7: CAD model of wheelchairs for Nigerian Paraplegics*

Anthropometry Data (Figure 8). The outcome of this invention was published in an Elsevier journal (Adeyeri *et al.*, 2020).

### 4.1.4 Adaptive Vehicle Control: The Left Throttling Pedal Solution

For individuals with right-leg paraplegia, the ability to drive is a gateway to agency. We developed an adaptive left-throttling pedal for the V-Boot Wagon 230, engineered for transfer to modern vehicles. To validate this intervention, we applied the Welch Two-Sample t-test in R, yielding a p-value of 0.4557 (Ayodeji *et al., 2015d;* Yakubu, *et al.*, 2014). This value confirms there is no significant performance differ-


***Figure 8: Dual-purpose wheelchair***

ence between the adapted and existing systems, thereby validating the modification's safety and responsiveness.

Furthermore, this adaptation enhances industrial productivity and sustainability. The engine idles at 1500 rpm with the adapted pedal, compared to 2000 rpm on the existing model (Table 1).

**Table 1:** Comparative Pedal Performance Evaluation (Engine Speed in RPM)

| Pedal Displacement (mm) | Existing Pedal (RPM) | Adapted Pedal (RPM) |
|---|---|---|
| Idle Position (0mm) | 2000 | 1500 |
| 20mm Displacement | 3200 | 3000 |
| 30mm Displacement | 4400 | 4500 |
| 45mm Displacement | 6000 | 6000 |

This reduction indicates superior fuel efficiency and reduced mechanical wear, even as both systems achieve a concurrent speed of 6000 rpm at a 45mm displacement. Madam Vice-Chancellor, our data reveal a critical engineering triumph: the adapted pedal achieved a lower idle speed (1500 RPM vs 2000 RPM), which directly translates to improved fuel efficiency and reduced consumption, a vital consideration for our users' economic realities.

#### *4.1.5 Restoring Pleasure and Agency: The Automated Page Turner*

True independence encompasses the preservation of the intellect and the soul. People with impaired upper body dexterity because of conditions such as quadriplegia, hemiplegia, cerebral palsy, severe arthritis, spinal cord injury, head injury, and other neuromuscular disorder, may find it difficult reading books, which is a significant challenge. Also, Automated page turner is relevant in the field of music. For centuries, the music industry has faced a lot of challenges, one of which is experienced during live performance or rehearsal, as musical instrument players are often forced to stop playing in order to turn printed music sheet or ask others to turn it for them. The challenges of having the page turned for the performer are that the page has to be read at the same pace as the performer and subsequently turned before the end of the music on the page, thereby creating the need for a device that would aid in the successful turning of pages of a book. My team developed an electromechanical page turner designed for individuals with limited upper-body dexterity or neuromuscular disorders (Ayodeji, 2018) (Figure 9). Unlike previous patents marred by mechanical complexity, our device prioritises portability and quiet operation. The device is capable of turning the pages of a book in a forward or backward direction for the physically challenged who have limited use of their hands, and the music players during rehearsals or live performances. The device achieved a 90% success rate at 15 pages/minute, with a response time of only 4 seconds. This metric is the restoration of the "simple pleasures", the ability to read or perform

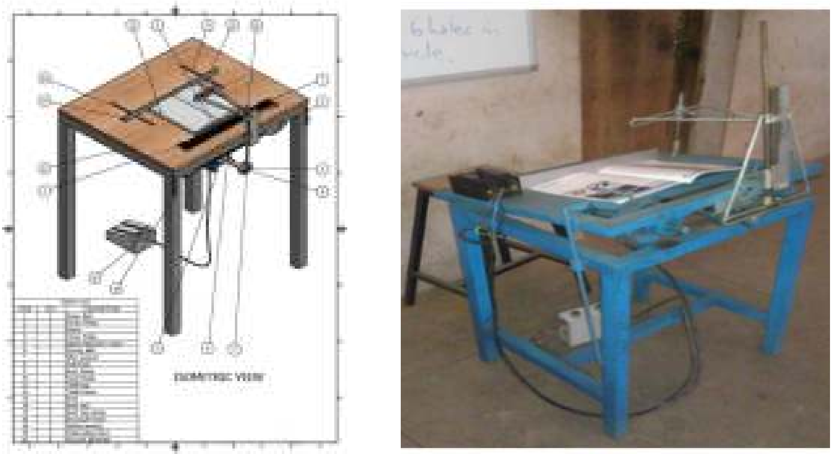


*Figure 9: Page Turner*

music without the constant, often frustrating, intervention of a caregiver. This is a critical component of the psychological well-being of our elderly and physically challenged citizens.

### 4.1.6 Exercise and Amusement Park

The elliptical cross trainer (a leg-and-arm exercise machine) has become popular for cardiorespiratory fitness training. They are found in almost every gym, recreation centre, and hotel in Nigeria, all of which are imported as new or fairly used. The use and maintenance of these machines have been problematic due to abuse, poor maintenance, sophisticated technology, and a lack of spare parts, which has reduced patronage of these products. We decided to develop a prototype of a leg-and-arm exercise machine (Figure 10) that addresses all the problems mentioned above without compromising functionality or efficiency. This design also functions as a weight-based resistance machine, reducing the machine's cost, size, and weight. The performance evaluation showed that the prototype performed better (Ayodeji & Adeyeri, 2013).

*Figure 10: Leg-and-Arm Exercise Machine*

Exercise helps children to be active, and a lack of it can lead to boredom. The unavailability of facilities designed for children's amusement parks that use the right anthropometric parameters, and the procurement costs due to import duties, have been significant challenges. Providing children's vehicles for amusement parks based on anthropometric parameters will go a long way toward addressing boredom. My team took up this challenge. Anthropometric parameters from 250 children (150 male and 100 female) aged 3 to 12 were collected and analysed. The 5th, 25th, 50th, 75th, and 95th percentiles for females and males, respectively, were used in designing the children's vehicle. Detailed drawings and a simulation of the design concept were produced using Autodesk Inventor CAD software (Figure 11). Three 200Ah, 12V deep-cycle batteries are required to drive the vehicle for 1 hour at a carrying load of 2280N. The simulation result ensures the stability of the vehicle (Ayodeji *et al.*, 2017).

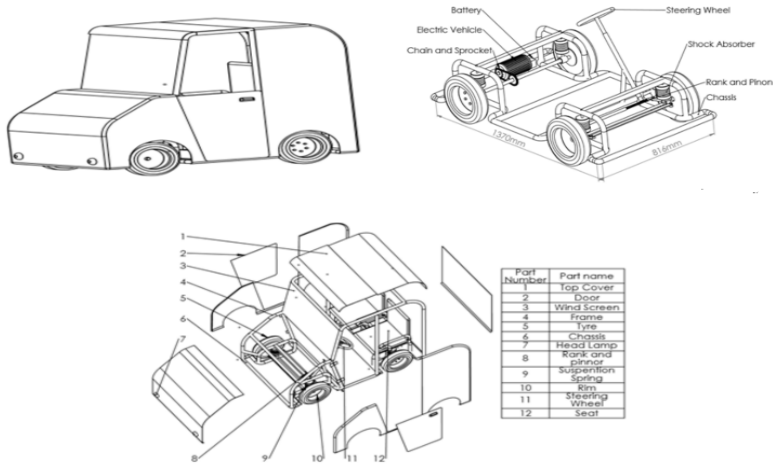



***Figure 11: Children's Vehicle***

### *4.1.7 Occupational Safety and Health: The Biomechanics of the Modern Workplace*

Beyond the scope of permanent disability, we must confront the silent epidemic of Musculoskeletal Disorders (MSDs) afflicting our industrial workforce. Biomechanical analysis allows us to identify the invisible exigencies that threaten to turn today's "occupational athletes" into tomorrow's disabled citizens.

#### *4.1.7.1 The Burden of Manual Material Handling: Lifting and Logistics*

Manual material handling in the Nigerian industry is frequently characterised by "grossly un-ergonomic" conditions. Our field study across six small-scale industries (Ayodeji *et al.*, 2015b) found that 51% of workers rated their tasks as "Hard," with an average load of 32kg that significantly exceeded the NIOSH standard of 23kg. These stresses are primary drivers of shoulder tendinitis, spinal kyphosis, and lordosis. This ergonomic neglect extends to the healthcare sector. In our evaluation of hospital meal carts in Southwestern Nigeria, we found that these manual carts frequently fail to comply with regional anthropometric data. The resulting physical fatigue does not merely cause pain; it leads to a “transfer of aggression” from exhausted health workers to the patients in their care, demonstrating that poor ergonomic design has direct social and medical consequences. Ayodeji (2019) therefore designed an automated over-bed hospital meal cart for public hospitals (Figure 12).

***Figure 12: Hospital meal carts: (a) Cupboard Type Hospital Meal Cart; (b) over-bed meal table***

### *4.1.8 Precision in the Textile Industry: The Ergonomic Sewing Chair*

In the garment industry, prolonged static posture leads to chronic pain and declining productivity. At Rivatex East Africa Limited, we redesigned the sewing chair by incorporating anthropometric data from 100 Kenyan workers. 5th-percentile seat height and depth to accommodate shorter workers, and the 95th-percentile width to ensure inclusivity for all body types was used, as shown in Table 2. By reducing the seat height mismatch from 63% to 33%, we ensure that even the smallest workers maintain a healthy posture, directly enhancing both worker longevity and industrial output (Esmaeel *et al.*, 2025a, b).

**Table 2:** Anthropometry Data used for the redesigned sewing Chair

| Dimension | Existing Design (Mismatch) | Proposed Redesign Dimensions |
|---|---|---|
| Seat Height (5th % PHS) | 63% Mismatch | 41.65 cm (33% Mismatch) |
| Seat Depth (5th % BPL) | 81% Mismatch | 46.20 cm (21% Mismatch) |
| Seat Width (95th % HBS + 15%) | 79% Mismatch | 47.78 cm (67% Mismatch) |
| Backrest Height (Upper) | N/A | 49.50 cm |
| Armrest Height (5th % EHS) | N/A | 13.25 cm |

### *4.1.9 Innovation in Health Monitoring: The BMI Measuring Device*

As a preventative tool within the Helix One framework, Adeyeri *et al.* (2023) patented (Patent number: F/PT/NC/2023/9210) an Android-deployable "Hip-Waist Circumference Ratio and Body Mass Index Measuring Device (Figure 13). By integrating health monitoring into mobile technology, we empower industrial managers to identify workers at high risk for MSDs before clinical injury occurs, shifting the industrial safety paradigm from reactive treatment to proactive vigilance. This device is only awaiting sponsorship for commercialisation so that it can be mass-produced for the benefit of the populace.

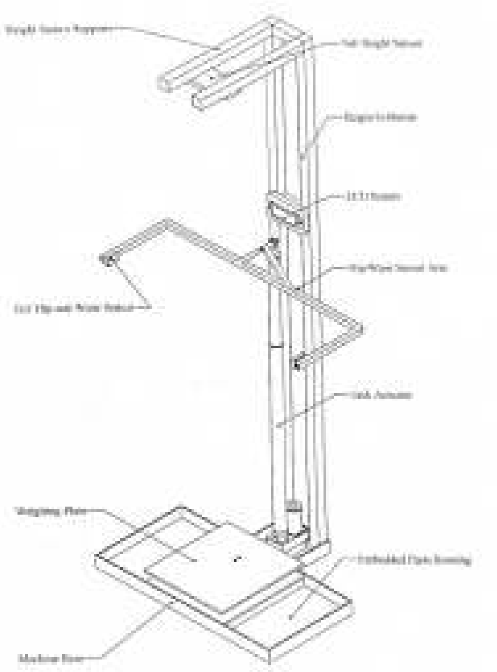


***Figure 13: Android-deployable "Hip-Waist Circumference Ratio and Body Mass Index Measuring Device***

### *4.1.10 The Vibration Frontier: Earthmoving Equipment and Monitoring Accuracy*

The operation of heavy machinery introduces a dynamic hazard: Whole-Body Vibration (WBV). Adherence to ISO 2631-1 standards is essential to protect operators from the debilitating effects of vibration-induced Low Back Pain (LBP).

**Assessing Whole-Body Vibration (WBV) in Operators:**
A dangerous trend has emerged: the use of low-cost consumer smartphone apps for formal WBV evaluation. Our research (Akinnuli *et al.*, 2017; Akinnuli *et al.*, 2018) compared the LIS331DLH consumer accelerometer against the GCDC X16-4 standard tri-axial data logger.

While consumer devices can detect when an operator enters the Health Guidance Caution Zone (HGCZ) (0.47 m/s² to 0.93 m/s²), they lack the precision required for formal safety certification.

The inaccuracy of these apps carries significant legal and medical liability. Should a firm utilise a smartphone app to declare a workspace "safe"? At the same time, a calibrated G-Force logger would reveal exposures in the danger zone, for which the firm is liable for the resulting musculoskeletal damage. Consequently, the use of phone apps for formal industrial evaluation is strictly prohibited; we recommend standard tri-axial loggers to ensure the operator's biomechanical safety. Madam Vice-Chancellor, the findings presented today confirm that the Helix One philosophy is the bedrock of a modern, inclusive industrial future. I have demonstrated that integrating indigenous anthropometric data enables us to engineer assistive technologies that restore independence, industrial equipment that protects the spine, and monitoring systems that accurately safeguard workers from vibration.

## 4.2 Manufacturing - Helix Two

### *4.2.1 Agro-Allied Innovation and National Food Security*

#### *4.2.1.1 The Strategic Imperative of Agro-Industrial Transition*

Madam Vice-Chancellor, distinguished colleagues, and guests, it is a profound honour to present this discourse on the technological pivot required for our national survival. We stand at a crossroads where the transition from subsistence agriculture to an automated industrial model is no longer a choice but a strategic imperative. For decades, our progress as a nation has been stifled by what my colleagues and I identified as "manual and strenuous methods of computation" (Adeyeri & Ayodeji, 2013). This manual drudgery is not merely an inconvenience; it represents a fundamental systemic failure. Manual computation results in a “limited system” error, which prevents the interchangeability of machine parts. Without interchangeability, a national manufacturing industry cannot scale; we remain locked in a cycle of village-level workshops rather than industrial giants.

By replacing these antiquated methods with automated systems, we fundamentally alter the state’s hygiene, quality, and economic resilience. This shift ensures that our agricultural output meets global standards, transforming farming from a struggle for survival into a high-productivity industrial engine. Permit me, Madam Vice-Chancellor, to detail the mechanical architecture of the flagship systems my team and I have pioneered to realise this vision.

#### *4.2.1.2 The Plantain Value Chain: A Flagship Innovation in Food Security*

The plantain (*Musa paradisiaca*) is a cornerstone of Nigerian nutrition, ranking third only to yams and cassava in importance for national food security. Beyond its role as a staple, it is a critical medical resource. Our research has highlighted its role in the management of Type-2 diabetes due to its low glycemic index (Ayodeji, 2016), and further, its integration into “soya-musa” formulations for the treatment of kwashiorkor. Despite this potential, the fruit’s high perishability leads to significant post-harvest losses. To combat this, my team developed the Automated Process Plant for Plantain Flour Production, an invention that has since been patented with the Federal Ministry of Industry, Trade and Investment, Abuja, Nigeria, with patent certificate number: 013249 and Patent Number NG/PT/NC/2023/9211 (Figures 14, 15 and 16) (Adeyeri *et al.* 2020a; Olutomilola *et al.,* 2020b,c; Olutomilola *et al.,* 2021a, b; Olutomilola *et al.*, 2022).
The constituent machines of this plant are designed with surgical engineering precision:

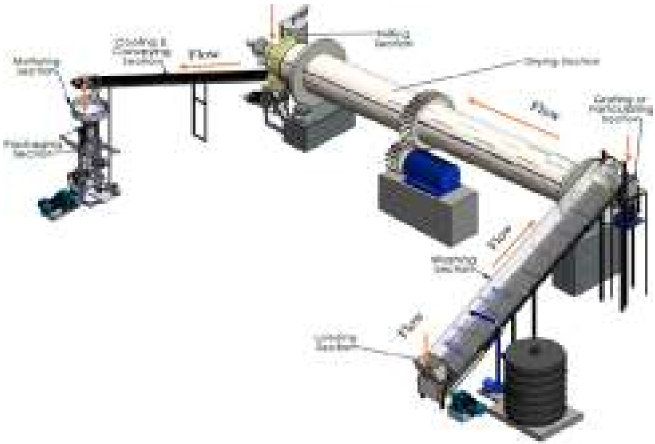



*Figure 14: Isometric View of the designed Plantain Process Plant*

*Figure 15: The Developed Plantain Process Plant*

**Washing & Slicing:** To ensure industrial-grade hygiene, we utilised a perforated conveyor belt system. Unlike traditional methods, this system uses cam-shaped rollers that deliver deliberate "jerks" to the plantain pulp. These jerks turn the fruit as it passes under high-pressure sprinklers, while the perforated belt allows for immediate drainage, ensuring every surface is decontaminated. The slicing mechanism employs a shear-cutting principle, using stainless steel blades perpen-


***Figure 16: From raw Plantain to flour***

dicular to a rotating shaft to ensure uniform dimensions, a prerequisite for even drying.

**The Drying Mechanism:** Precision temperature control is vital to prevent nutrient loss and "case hardening." Our system utilises a carousel tray mechanism within a chamber heated by 1200W zinc heating coils. Integrated circulation blowers maintain a strictly forced convection environment, keeping temperatures between 60°C and 70°C. This ensures we reduce moisture to the required 10% level without degrading the flour's medicinal properties.

**Milling & Sieving:** The final stage employs a hammer mill for pulverisation. To ensure the product is ready for international markets, we use particle shape analysis, specifically the Coefficient of Uniformity, to verify consistent grain-size distribution and fineness.

Madam Vice-Chancellor, it was the development of this specific plant that earned our team the 2022 Nigeria Prize for Science from Nigeria Liquified Natural Gas (NLNG), which was presented by the former President of the Federal Republic of Nigeria, Chief Olusegun Obasanjo on behalf of NLNG (Figure 17). This award validates our vision to



***Figure 17: NLNG 2022 Nigeria Prize for Science Award***

bridge the gap between mechanical engineering and national nutritional sovereignty. My team is working diligently to commercialise this patented invention with the Federal Ministry of Industry, Trade and Investment, Abuja, Nigeria, with patent certificate number: 013249 and Patent Number NG/PT/NC/2023/9211. However, our commitment to agricultural diversification extends beyond plantain.

#### *4.2.1.3 Diversification of Agricultural Processing: Vegetables and Indigenous Crops*

To prevent post-harvest losses that plague our rural farmers, processing of the entire Nigerian flora must be standardised (Ayodeji *et al,* 2020). My team has extended our automated framework to high-value vegetables and traditional crops that define our cultural and economic landscape.

a. Vegetable, Moringa, and Roselle Tea Processing

Our innovations in the pulverising and packaging of vegetable powders represent a transition to commercial-scale distribution. We engineered a vegetable pulveriser with a shaft speed of 900 rpm, seamlessly integrated into a packaging unit with a capacity of 30.3 tons/hr. This scale enables the commercialisation of indigenous vegetables, which were previously limited to local markets (Figure 18) (Ayodeji *et al.,* 2020; Adeyeri *et al.*, 2018; Ojo *et al.*, 2022; Ojo *et al.*, 2024).

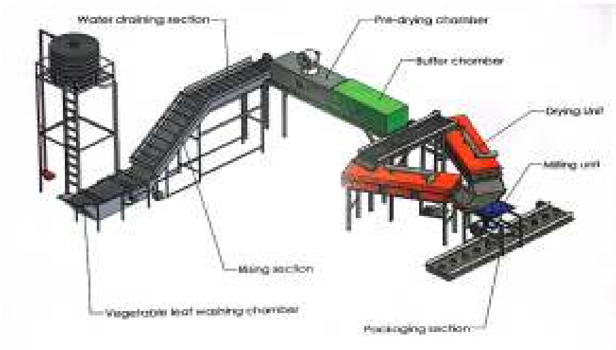



***Figure 18: Assembly View of Vegetable Leaf Process Plant***

Furthermore, for the Roselle tea processing plant, we advanced to high-level automation by designing a 4-degree-of-freedom (DOF) robotic arm (Figure 19) to manage particulate movement along the production line (Ayodeji *et al.*, 2016).

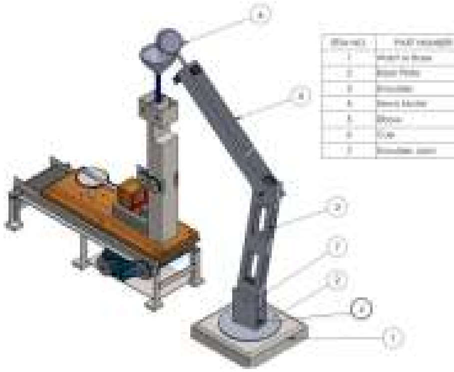


***Figure 19: Isometric view of robotic arm with roselle form fill sealing machine***

b. Indigenous Crops Portfolio

Our "Indigenous Crops" portfolio addresses the complexities of traditional staples through modern mechanics:

**Poundo Yam:** Ayodeji *et al.* (2012) designed a process plant for the production of poundo yam (Figure 20), coupled with sophisticated control systems, to produce instant yam flour, removing the physical drudgery from one of our most labour-intensive foods (Ayodeji & Abioye, 2011; Ayodeji *et al*., 2012; Ayodeji *et al*., 2014a; 2014b; Ayodeji *et al*., 2015c; Ayodeji *et al*., 2017b).

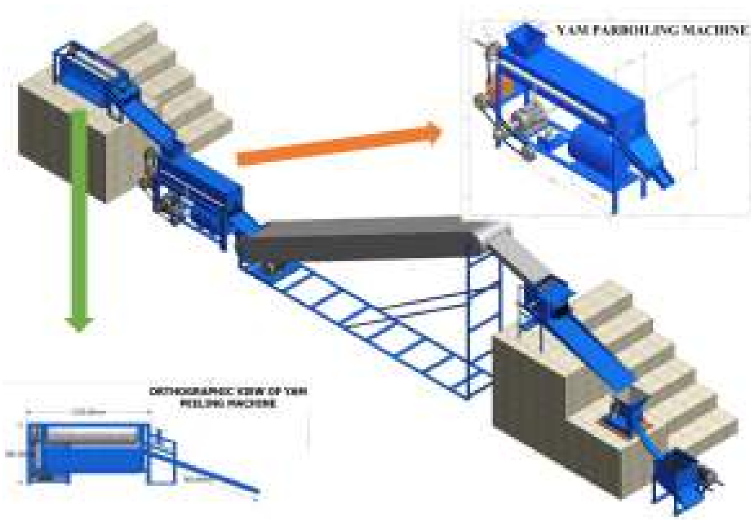



*Figure 20: Processing plant for the production of poundo yam*

**Locust Beans:** Madam Vice-Chancellor, Locust beans were my maternal grandmother's and my mother's business. I sold Locust beans for most of my teenage years, so you will understand my interest in solving problems in this direction. Locust beans are seeds from the pods of the African locust tree, scientifically known as Parkia biglobosa, which belongs to the family Mimosaceae and is mostly found in tropical and subtropical climates. Most parts of the African locust bean are used for food in West Africa, with the seeds being the most prominent. These are fermented and turned into condiments. Fermented locust beans are a common traditional condiment in Nigeria and other West African countries. It is called “iru” in Yoruba land, “dawadawa” in Hausa, “ogiri okpe” in Igbo, and “netetou” in the Gambia. The yellow pulp in the pod is very sweet and also edible. Locust bean seed is a major commodity in West Africa. However, producing the pungent paste is a traditional family craft, although some dried beans are sold in local markets, most are collected and processed by individuals for their own use. An estimated 200,000 tons of locust seeds are collected annually for dawadawa in northern Nigeria alone.

The locust bean seed is usually processed using several methods before being used or consumed. The traditional method of processing locust beans is most prevalent in Africa today and is characterised by the use of crude tools. There are several challenges associated with the traditional processing of locust beans. Some of these challenges include the unavailability of raw materials, the crude method of seed dehulling, water problems, and storage issues. All these challenges led my team to develop effective solutions through the latest technologies and tools to mechanise and automate the processing stages of the raw material. The processing activities usually carried out on locust beans mostly end at the fermentation stage, especially when the processing is traditionally done. At this stage, it is usually used as a solid condiment in cooking.

Therefore, our work further expands the processing scope of locust beans to include the cubing of fermented and ground beans. These cubes are intended to serve as an acceptable, nutritious alternative to conventional condiment cubes, which have been linked to health complications and other negative effects. These are being integrated into our automated processing framework to ensure that nutrient-dense resources can be moved to global markets with their integrity intact (Figure 21).

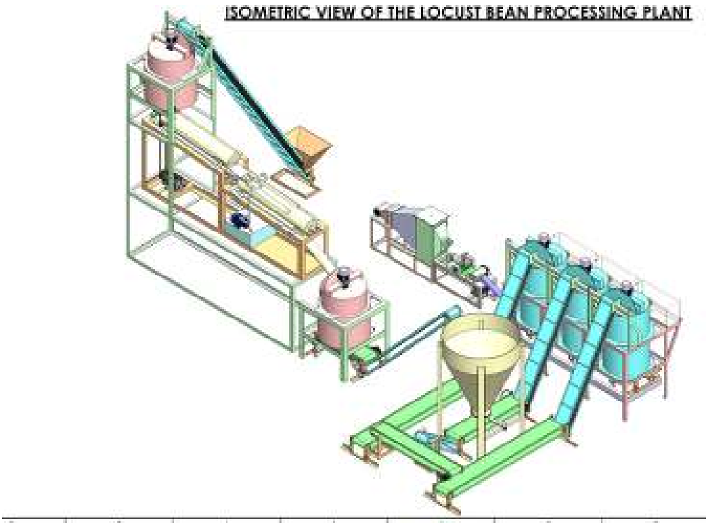



***Figure 21: Isometric View of the Locust beans Processing Plant***

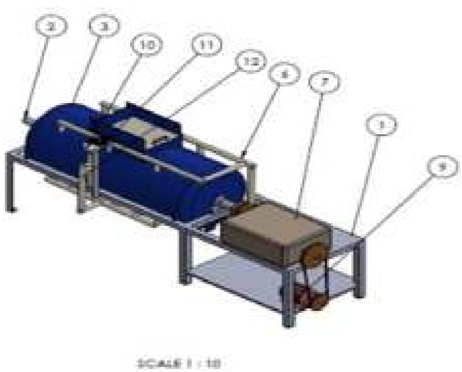
As we optimise these crops, we also look to the circular economy, transforming agricultural waste into value (Ayodeji *et al.* 2025a; Ayodeji *et al.* 2025b).

### 4.2.2 Poultry and Waste-to-Wealth: Pelletized Organic Fertilizer

Madam Vice-Chancellor, industrial engineering provides the tools to close the loop of agricultural production. The conversion of agricultural waste into resources is an economic and environmental necessity.

Our work in converting poultry droppings into pelletized organic fertiliser exemplifies the "Waste-to-Wealth" paradigm.

There are environmental problems associated with raw poultry manure application. As a result, many poultry farm owners have been finding it difficult to cope with the disposal of the dung from their birds. Composting can stabilize the nutrients of poultry dungs turning the organic waste into suitable organic fertilizer. My team designed a poultry dung in-vessel composting machine that will speed up the composting process by constant turning and proper aeration while still maintaining a quality compost output (Figure 22). This process is not merely about waste disposal; it is an environmental mitigation strategy.




| Item No | Part Description |
|---|---|
| 1 | Frame |
| 2 | Shaft Assembly with Paddle |
| 3 | Composter Drum |
| 4 | Bearing |
| 5 | Gear Box Pulley |
| 6 | Water Spray Assembly |
| 7 | Gear Box |
| 8 | Big Pulley |
| 9 | Motor |
| 10 | Air Duct |
| 11 | Fan |
| 12 | Air Manifold |
| 13 | Gear Box Belt |

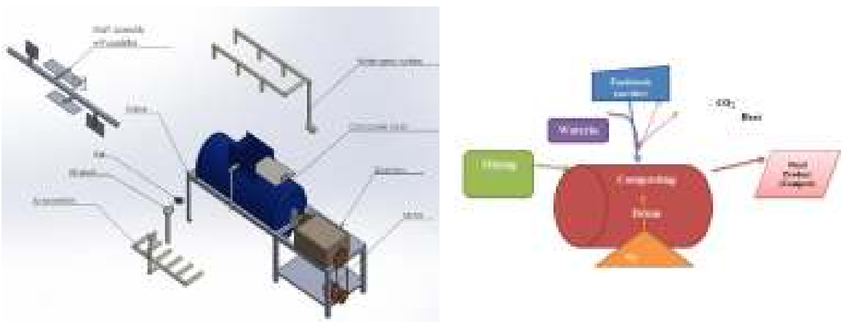


*Figure 22: Designed Poultry Dung in-vessel Composting Machine*

By pelletizing droppings, we reduce pathogen risks and environmental hazards while simultaneously creating a low-cost, nutrient-rich input for our farmers. This circular approach ensures that every byproduct of the agro-allied industry contributes to restoring soil fertility and driving national economic growth (Adeyeri, 2016)

#### *4.2.3 The Technical Foundation: Precision, Reliability, and Human Factors*

The visible machinery of the agro-industrial transition rests upon what can be called the "Invisible Pillars" of manufacturing: precision engineering, material integrity, and the protection of our workforce.

**Technical Optimizations**

Our research has focused on the mathematical and computational foundations that ensure these machines remain operational in harsh environments:

***Precision Engineering:*** Visual Basic 6.0 software has been utilised to solve the complex problems of "Limits and Fits." This is the solution to the historical "drudgery" of manual computation. By automating these calculations, absolute interchangeability of parts is ensured, a requirement for the mass production and maintenance of agricultural machinery across the federation (Adeyeri & Ayodeji, 2013c).

***Material Integrity:*** To ensure our processing machinery can withstand the abrasive nature of organic materials, carbonitriding of steels in cyanide salt baths was worked on. Specifically, Ceconstant-80 salt was used, maintaining a precise 50:50 NaCN:KCN ratio. This balanced concentrate enhances the simultaneous release of carbon and nitrogen, providing the surface hardness and wear resistance required for industrial longevity (Ayodeji *et al*., 2011).

***System Stability:*** Nigerian manufacturing often faces "Random Disruptions." Our production-scheduling simulation models account for machine breakdowns, power failures, material unavailability, and employee absenteeism (Ikome *et al.,* 2015a; 2015b; Ikome *et al*., 2016). By modelling these disruptions, system instability can be minimised, and production targets met despite volatile conditions. Modelling of facility layout improvement, breakeven point forecast and comparative analysis of static and dynamic layouts design for agro processing was carried out to ensure sustainability of the developed system (Adeyeri, *et al*., 2021; Adeyeri & Ayodeji, 2022)

## 4.3 Technology (Automation, Robotics, and AI) - Helix Three

### *4.3.1 The Strategic Imperative: Bridging Mechanisation and Digitisation*

Madam Vice-Chancellor, it is with a profound sense of academic responsibility and a vision for our nation's industrial future that I present the technological underpinnings of our transition from a mechanised past to a digitised future. For decades, the backbone of our indigenous manufacturing has been hindered by manual processes that are not only "strenuous and non-hygienic" but also fundamentally limited in their scalability. My team has dedicated our research to a critical strategic imperative: replacing human drudgery with intelligent, autonomous systems. This shift is not merely an academic exercise; it is the prerequisite for industrial sustainability and global competitiveness in the era of the Fourth Industrial Revolution. We seek to move beyond merely replacing muscle with motors; we explored the infusion of intelligence into the fabric of production. As we transition from this broad vision of digitisation, the physical embodiment of this intelligence must first be analysed, the mechanical implementation of robotic precision within our local agricultural and manufacturing sectors.

#### *4.3.2 Robotics and Intelligent Systems: Precision in Agricultural Processing*

The modernisation of the agricultural value chain requires more than basic automation; it demands intelligent motion control. My research has focused on the development and finite element analysis of 4- and 5-degrees-of-freedom (DOF) robotic arms, specifically optimised for the processing of local crops such as Roselle Tea (*Hibiscus sabdariffa L.*). In our simulations and physical modelling of the Roselle Tea process plant, we used 4-DOF robotic arms with an aluminium-framed arm to ensure both agility and structural integrity (Ayodeji *et al.*, 2016b; 2016c; Adeyeri *et al.*, 2017). The "So What?" factor of this research extends beyond simple automation. Through the optimisation of forward and inverse kinematics, we have engineered systems that maintain stability under significant operational loads.

Our analysis confirms that the aluminium-framed arm, with a total mass of 33.1 kg and a reach height of 1850 mm, remains rigid and stable while experiencing a maximum equivalent stress of and a displacement of only 2.796 mm. This precision facilitates the transition from manual sealing, which is inherently energy-intensive and emits environmental pollutants, to an automated form-fill sealing system. Utilising a control circuit developed for the PIC16F series microcontrollers, a throughput of 25 packs per minute was achieved (Table 3). Crucially, the power circuit design ensures system stability within the typical 190–240V AC supply range found in our local infrastructure (Ayodeji *et al.*, 2017).

The mechanical precision of these robotic systems provides the physical framework, but the underlying logic of Artificial Intelligence modernises the indigenous production line into a data-driven enterprise

**Table 3:** Comparison between Manual Processing and Automated Robotic Integration

| **Feature** | **Manual Processing** | **Automated Robotic Integration** | **Technical Mechanism** |
|---|---|---|---|
| Productivity | Low; limited by human fatigue | High; 25 packs per minute throughput | PIC16F series microcontroller logic |
| Hygiene | Low; frequent human contact | High; hermetic form-fill-sealing | Automated crank-slider mechanism |
| Structural Integrity | Subjective/ Variable | High; verified at stress | Finite Element Analysis (FEA) |
| Operational Range | Limited by reach and stamina | 1850 mm reach; 33.1 kg mass frame | 4 DOF Kinematic Optimisation |
| Electrical Stability | N/A | High; stable within 190–240V range | Voltage regulator & relay isolation |

#### *4.3.3 Artificial Intelligence in Manufacturing: Modernising Indigenous Production*

Artificial Intelligence (AI) serves as the bridge between traditional mechanisation and the modern smart factory. It is my submission, Madam Vice-Chancellor, that the bridge between our traditional heritage and the fourth industrial revolution is paved with the predictive logic of AI. By applying computer-aided predictive models to indigenous processes, such as leather cutting and locust bean processing, we can transform guesswork into mathematical certainty.

A primary baseline for this transition is our research into cocoa bean processing. We developed a mathematical model and algorithm that achieved 95.71% accuracy in predicting cocoa butter and cake yields (Akinnuli *et al*., 2014). This efficiency is not merely a number; it is a template for digitising any indigenous crop. By identifying parameters such as foreign material mass, shell-removal ratios, and liquor waste, we can develop predictive templates for materials such as locust beans and leather. Furthermore, integrating CAD/CAM software reduces industrial expenses by optimising material storage and inventory management. This evolution from "mechanisation to digitisation" transforms our local manufacturing from isolated tasks into a cohesive, data-driven industrial base.

#### *4.3.4 Smart Maintenance and Monitoring: The Patented Safeguards of Infrastructure*

Madam Vice-Chancellor, as we deploy these intelligent systems, we must also ensure the stability of the infrastructure that supports them. Technological progress is precarious without a foundation of smart maintenance and patented safeguards. My contributions in this area focus on protecting both machinery and national infrastructure assets.

To prevent catastrophic failure of industrial flooring and adjacent structures, we developed a "Dashpot" vibration-isolation system for machines with masses ranging from 40kg to 2000kg (Adeyeri *et al*., 2011). Through virtual engineering and simulation, we demonstrated how these systems absorb mechanical energy, preventing floor cracking and building collapse that are often associated with heavy grinding and milling operations. In the food processing context, we successfully integrated Programmable Logic Controller (PLC) systems into Poundo Yam facilities. This automation collapsed the production process from eight manual steps to just two, resulting in a 75% reduction in human involvement and significantly higher hygiene standards (Ayodeji *et al*., 2015).

Beyond the factory floor, our work on Monitoring System for the Torqueing of Bolts and Nuts on a Telecommunication Mast, patented with the Federal Ministry of Industry, Trade and Investment, Abuja, Nigeria, with Patent Number NG/PT/NC/O/2024/14194 (Figures 23 and 24) is vital to the stability of national telecommunication masts, ensuring that our digitised economy remains connected and resilient.

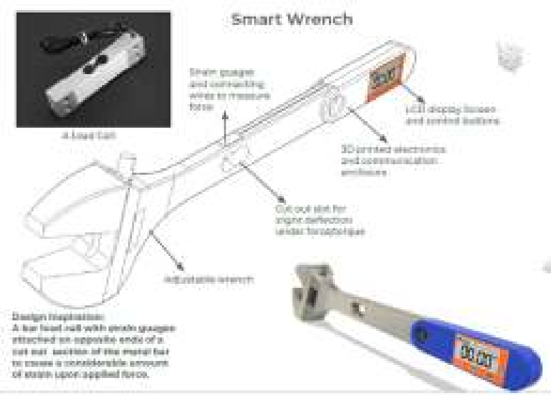



***Figure 23: Annotated Drawing of the Torqueing Wrench***


***Figure 24: Monitoring System for the Torqueing of Bolts and Nuts on a Telecommunication Mast***

## 4.4 Energy Consumption Optimisation: Sustaining the Industrial Future

Energy usage is the primary driver of production costs and, by extension, industrial sustainability. In our plantain flour processing facility, we have demonstrated that automation is the key to energy conservation through:

*Direct Energy Reduction:* Our automated process control saved 30% more energy compared to manual operation by precisely modulating heaters and motors based on real-time demand (Adeyeri & Ayodeji *et al.*, 2022).

*Precision Timing:* Utilising a modular Arduino Mega 2586 control system, we achieved a system response time of 30 milliseconds. This rapid response ensures motors and heaters are energised only when product presence is detected.

*Multi-Stage Thermal Control:* The system facilitates multi-stage drying between 0°C-150°C, optimising the thermal energy required for different moisture levels and agricultural products.

*Sensing Logic and Operational Certainty:* This "sensing logic" is the same principle applied in our research on Simultaneous Localisation and Mapping (SLAM) for Autonomous Underwater Vehicles (AUVs). By using corner feature extraction to navigate structured environments, reducing operational uncertainty (Matsebe *et al.,* 2013). Whether in an underwater environment or a plantain-drying chamber, feature extraction (from analogue sensor readings or corner features) is essential for reducing waste and maximising efficiency.

Madam Vice-Chancellor, these advancements in energy optimisation ensure that our technological solutions are not only innovative but also sustainable over the long term. The technical contributions I have detailed today, spanning from the kinematic optimisation of aluminium robotic arms to the 95.71% efficient AI yield prediction models, represent the realisation of a modernised, indigenous industrial base. I have bridged the gap from manual, repetitive work to intelligent automation. By integrating patented vibration safeguards, PLC-driven process reduction, and energy-efficient control models, we are building more than machines; we are building national self-reliance. This synthesis of robotics, AI, and smart maintenance is the technological helix that will propel our industrial systems into the global future.

# 5.0 CONCLUSION AND RECOMMENDATIONS

## 5.1 Conclusion

In conclusion, Madam Vice-Chancellor, my team remains steadfast in our mission. We are not merely building machines; we are engineering a nation's resilience. By bridging the gap between subsistence and industrialisation through precision, automation, and human-centred design, we are securing the future of Nigerian food sustainability and economic sovereignty.

Madam Vice-Chancellor, distinguished colleagues, ladies and gentlemen: this lecture has advanced one central claim, manufacturing performance is not won by any single "silver bullet," but by the disciplined alignment of three inseparable strands: the human factor, manufacturing systems, and technology. When these strands are aligned, performance compounds: safety improves, quality stabilises, productivity rises, waste declines, and innovation becomes repeatable. When one strand is weak, when people are overstretched, processes are broken, or technology is misapplied, the entire system loses strength, and investments that should have accelerated progress instead amplify inefficiency.

First, I established why this alignment is urgent. Global manufacturing is increasingly unforgiving: customers demand speed, customisation, sustainability, and near-zero defects, while firms face volatile markets and intense competition. In emerging economies, the pressure is even sharper because SMEs carry the weight of industrial output while operating under constraints, skills gaps, maintenance limitations, unstable infrastructure, and limited capital. In such contexts, *technology-first strategies* often disappoint because they are introduced into systems that have not been ergonomically designed, process-stabilised, or socially prepared to absorb change. The practical lesson is clear: technology is an amplifier, not a magician; it magnifies either capability or dysfunction.

Second, I framed the triple helix as a practical engineering model, rooted in sociotechnical systems thinking. Human factors and ergonomics are not “soft add-ons”; they are design requirements that directly translate into fewer errors, less fatigue, safer work, and more reliable output. Manufacturing, understood as an end-to-end system of flow, quality control, reliability, and improvement, provides the operating backbone that prevents automation from simply speeding up waste. Technology, properly selected and human-centred, becomes the force multiplier that scales throughput, improves consistency, and enables modern decision-making, but only when it fits the worker and the workflow.

Third, I demonstrated that this model is not theoretical; it has been expressed in tangible scholarly and practical contributions across the three helices. Helix One showed how indigenous anthropometry, ergonomics, assistive technologies, and workplace biomechanics can restore dignity, prevent injury, and improve performance, proving that design must begin with the real human body and the real work context. Helix Two illustrated how agro-processing and manufacturing system design, plantain, yam, vegetables, and other value chains can convert post-harvest losses into industrial opportunities, linking engineering directly to food security, job creation, and national resilience. Helix Three showed how automation, robotics, AI modelling, and smart maintenance can move production from manual drudgery to controlled, data-driven capability, while insisting that adoption succeeds only when usability, training, maintainability, and infrastructure realities are addressed.

The integrated implication is this: Nigeria's industrial future will not be secured by importing machines alone, or by training alone, or by process improvement alone. It will be secured by making the triple helix the default logic of engineering education, industrial practice, and national policy, so that three questions can judge every intervention: *Does it fit the human? Does it stabilise the process? Does the technology truly amplify value rather than amplify waste?* This is the pathway to sustainable competitiveness, inclusive development, and a manufacturing sector that serves national purpose rather than merely producing output.

## 5.2 Recommendations

*i. Institutionalise the Triple-Helix Standard as a non-negotiable design rule*

Institutions should adopt a simple rule for all improvement projects: Human Factor - Process (Manufacturing) - Technology, in that order. Every new machine, automation, software, or factory upgrade should be made to pass a Triple-Helix ***Readiness Check:***
Human fit (skills, ergonomics, workload, usability, safety),
Process fit (flow, bottlenecks, quality controls, standard work, maintainability),
Technology fit (appropriateness, reliability, integration, lifecycle support).

*ii. Build a Nigerian Anthropometry and Ergonomics Infrastructure*

The government should mandate ergonomic standards that fit the African body and build an industry that respects the human factor. A machine that breaks the person who operates it is not a triumph of engineering, but a failure of design.
The government should establish a living national anthropometric databank, regularly updated across regions, genders, age groups, and

special populations, and make it usable for designers, manufacturers, and regulators.

Regulators and professional bodies should be encouraged to treat ergonomic compliance as a productivity and safety standard, not optional "welfare."

*iii. Make ergonomics a productivity strategy in industry, not just a safety programme*

Manufacturers should be encouraged to run ergonomic Kaizen: redesign tasks, fixtures, and workstations to reduce strain and error, alongside lean waste elimination.

Structured fatigue-risk management (shift design, task rotation, microbreaks, workload balancing) should be introduced by organisations as part of quality assurance, not as an HR afterthought.

Organisations should tie ergonomic improvements to measurable Key Performance Indices (KPIs): defect rate, rework, downtime, injury incidence, near-miss frequency, and throughput stability.

*iv. Prioritise appropriate technology and maintainability as the true definition of "advanced"*

For SMEs and emerging-economy contexts, define "best technology" as the technology that runs reliably in local conditions, not the most complex option on paper.

Design and procure with lifecycle support in mind: spare parts availability, technician skill requirements, power stability, and modularity for repairs.

Promote local fabrication, adaptation, and incremental automation, so that firms can climb the capability ladder sustainably rather than importing fragility.

v. *Strengthen manufacturing systems capability: reliability, quality discipline, and energy realism*

Encourage firms to invest in process stability (standard work, mistake-proofing, statistical thinking, preventive maintenance) before major automation.

Embed energy-aware design in all process plants, especially heat-based agro-processing, so energy use is monitored, controlled, and optimised by design.

Treat maintenance engineering as a strategic function: downtime is not "bad luck"; it is usually the price of weak system design.

vi. *Accelerate responsible digitalisation and AI adoption through human-centred implementation*

Make usability and operator workflow the centre of digital projects: dashboards and controls must be readable, trusted, and actionable at the shop-floor level.

Require a minimum adoption package for digital systems: role-based training, on-the-job support, feedback loops, and iterative interface redesign.

Direct AI use toward predictive quality, yield optimisation, preventive maintenance, and scheduling, with transparency and "human-in-the-loop" decision safeguards.

vii. *Create a FUTA-led translation pipeline from invention to industry*

Establish a Triple-Helix Innovation Hub (or strengthen existing structures) with three functions:

(i) Prototype-to-pilot support (test rigs, pilot plants, validation),

(ii) Commercialisation support (IP, licensing, spin-outs),

(iii) Industry problem-intake (real factory constraints feeding research).

Build "living laboratories" with local manufacturers and agro-processors where solutions are tested under real operating conditions, not only in controlled environments.

viii. *Align funding and procurement with local innovation and measurable impact*

Encourage funding agencies to prioritise deployment grants, not just publication grants, to support pilot installations, field testing, and scale-up.

Recommend that public procurement frameworks include local content requirements, maintainability scoring, and training requirements, so that procurement strengthens national capability rather than creating import dependency.

ix. *Set a forward research agenda that measures real-world outcomes*

Prioritise longitudinal studies that quantify the impact of triple-helix interventions on: productivity stability, injury reduction, quality improvement, energy use, and adoption success.

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# CLOSING

Madam Vice-Chancellor, distinguished colleagues, ladies and gentlemen, the parting message is simple: a nation that wants a competitive industry must develop people, stabilise its processes, and apply technology with wisdom. The enduring lesson of this lecture is that manufacturing excellence is engineered, when the human factor is respected, the production system is stabilised, and technology is applied as a disciplined amplifier of value. If we embed this triple-helix logic into our teaching, research, industrial practice, and policy, we will move from episodic improvement to sustained competitiveness, building factories that are safer, smarter, more productive, and truly fit for purpose. FUTA, industry, and government should adopt the triple helix not as rhetoric but as routine practice, then our machines will last longer, our workers will suffer less, our products will compete better, and our development will be more inclusive and enduring. This is the work before us, and it is the contribution we must collectively deliver. As recorded in 1 Corinthians 15:58: *"Therefore, my beloved brethren, be ye steadfast, unmovable, always abounding in the work of the Lord, forasmuch as ye know that your labour is not in vain in the Lord."* May we continue to make progress in good works as we go.
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