OBAFEMI AWOLOWO UNIVERSITY, ILE-IFE, NIGERIA.

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MAN MINUS MACHINES EQUALS A LABOURER

By

LAWSON OLABOSIPO ADEKOYA
Professor of Mechanical Engineering

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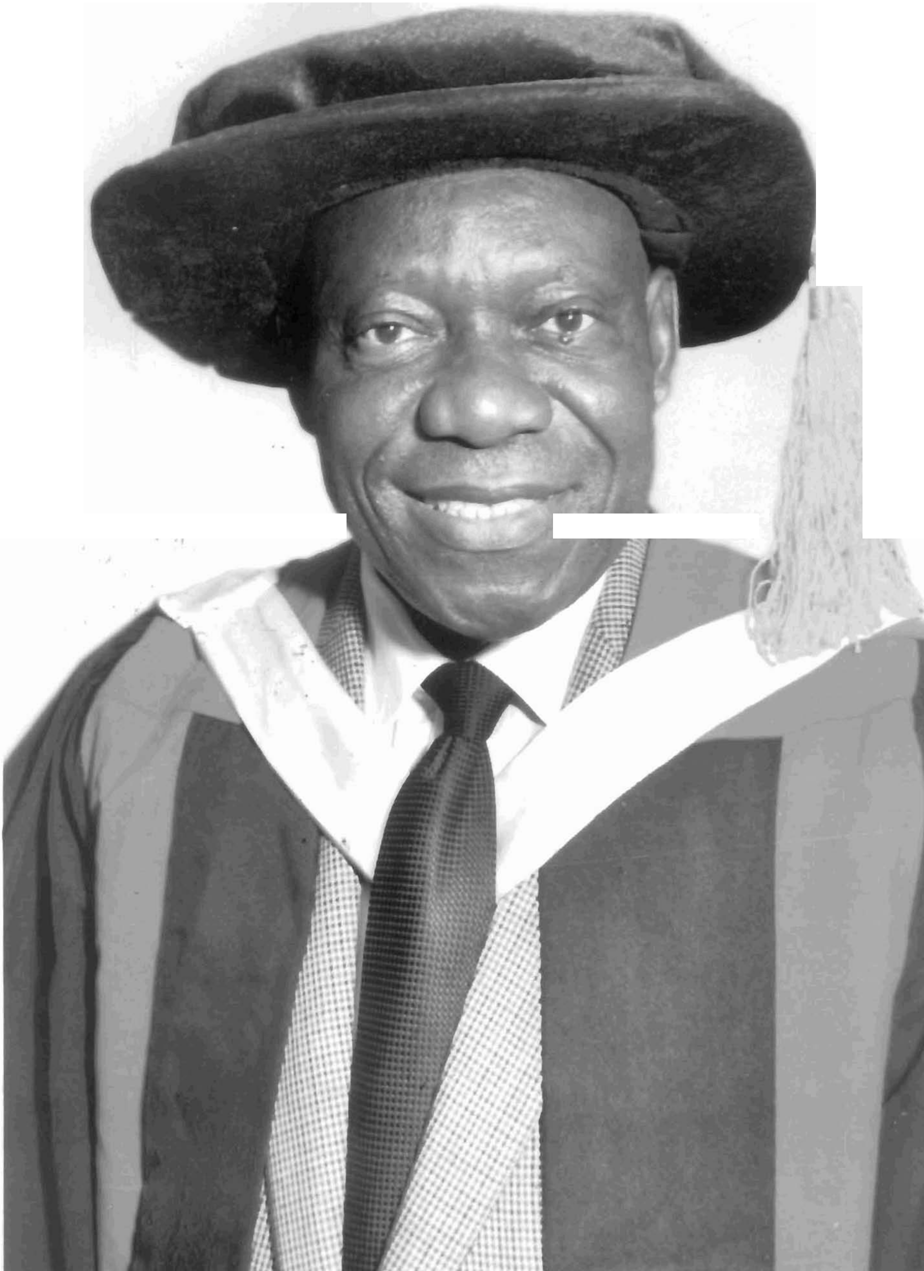

LAWSON OLABOSIPO ADEKOYA
B.Sc. (Ife), MS (California, Davis), Ph.D. (Iowa State)
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An Inaugural Lecture Delivered at Oduduwa Hall, Obafemi Awolowo University, Ile-Ife, on Tuesday 26th August, 2014.

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1. PREAMBLE

Mr. Vice-Chancellor, distinguished guests, ladies and gentlemen, it is with a gladsome heart that I stand before you this afternoon to deliver the 267th Inaugural Lecture of the Obafemi Awolowo University, Ile-Ife. This is the second inaugural lecture to be delivered from the Department of Mechanical Engineering of this great university following the one titled "The Heart, Life, and Soul of Technology" delivered on 12th April 1988 by Prof. O. O. Mojola.

The inaugural lecture of today is to formally inaugurate my 1997 Chair in Mechanical Engineering. Apart from educating the audience on the chosen topic, the lecture will also serve as a chronology of my academic odyssey in the past several years.

Before graduation in 1975, I had secured three appointments with two private companies and a government ministry that were all located in Lagos. After the one-month post-National Youth Service leave in July 1976, I went to the organisations on Monday 2nd August with the aim of starting work. One after the other, they rejected me after being informed of my graduating result. Ironically, all the employers had found me appointable during interviews held before the final-year examinations. They all insisted that "people like you should go back to the university". The only basis for this advice was that I had graduated with a First Class Honours degree in Agricultural Engineering. I was completely devastated by these rejections especially given the fact that I had not planned to take up a university appointment.

In the mean time, most of my contemporaries who had job offers in 1975 had resumed at their duty posts on 2nd August 1976. All the while, the department kept sending messages to me that I was being expected to come and start work and that my colleague, Mr. Obafemi Ajibola (now a retired Professor of Agricultural Engineering), who graduated with a similar result, had already assumed duties in the department. I was clearly in a fix. After staying at home and being unemployed for two weeks, which were as long as eternity then, I had to quickly reappraise my plans. I came to the conclusion that, given the "discrimination" against my class of degree, I was not likely to secure any employment outside the universities!

Based on the standing invitation from the department and the encouragement of my senior brother, Otunba Babatunde Adekoya, I finally reported in the department on 16th August 1976. I submitted a hand-written application, and was instantly offered an appointment as a Graduate Assistant. It was with great trepidation that I assumed duties the same day!

Because I never planned to be in academics, my hidden agenda was to leave the University as soon as possible. However, one thing led to another, and I strongly believe that it is providential that I have been on this job for over 38 years!

2. MAN, MACHINES AND LABOURER

2.1 Man

It had been realised, since time immemorial, that man needed assistance of machines to live a productive life. According to history, the early man lived in existing caves. However, he soon realised that in order to survive, he needed to kill animals for meat, plant and harvest crops and transport self and goods. To achieve these goals, he had to conceive and fabricate simple tools (which in essence are simple machines) from stones and wood. These multiplied his efforts, increased his work rates, and made him mobile. According to an ancient Egyptian legend, man was instructed on how to make agricultural tools by the great god Osiris (Quick and Buchele, 1978). As man developed, his ability to conceive and fabricate tools became more adroit. With time, man developed very sophisticated machines for planting, harvesting, handling and processing crops.

2.2 Machines

Generically, machines can be defined simply as devices used for performing tasks or for doing work. However for the purpose of this inaugural lecture, it is more appropriate to define machines as mechanical devices (usually) with moving parts, that are powered by humans, engines, electricity, etc, and are capable of performing useful work.

Machines play indispensable roles in the life of man. They exist in every facet of human endeavour, namely in sports, mechanised agriculture, food processing, education, medical services, transportation (air, land, and water), military, construction, banking and commerce, home, office, information/entertainment, water supply, and manufacturing, to mention a few. Machines have taken man to the end of the world and to the moon and back.

History is full of accounts of how machines have improved human activities. The Industrial Revolution, a major turning point in the history of man, was the process of change from an agrarian, handicraft economy to one dominated by industry and machine manufacture. This process began in England in the 18th century (from about 1760 to sometime between 1820 and 1840) and within a few decades spread to Western Europe and the United States (Encyclopaedia Britannica, 2014).

The main features involved in the Industrial Revolution were technological, socioeconomic, and cultural. The technological changes included the following: (1) the use of new basic materials, chiefly iron and steel, (2) the use of new energy sources, including both fuels and motive power, such as coal, the steam engine, electricity, petroleum, and the internal-combustion engine, (3) the invention of new machines, such as the spinning jenny and the power loom that permitted increased production with a smaller expenditure of human energy, (4) a new organization of work known as the factory system, which entailed increased division of labour and specialization of function, (5) important developments in transportation and communication, including the steam locomotive, steamship, automobile, airplane, telegraph, and radio, and (6) the increasing application of science to industry. These technological changes made possible a tremendously increased use of natural resources and the mass production of manufactured goods (Encyclopaedia Britannica, 2014).

The worker acquired new and distinctive skills, and his relation to his task shifted. Instead of being a craftsman working with hand tools, he became a machine operator, subject to factory discipline. Finally, there was a psychological change: man's confidence in his ability to use resources and to master nature was heightened.

It is pertinent to note that the development of machines have never been sudden. A typical chronology is in land transportation. Before the invention of the wheel, land transportation was by sledges. The invention of the wheel around 4000 BC marked a significant milestone in the evolution of land transportation. The two-wheeled cart evolved by fitting a pair of wheels to the sledge. Archaeological evidence suggests that the first vehicles were heavy two- or four-wheeled chariots that were pulled by oxen.

The development of light wheels with spokes and the introduction of the horse as the draft animal around 2000 BC was the final step in the evolution of the chariot into a military vehicle that revolutionised warfare in the ancient world by providing armies with unprecedented mobility. In the 14th century the passenger coach, a modified version of the chariot pulled by one horse, began to evolve (Adekoya, 2013).

The transition from horse-drawn carriages to the horseless carriage was not achieved until 1769 when Nicholas-Joseph Cugnot (1725-1804) invented a heavy, three-wheeled, steam-powered, clumsy vehicle. The vehicle was slow, ponderous, and moved by fits and starts. In tests, it carried four passengers at a slow speed of a little over 3.2 km/h and had to stop every 20 minutes to build a fresh head of steam.

The direct progenitor of the modern car is based on a patent obtained in 1886 by Carl Benz (1844-1929) for his invention titled "a carriage with petrol engine". This patent was based on a fragile, carriage-like, three-wheeler with tubular framework, mounted on a 0.75 kW (1 hp), one-cylinder engine. Even though Benz's creation was awkward and frail, it incorporated some essential elements that characterise the modern car, namely: electric ignition, differential, mechanical valves, carburettor, engine cooling system, oil and grease cups for lubrication, and a braking system (Adekoya, 2013). The Benz Velo (Plate 1) was a four-wheel commercial version of the invention and was produced by Benz's company from 1886-1893 (Wikipedia, 2014).

As the years rolled by, many inventions were incorporated in the car such that by 1929 the modern car was "mechanically complete". The car we drive today was developed bit by bit from the ideas, imaginations, fantasies, and tinkering of hundreds of individuals through hundreds of years (Table 1). It is estimated that over 100,000 patents created the modern car (Adekoya, 2013).

Worldwide, cars have remained the major means by which individuals go to work, go shopping, and go visiting friends and relatives. Even in places with highly organised public transportation services, cars have made it possible for people to live lives independent of rail, bus, and air schedules. Cars have therefore become a necessity of life in contemporary living.

Table 1: Landmark dates in the development of the modern car

S/N	Date	Invention incorporated in the car
1	1769	The first horseless carriage
2	1876	The Otto engine
3	1886	A patent for "a carriage with petrol engine"
4	1894	Front-mounted engine under the bonnet
5	1903	Enclosed car and glass windscreen
6	1904	Steering wheels in place of tillers
7	1906	Built-in baggage compartment
8	1908	The first rumble seat
9	1909	Compressed air self-starter
10	1911	Electric self-starter and electric headlights
11	1912	Perfection of the electric self-starter of today by Samuel Kettering
12	1914	Opening of the world's first car assembly line by Henry Ford
13	1916	Something for women: vanity cases, clocks, crystal flower vases, etc
14	1917	Introduction of car heaters
15	1920	Pneumatic tyres
16	1922	Reverse lights
17	1925	Car rental service
18	1926	Shock-proof glass
19	1927	Chrome trim
20	1929	"Mechanically complete" modern car
21	1930	Front-wheel drive
22	1931	Sun visor for the car interior
23	1933	Independent front suspension
24	1936	First diesel-engine car (a Mercedes Benz)
25	1937	Moving of batteries to a new position under the bonnet
26	1938	Turn signals
27	1940s	Sealed-beam headlights, tubeless tyres, and automatic transmission
28	1950s	Air-conditioning, electrically-operated car windows, and seat adiusters
29	1970s	Catalytic converters
30	1980s	Digital speedometers, electronic prompts, and monitoring on-board computers
31	1990s	Computer-control of car sub-systems: engine, air-conditioning, etc
32	2000s	Rotating headlights, hybrid engines, internet-based tracking systems, etc

2.3 Labourer

A labourer is a person whose job involves hard physical strength and stamina (Oxford University Press, 2009). From the same dictionary, stamina is defined as enduring physical or mental energy and strength that allows somebody to do something for a long period of time. According to Makanjuola (1977), man as a source of continuous power can work at a rate of not greater than 0.1 kW. This is not enough to cope with the really difficult jobs and cannot be sustained for long periods. By comparison, a small machine powered by a 0.1 kW electric motor will work continuously for several hours provided it is powered and well-maintained. Therefore, without machines, man can labour for only short durations, after which he will tire.

2.4 Man Minus Machines

Machines have become an integral part of our daily routines and in the process transformed our lives. Machines are used for farming, for life-support services in hospitals, and general processing of foods. They are used for manufacturing durable consumer goods such as cars, hand tools, washing machines, etc; industrial goods such machine tools, robots, etc; and consumables such as paper, soaps, toothpastes, tissues, etc. Cars, buses, boats, ships, trains and airplanes have been taken for granted as transportation machines. Without them, travelling will be unimaginable. Hazardous tasks that cannot even be done by man are doable by machines such as industrial robots. Without machines, simple chores become laborious and the very difficult tasks become humanly impossible!

From the foregoing, it is apparent that without machines, man will labour a lot but will achieve only a little, and that life will be very tough, if not outright impossible!

Mr. Vice-Chancellor, distinguished guests, ladies and gentlemen, I therefore hereby submit "mathematically" that:

(Man) – (Machines) = (Labourer).. (1)

This is the topic of my inaugural lecture which in prose form can be written as "Man minus machines equals a labourer".

However, for man to effectively and efficiently carry out tasks, he needs the right or appropriate machines. The qualities of the right or appropriate machines include affordability, safety, reliability, ease of maintenance, aesthetics, adequate strength, efficient performance, ease of operation and user-friendly technology, to mention a few. These qualities imply that the machines needed to have been properly designed, perfectly manufactured, and diligently managed (that is operated and maintained).

2.5 Machine Design, Manufacture and Management

2.5.1 Introduction

The engineering activities that produce every machine are design and manufacture. Engineering design is the process by which an engineer applies his knowledge, skills and point-of-view to the creation of functional, economical and otherwise satisfactory solutions to given real-life problems in accordance with some codes or standards. It is the central activity in the practice of engineering. It is one of the qualities that differentiate the engineer from other members of the engineering family! For the benefit of the general audience, the engineering family consists of engineers, technologists, technicians and craftsmen/artisans.

2.5.2 Machine Design

Machine design is a subset of engineering design. The classical machine design methodology consists of the following phases: recognition of need, problem formulation, creative design, preliminary design and development, detailed design, prototype building and testing, design for production and product release.

The creative design phase is perhaps the most challenging and interesting part of the design process. This is because it is at this stage that the engineer comes up with as many alternative solutions as possible to a given problem. The synthesis of various new and/or old ideas and concepts takes place in such a way as to produce an overall new idea or concept of solving the current problem.

One of the solutions generated in the creative design phase is then selected as *the* solution to be developed further. The bases of making this decision are many and varied. The techniques used include decision matrix, probability theory, optimisation technique, etc. The prototype building and testing phase normally ends the machine development process in a university research setting.

2.5.3 Design for Manufacture

In order to commercialise the machine, further work needs to be done in the form of design for development. This involves design changes that would be compatible with the best and often the most economical methods of production, and the selection of the best materials. This process is called value analysis and is normally carried out outside of the university environment by companies that intend to commercialise the machine. Product release, which is the commercial marketing of the machine, follows the manufacture.

2.5.4 Machine Manufacture

Machines are made by manufacturing and assembling the components or parts of the machine. The components are made from a variety of materials by different manufacturing methods. For example, a typical family car is assembled from about 15,000 parts. Of this number, 1,500 are synchronised to move together, many of them working within tolerances as small as 2.54×10^{-3}mm. Nearly 60 different materials, from cardboard, plastic, and rubber to platinum, are used in a car's construction (The Reader's Digest Association, 1981). A C-5A transport plane consists of more than 4 million parts, and a Boeing 747-400 has 6 million parts (Kalpakjian, 1997). It is noteworthy that each part of every machine is individually designed and manufactured.

2.5.5 Product Liability

Simply put, product liability is the legal term used to describe an action in which an injured party (plaintiff) seeks to recover damages for personal injury or loss of property from a seller (defendant) when it is alleged that the injuries resulted from a defective product. The term has also been used when a consumer or business enterprise has suffered commercial loss owing to the breakdown or inadequate performance of a product (Weinstein, *et al*, 1978).

In most instances, an action based on products liability requires the establishment of a defect in the product. Product defects arise from two sources. The first and most basic is production or manufacturing defect. This is a defect arising from an error occurring during the manufacture of the product. The classic example is the soft drink bottle that explodes as a result of either an imperfection in the glass structure of the bottle or of over-carbonisation. In other words, a production defect arises when a product does not meet the manufacturer's own standards for that product. This would presume that products that meet the manufacturer's standards are not defective, at least from the viewpoint of the manufacturer.

The second type of product defect is called design defect. It occurs when a product that meets the manufacturer's own standards does cause an injury, and it is alleged by the plaintiff that the design or the manufacturer's standards were inferior and should be judged defective.

The following three basic legal principles can be used as the framework within which the plaintiff can bring an action in product liability: (i) Negligence: This principle tests the conduct of the defendant in the saga, (ii) Strict liability and implied warranty: This combined principle tests the quality of the product, and (iii) Express warranty and misrepresentation: This combined principle tests the performance of the product against the explicit representations made on its behalf by the manufacturer and sellers.

As if to make life more difficult for the design/production engineer (and his employer), courts have developed evidentiary rules to assist the plaintiff in proving his case in certain situations where it has been difficult to prove negligence of the manufacturer. The most significant of these rules is the doctrine of *res ipsa loquitor,* which literarily means "the thing speaks for itself". This is a rule of evidence that allows that the mere proof that an injury occurred establishes a presumption of negligence on the part of the defendant! (Weinstein, *et al,* 1978). Thus, the fear of product liability has become the beginning of wisdom for design/production engineers.

2.5.6 Machine Management

Machine management is the operation and maintenance of machines. The best machine in this world will malfunction if it is not correctly operated and/or properly and regularly maintained. Machine maintenance is the keeping of the machine in a specified operating condition or restoration of the machine to operational status after a breakdown, accident or wear.

The major objectives of machine maintenance are:

i. To extend the useful life of the machine.

ii. To assure the optimum availability of the machine for service or production and obtain maximum possible return on investment.

iii. To ensure the safety of users/operators of the machine.

Machine maintenance can be conveniently divided into three major types: improvement, preventive and corrective maintenance. Preventive maintenance can be further sub-divided as shown in Figure 1.

Mr. Vice-Chancellor, kindly permit me to use this forum to correct a wrong notion about Nigerians. It is often said that Nigerians have no maintenance culture! This is a fallacious statement. From research, it has been established that Nigerians use their machines (and facilities) until they break down, at which point repair is carried out (Adekoya and Otono, 1990).

It can therefore be posited that Nigerians practice corrective (or repair or breakdown) maintenance, which in any case is a form of maintenance. Thus, Nigerians have a maintenance culture! It is

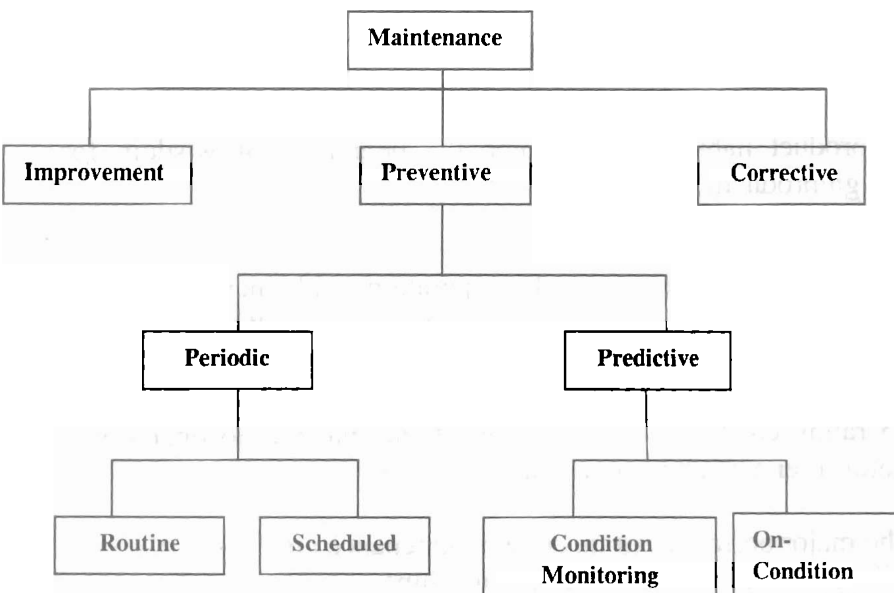

Figure1: Types of maintenance

breakdown maintenance culture. Honestly, this is not the best type of maintenance culture. That notwithstanding, Nigerians should correctly be said to have poor maintenance culture!

Based on works carried out on the subject by Adekoya and Otono (1990) and Adekoya and Hart (1997), it is recommended that Nigerians should practice preventive maintenance. The advantages of preventive maintenance include (1) prevention of breakdown at inopportune times, (2) prevention of injuries to users/operators, and (3) lowered cost of carrying out maintenance.

3.0 MY CONTRIBUTIONS TO MACHINE DEVELOPMENT AND MANAGEMENT

3.1 Introduction

My research focus has been in Machine Development and Management. Machine Development consists of Machine Design, Production and Testing while Machine Management consists of Machine Operation and Maintenance. My interest in machine development dates back to 1974 when, as an undergraduate in this university, I stayed behind on campus during the long vacation of Part IV to commence work on my final-year project so that I could have enough time to complete it during the final year. I will now discuss my contributions in these areas by highlighting some of my research efforts over the years.

3.2 Machine Development

3.2.1 Cassava Planting

Cassava (*Manihot esculenta* Crantz) is grown mainly in the tropical parts of Africa and in Brazil, Malagasy, Indonesia, South India, Philippines, Malaysia, Thailand and China (Ajibola, 2000). In the tropical part of Africa, cassava has become the most important crop in terms of both the total land area devoted to its production and the proportion it contributes to human diet. Jeon and Halos (1992) reported that 60% of root crop consumption in Africa is accounted for by cassava. Production of cassava on large acreages has been limited because of the high labour requirements for planting and harvesting.

My first attempt at machine development was done as a final-year project. It was the design, construction and testing of a low-cost, mechanical cassava planter capable of planting stem cuttings on freshly-made ridges with minimum damage to the buds (on the stem cuttings), minimum crushing, minimum loss of time and capable of being manufactured locally. The machine was operated as a semi-automatic planter and was drawn from a single hitch-point behind a conventional disc ridger to form a combined ridger-planter as shown in (Plates 2 and 3). Results of field tests (Table 2) showed that the machine was superior to hand-planting (Adekoya, 1975).

After more work on the machine by my supervisor, Dr. G. A. Makanjuola (now Emeritus Professor of Agricultural Engineering), the principle was patented by the University of Ife as "A device for planting stem cuttings", British Patent No. 1591025 of 1981.

Table 2: Comparison of cost of machine and hand planting

S/N	Operation	Govt. Hire		Private Owner	
		Hand	Machine	Hand	Machine
1	Ridging	5.19	5.19	5.19	9.51
2	Fuel	0.79	1.78	0.79	1.78
3	Labour i. Planting ii. Extra ridging	 23.72 -	 3.51 0.98	 23.72	 3.51 0.98
4	Depreciation		1.75		1.75
5	Preparation of cuttings	3.16	4.67	3.16	4.67
	Total(₦/ha)	32.86	17.88	32.86	22.20

3.2.2 Tomato Harvesting

Tomatoes rank as the number one vegetable crop in California, USA (Sims *et al*, 1968). There are two types of tomatoes planted in the state, namely table and processing tomatoes. Table tomatoes are eaten raw as salads or as freshly-blended tomato drinks. Processing tomatoes are processed as tinned or bottled purees, ketchups, and sauces.

As at 1967, approximately 85% or 75 000 hectares of processing tomatoes were machine-harvested in the State of California, USA. In 1978, all the 105,000 hectares of processing tomatoes were harvested with machines (Sims *et al*, 1979). This quantity represented 86% of the total US production of processing tomatoes.

As at the time of our work in this field there were four types of commercially-available processing tomato harvesters in use in California (Adekoya, 1979). These were the UC-Blackwelder harvester (based on a principle developed at the Department of Biological and Agricultural Engineering, University of California, Davis, and commercialised by Blackwelder Inc.), the Dask harvester, the Button-Johnson harvester and the FMC harvester. The above machines used various principles to impart oscillatory motions to the fruit-vine system in order to detach the fruits from their vines as they travel on the shaker bed.

Irrespective of the principle used at the time, the following short-comings were observable:

i. the shaker beds for effective fruit-vine separation were long, resulting in long harvesters (see Plate 4),
ii. the imparted vibratory forces were high, resulting in significantly high forces being transmitted to the workers on the machines,
iii. the high imparted vibratory forces resulted in high accelerations to the fruits at the instant of detachment,
iv. the high accelerations at detachment resulted in high damages to the harvested fruits, and

v. the high transmitted forces resulted in high failures of machine components.

Previous researchers worked on various concepts to eliminate or at least ameliorate the above shortcomings. Previous works included those of Privette (1968), Hood *et al* (1975), Lorenzen and Hanna (1967), Deen and Hayslip (1968), and El Domiaty and Lorenzen (1967).

My contribution to the solution of the problems still bedevilling tomato harvesting at that time was the work done on a rotary shaker as a device for fruit-vine separation (Adekoya, 1979; Adekoya and Studer, 1979). The salient features of the shaker are shown in Plate 5. Essentially, a horizontal drum with a centrally-located shaft is driven back-and-forth through a specially-arranged sprocket-and-chain drive. The drum was made from sheet aluminium and had forty-five radially-mounted hollow fingers on it. The fingers were arranged equidistantly in nine rows parallel to the drum's longitudinal axis. Struts welded to the shaft and to circular channel bars on the inside surface of the drum, reinforced it (i.e. the drum). The final drum motion is made up of a constant velocity motion and an oscillatory motion. The constant velocity motion is used for vine movement while the oscillatory motion is used for fruit detachment.

The principle was tested with two varieties of processing tomatoes, namely VF 134 and 7879. The 7879 variety is easier to detach than VF 134. When compared with two popular commercial harvesters (Table 3), it was observed that the accelerations required for virtually-complete fruit detachment using the rotary shaker were significantly smaller.

The principle was patented by the University of California, Davis as United States Patent No. 4232506 of 11th November 1980. The principle has now been adopted by all California manufacturers of tomato harvesters and is the only one available on California machines. Because of its simplicity and the absence of fast-wearing parts, the principle virtually eliminates downtime due to shaker wear, adjustments, malfunction or failure during the harvest season. For these reasons, the work has made a profound impact on the industry (Biological and Agricultural Engineering Department, UC Davis, 1994).

Table 3: Comparison of accelerations imparted by shaker mechanisms for virtually 100% fruit detachment.

Harvester	Machine Stroke (cm)	Tomato Variety	Operating Frequency (cpm)	Fruit-vine Acceleration (g)	g/g_{rs}
FMC+	12.7	VF 134	340	16.40	2.36
		7879	200	5.68	1.67
UC-Blackwelder+	17.8	VF 134	240	11.44	1.64
		7879	180	6.44	1.90
Rotary Shaker	14.61	VF 134	200	6.95	1.00
		7879	140	3.40	1.00

+Data provided by manufacturer. g_{rs} = Fruit-vine acceleration in rotary shaker.

The principle of the rotary shaker has subsequently been adopted by various manufacturers in the commercial harvesting of blackberries, raspberries, black currants, wine grapes, raisins, coffee and cucumbers (Biological and Agricultural Engineering Department, UC Davis, 1994).

3.2.3 Zero-Tillage Planting

Tillage is the mechanical manipulation of the soil for any purpose. In agriculture its main objective is the provision of a desired soil structure for crop production. Tillage operations are either conventional or conservational. Conventional tillage consists of a series of primary and secondary operations. It is an energy-intensive operation. In conservation tillage, the degree and number of soil manipulations are reduced. Apart from the issue of high energy consumed during conventional tillage, it is also observed that the process makes the soil to be more susceptible to excessive erosion. Consequently, as far back as early 1970s, the concept of conservation tillage started to gain ground.

Conservation tillage is tillage carried out with a modified crop production objective to provide for effective soil erosion control and reduced mechanical and labour inputs. Conservation tillage reduces mechanical energy, labour requirements, number of trips over the field, erosion, and conserves moisture. Lal (1975) studied soil losses through water erosion in Nigeria and found them to be as high as 200 tonnes/ha per year on tilled soils of just 10% slope even when under a crop of maize. This erosion could be reduced by 98% by leaving the soil untilled. Water run-off was likewise reduced from 42% of rainfall falling on the bare soil to less than 2.5% on untilled soils.

A very effective way to reduce soil erosion on farmlands is to leave residue from previous crop on the soil surface, and to plant through the residue without any form of tillage. This concept is called zero tillage and requires a new breed of planters which are drastically different from conventional planters. This is because research showed that plant residue, hard soil or sod, usually prevent conventional furrow openers from functioning properly on non-conventionally tilled soils (Erbach and Lovely, 1976). Planting depth, planting distance, seed metering and coverage are often erratic, resulting in non-uniform emergence, growth and maturity, harvesting delays and yield reductions (Erbach *et al*, 1980).

Several attempts have been made to solve some or all of the above problems with varying degrees of success. Previous workers include Ul'yanov and Ivzhenco (1968), Huang and Tayaputch (1973), Wilkins *et al* (1979), Wijewardene (1978) and Garman *et al* (1982).

My contribution to the solution of the problems was the design, fabrication and testing of a rolling injection planter (Adekoya, 1982; Adekoya and Buchele, 1987). The planter consisted of radially-mounted injectors on a wheel made up of two discs as shown in Plate 6. The machine punched holes in untilled soils with residue from previous crop on the surface, and then dropped a seed in each hole. Soil punching and seed dropping took place in one operation.

The machine was tested for planting maize on a farm with 75% residue cover from the previous crop at 5520 kg/ha (Plate 7). Results showed that the within-the-row spacing of the planted seeds was 25.7 cm (instead of the design value of 25.4 cm) and that the depth of planting was 4.3 cm (instead of the design value of 5.0 cm). Neither statistic was affected by the travel speed of the machine. Ninety-one percent of the punched holes had a seed in them at a travel speed of 3.2 km/h. The percent emergence of the planted seeds was 81% as against the percent germination of 82% under laboratory conditions. Hence the machine did not affect the viability of the seeds in any way.

3.2.4 Grain Cleaning

The presence of foreign materials, especially stones, in locally-produced grains is a major reason for their poor acceptance by consumers. Popular grains in this category are maize, rice, and cowpea (beans). Stones and other foreign matter are introduced into grains during harvesting and post-harvest operations such as threshing, drying, storage, etc. With respect to grain cleaning, stone is a generic term referring to sand and other similarly-sized gravels, limestone, clay, etc.

Previously-developed cleaning machines include sieve cleaners (Henderson and Perry, 1976), winnowers, inclined drapers, magnetic separators, electrostatic separators and specific gravity separators (Araullo *et al*, 1976), and aspirators and indented cylinders (Culpin, 1981). Sieve cleaners separate grains from foreign matter on the basis of differences in size. However, particles having the same size with the grains will be retained. Winnowers separate foreign matter from grains based on weight differences. Therefore, lighter-than-grain materials are easily removed, but particles having the same weight size with the grains may be retained.

In pneumatic separating machines, the grains are passed into a vertical air current which lifts the chaff, dust and other light contaminants, and allows the grains and other similarly-heavy foreign matter to fall through the air stream. It is therefore impossible to separate any stones from grains using pneumatic aspirating machines. Indented cylinders separate grains based on differences in shape while inclined drapers effect separation on the basis of differences in surface textures of the particles. In contrast, the electromagnetic separator effects separation based on differences in the electrical properties of the grains and the foreign matter.

All the above previous methods have limited successes in removing stones from grains. However, the specific gravity table has been reported to achieve efficient separation of stones from grains (Henderson and Perry, 1976). In order to domesticate the principle for the cleaning of local grains, such a machine will have to be specifically designed and made adjustable for varieties of local food grains such as maize, rice and cowpea.

As a first step in meeting this goal, Koya and Adekoya (1994) determined some physical, mechanical and aerodynamic properties relevant in mechanically-removing stones from some local food grains. The relevant properties were physical (size, shape, mass and density), mechanical (coefficient of static friction) and aerodynamic (suspension velocity). The properties were determined for two varieties of maize (Farz7 and TZSR-W), two varieties of rice (Faro II and BG 90/2), and three varieties of cowpea (Ife Brown, TVX 3236 and IT84E-124). Relevant properties of rock and mineral particles (often referred to as stone) that usually constitute impurities in grains were compiled from Telford *et al* (1976).

Using the above data and basic design principles, a machine for removing stones from local grains was designed and fabricated (Adekoya and Koya, 1998). The machine consisted of an oscillating table, the transmission, the fan and air chamber, and the power source. The oscillating table was an inclined perforated plane made from expanded metal with an overlay of mosquito netting. The oscillatory motion of the table was imparted through a crank-rocker mechanism driven by an electric motor (Plate 7).

Separation by specific gravity separator is based on two conditions. (1) the lifting or floating effect produced by the upward motion of air through the perforations in the oscillatory table, and (ii) pure-slip conveyance of granular materials on an oscillating conveyor within a certain range of frequencies. Test results showed that for varieties of the same grain, the optimum values of the parameters that affected the machine operation were basically the same but were different for different grains. The machine successfully separated up to 94%, 90% and 74% of the stones present in rice, cowpea and maize varieties respectively in the first pass of the grains.

3.2.5 Oil Palm Harvesting on Plantations

The oil palm (*Elaeis guineensis* Jacq.) is a tree without branches but with many wide leaves (or fronds) at its top (or crown). Bunches, each of which contains over a thousand fruits, are held in the axils of the leaves and are arranged in a rosette around the crown. The oil palm is a native of tropical Africa growing wild in many parts of West Africa and the Congo basin.

The oil palm is a very important economic tree. The two most important products of the oil palm are palm oil and palm kernels, both of which are obtained from the fruits. Palm oil is used primarily for human consumption, but a substantial amount is also used in the manufacture of margarine, soaps, etc, while the oil from the kernel is used mostly for pomades, oil paints, etc.

Generally, for fruit crops, the majority of mechanical harvesting systems utilized today are shake-and-catch methods (Futch *et al*, 2006). The oil palm defies this harvesting method because the fruits are compactly packed in bunches which are hidden in leaf axils in the crowns. Also, the trunk of the oil palm is not compliant enough to create the required vibration phase difference between it and the fruits (as is found between the tomato fruits and vines for example). Additionally, the bunches have very thick and strong stalks and could be at heights of over 9m.

Work done by Bevan and Gray (1969) in Malaysia showed that for palms aged between 9 and 16 years, 43.5% of the total man-hours for annual production was expended on harvesting. The corresponding value for palms aged between 17 and 25 years was 45.4%. According to Hartley (1977), booms mounted on tracks or high floatation wheeled tractors were tried in Honduras and Costa Rica. The booms took the harvesters to the crowns of palms up to 12m in height, and the bunches were cut and they fell into a trailer drawn behind the tractor. The method was cumbersome because it was difficult to manoeuvre the tractors around the tree trunks and also ensure that the bunches fell into the trailer.

Locally, the oil palm is currently being manually harvested using simple implements such as cutlasses, axes, chisels and the Malaysian knife. The method used depends largely on the height of the tree. The methods currently being used in Nigeria are: the chisel method (for plants less than 2.5m in height or within arm-reach), the ladder and cutlass/ladder and axe method (for moderately tall trees beyond arm-reach), the knife and bamboo pole method (for trees up to 9m in height), and the rope and cutlass/rope and axe method (for trees beyond the reach of the knife and pole method).

Adekoya and Makinde (1990) carried out preliminary investigations to obtain data on oil palm and oil palm harvesting on plantations in Nigeria in order to facilitate the mechanisation of the process. The research was carried out on the oil palm plantations of the Nigerian Institute for Oil Palm Research (NIFOR) in Benin-City. The data sought were the following:

i. Base circumference of the oil palm measured at a height of 30 cm from the ground surface,
ii. trunk circumferences measured at a height of 2 m from the ground surface and at intervals of 1 m,
iii. bunch stalk circumference,
iv. force required to cut a palm frond,
v. force required to cut a palm bunch,
vi. number of bunches on a tree, and
vii. mass of a ripe bunch.

Further work by Adetan and Adekoya (1995) showed that harvesting of the oil palm can be broken down into five separate activities which can be classified as:
i. locating, reaching and cutting of the ripe fruit bunches and underlying fronds,
ii. stacking of the cut fronds along the row,
iii. searching for and collecting the cut fruit bunches and the scattered loose fruit from the ground,
iv. transporting the fruit bunches and the loose fruit to the collection centres in the field, and
v. loading the fruit bunches and the loose fruit into vehicles for transportation to the processing plant.

Additionally, a time and motion study was carried out on the two methods used for harvesting tall trees: the bamboo pole and knife (BPK), and the single rope and cutlass (SRC) methods, in order to determine where intervention was most urgently needed (Adetan and Adekoya, 1995). Data was collected on the times used for carrying out the first four activities described in the previous paragraph.

The research showed that:

i. With the BPK method, the greater mass and length of the harvesting pole made harvesting very uncomfortable.

ii. Transportation of the long and heavy harvesting pole to, from, and on the field was very onerous. There was the risk of injuring other field workers with the Malaysian knife on the long pole.

iii. Severe damages were inflicted on the fruits from tall trees as they impacted the ground. This was likely to substantially raise the free fatty acid level of the oil produced from them, which would lead to a lower quality of oil.

iv. There were the risks of accidental falls and snake and insect bites in the SRC method.

v. In either method, the search for, and the collection of the detached and scattered fruits were never fully accomplished because it was impossible to know how many fruits were detached from the bunches, and hence when the search and collection should be terminated. Therefore, there is always the probability of leaving an appreciable proportion of the detached fruits uncollected especially in high-yielding but weedy plots.

vi. The fruit collector always complained of waist pains, and because of this problem, there was a tendency for an incomplete search and collection of detached loose fruits. The preceding and current observations informed us that there could be resultant high cumulative losses in the collection activity.

Based on the facts that the climbing before cutting substantially reduced harvesting rate, and that much risk was involved in climbing, it was decided that further research should be done to make the BPK method more suitable for harvesting tall trees. This was effected through an improved pole-and-knife method of harvesting the oil palm (Adetan *et al*, 2007).

Basically, the research consisted of the design and fabrication of a telescoping mechanical pole that was easier to carry, was easier in engaging fronds and bunch stalks, and was able to harvest both short and tall trees. By treating the pole as a cantilever, deflection analysis was carried out (Juvinall, 1967) on various lengths and diameters of locally-available aluminium poles to determine the sizes to procure for the construction. The telescoping was achieved by using three sections of aluminium pipes of different diameters with the Malaysian knife attached to the topmost section.

To complement the telescoping pole, a catchment platform was designed and fabricated from high density foam sandwiched between a tough polyethylene tetraphalate tarpaulin material on top and a fairly tough nylon (polyamide) material at the bottom. The foam made the spreading and folding of the platform easy and also helped to absorb some of the kinetic energy of the falling bunches.

Field tests showed that the combination of telescoping pole and catchment platform significantly reduced the detachment of the fruits from the bunches and also ensured that the few detached fruits do not possess enough kinetic energy to be dispersed from the catchment platform. These actions reduced the severe damages inflicted on the fruits as they impacted the ground. The telescoping harvesting pole was easily disassembled and packed together for easier transportation to the fields, was much lighter than the bamboo pole, and was easily used to harvest trees of different heights (Plate 9). Of course, it also had a longer life than the bamboo pole.

Mr. Vice-Chancellor, I am happy (or is it sad?) to inform you that the telescoping harvesting pole is presently being manufactured in Malaysia and exported to many oil palm producing countries including Nigeria. The telescoping harvesting pole (without a catchment platform) has been sighted in service at the Araromi Oil Palm Plantation, Araromi-Obu, Ondo State and Swanlux Farms, Coker Village (near Osogbo), Osun State. My sadness is due to the fact that there is no royalty accruing to the University or the researchers from the commercialisation of the idea!

With the "successful" commercialization of the telescoping harvesting pole, as it were, attention was shifted back to the improvement of the traditional climbing rope. The traditional climbing rope is made from vines or some other vegetative material. The major problem of the traditional climbing rope is failures due to rope breakages. These failures resulted in falls that were either minor or fatal. On some occasions, the climber is attacked by snakes or insects. In an attempt to strike the snake and /or drive away the insects, the climber sometimes loses his balance and is cut by the cutlass or bruised by the tree. In this climbing method, it is impracticable for both legs of the planter to leave the tree at the same time. If done, the climber either gets bruised during the impaction of his body on the tree or he is completely immobilised by the rope pinning his body to the tree.

A simple solution to these problems was to design an engineered rope with a device that enabled the climber to free his hands and legs from the rope and the oil palm tree without falling down. Thus he can use his hands, cutlass and legs to defend himself in the case of an attack by either a snake or insects.

The engineered rope was made up of two parts: the body brace belt and the rope. The body brace belt consists of a belt part made of canvas and a brace part made of gauge 16 sheet metal strip padded with rubber foam. The gauge 16 sheet metal strip carried

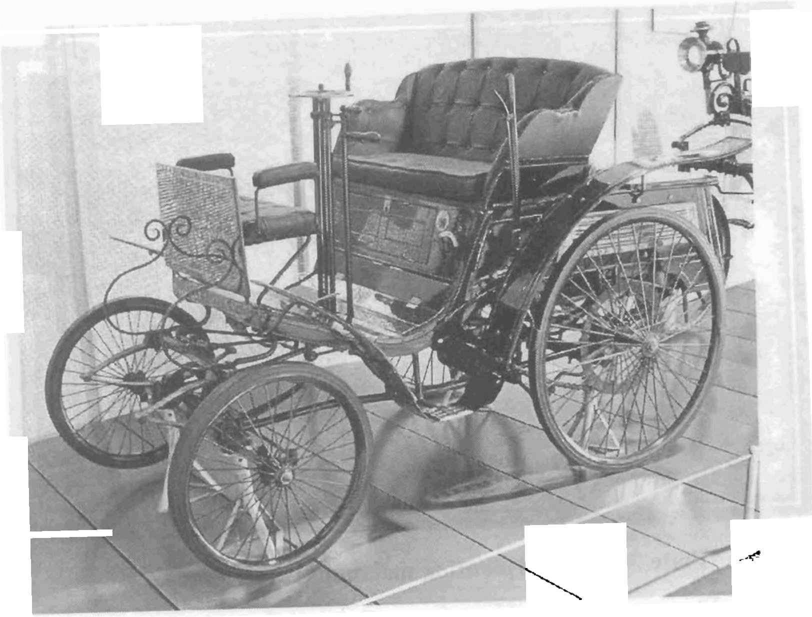

Plate 1: A replica of Benz *Velo*: The truly first car (Wikipedia, 2014).

Plate 2: Cassava planting machine (side view).

Plate 3: Cassava planting machine (rear view).

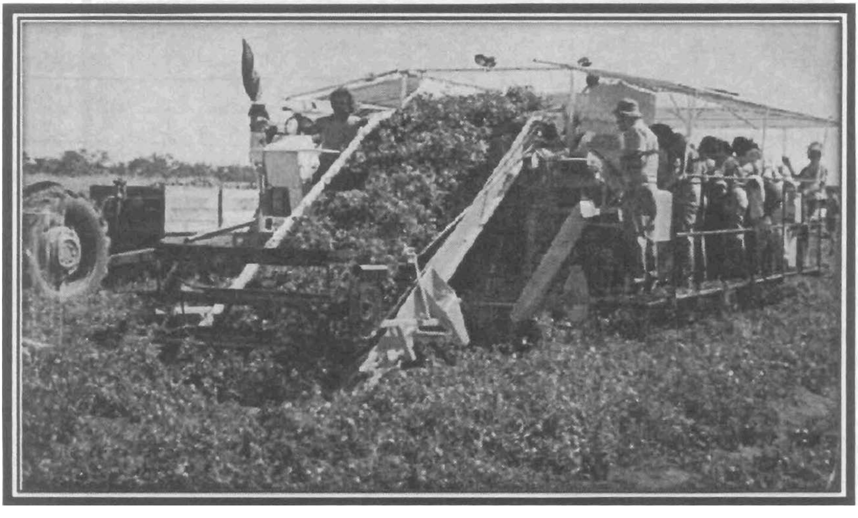

Plate 4: A commercial tomato harvester.

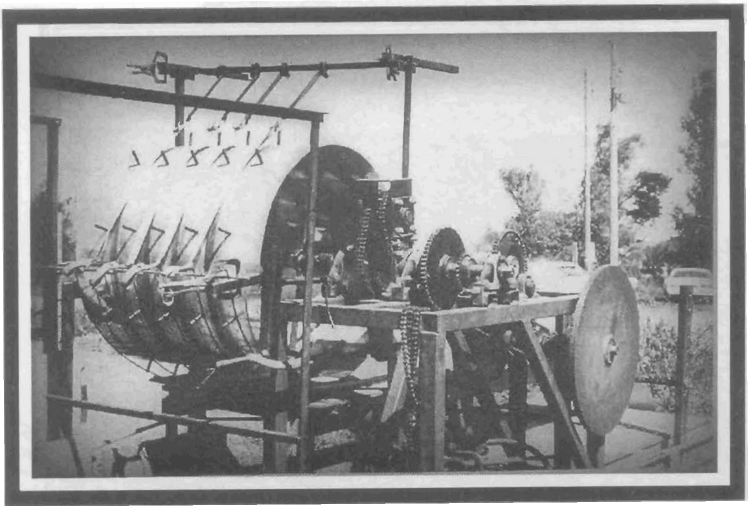

Plate 5: The rotary tomato harvesting machine.

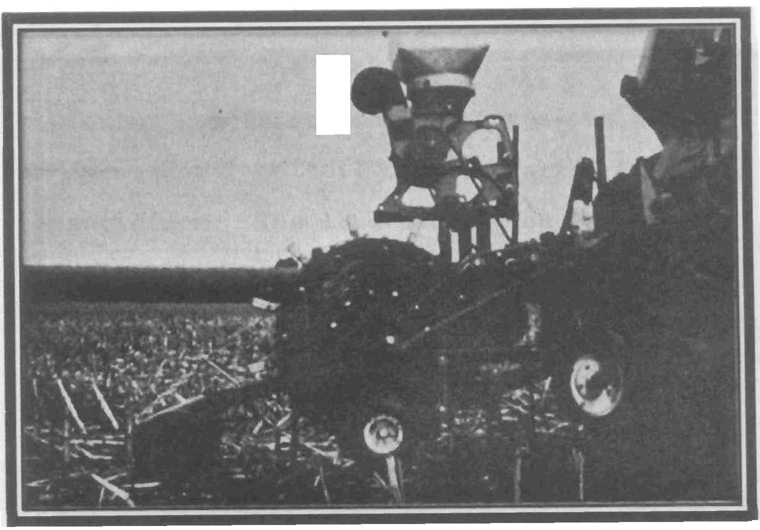

Plate 6: Zero-tillage planter.

Plate 7: Residue-covered field used for the testing of the zero-tillage planter.

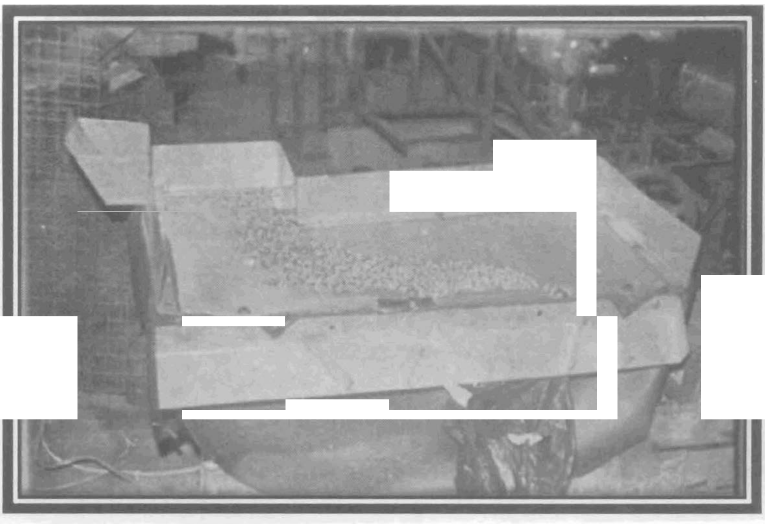

Plate 8: Machine for removing stones from grains.

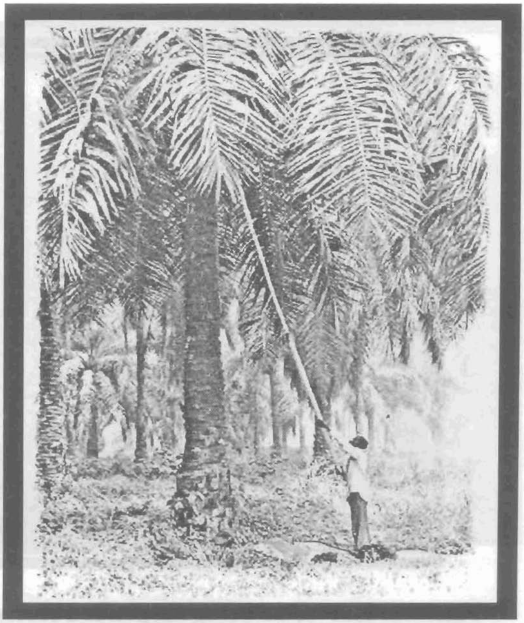

Plate 9: The telescoping oil palm harvesting pole.

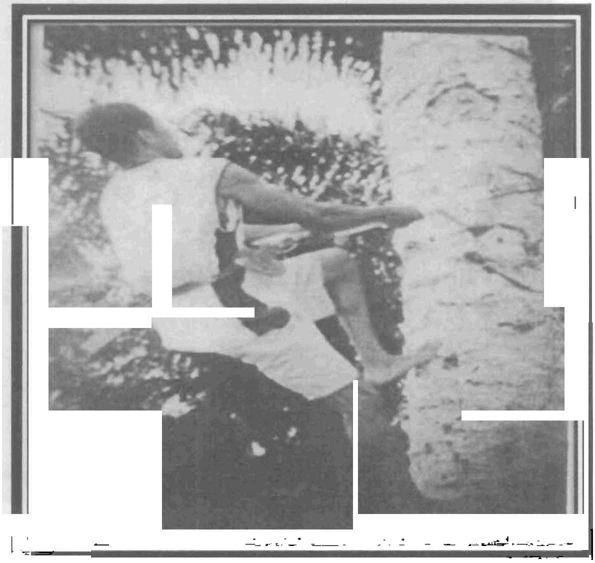

Plate 10: Engineered climbing rope.

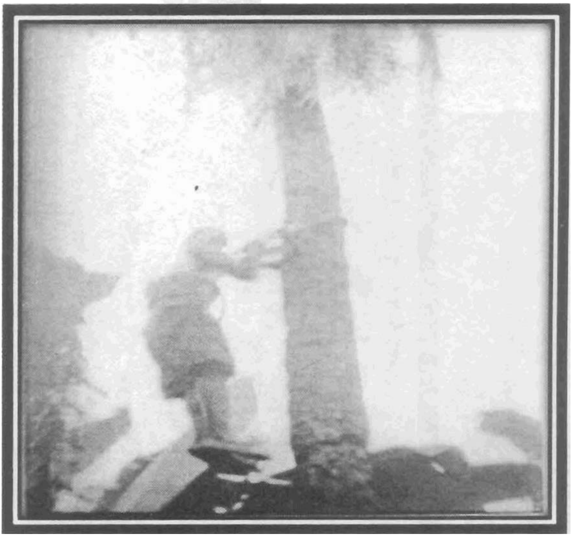

Plate 11: Harvester being suspended safely away from the oil palm tree by the engineered climbing rope.

Plate 12: Human-powered lawn mower.

Plate 13: ***Molue*** **bus.**

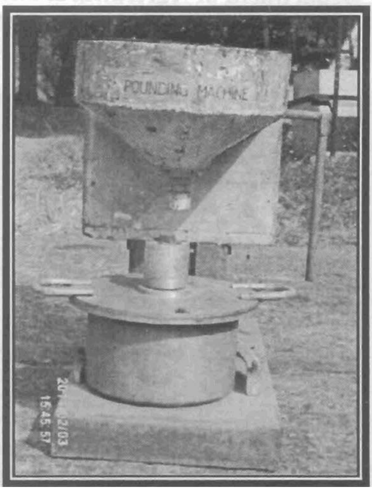

Plate 14: Prototype of the yam pounding machine (Courtesy of Emeritus Prof. G. A. Makanjuola).

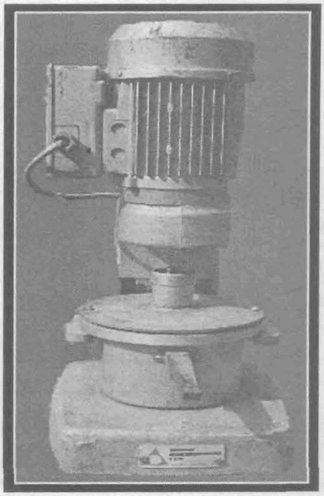

Plate 15: Commercial version of the yam pounding machine manufactured by Addis Engineering Limited (Courtesy of the Department of Agricultural and Environmental Engineering, OAU, Ile-Ife).

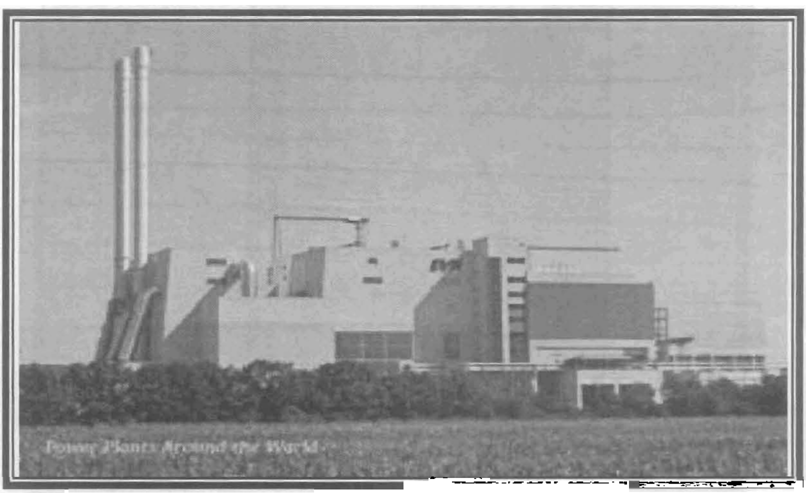

Plate 16: A waste-to-energy plant for generating electricity.

two locks for attaching the rope part. The rope part was also made of two parts: a safety arm made of aluminium and the rope made from 6 mm-thick canvas lined with a stainless strip, punched so that the surface was rough enough to grip the oil palm tree (Plates 10 and 11). The safety arm was constructed of aluminium and weighed a only 2.5 kg. Accelerated testing showed that the engineered climbing rope had a life of at least five years while the traditional climbing rope had a life of a few months (usually a harvesting season).

3.2.6 Peeling of Cassava Tubers

The cassava root is a tuber. It is the main economically-useful part of the plant. Apart from its use as a source of food for humans, the cassava tuber has many non-food uses. These include its use as industrial starch in the textile industry and as cassava flour used for blending wheat flour in processing of biscuits, bread, etc.

Several attempts have been made to mechanise the peeling of cassava prior to our work. Chemical peeling using a hot solution of sodium hydroxide (which has been successful in peeling potatoes) were shown to be unsuitable for cassava tubers (Igbeka, 1985). Abrasion has had limited success mainly because the process reduced the tubers to uniform cylinders before all peels could be removed (Ezekwe, 1976). Additionally, before the big tubers are adequately peeled, the small tubers would have been literally grated. Ohwovoriole *et al* (1988) reported a simple manual rig that worked on the principle of peel/flesh separation through compression followed by peel removal with knives. The principle looked promising for further research. However, before the design could commence, experiments had to be carried out on the physical properties of the cassava tuber. This resulted in the characterisation of the cassava tuber (Adetan *et al,* 2003).

The data obtained was used in the development of a cassava tuber peeling machine (Adetan *et al*, 2005). The machine works on the principle of peel/flesh separation by compression and peel removal with knives. It comprised a horizontal belt conveyor unit and a spring-loaded knives unit. In operation, the belt conveyor transfers slices of cassava tubers which are peeled under an array of spring-loaded knives. Tests were carried out on root slices of different sizes with the conveyor belt driven at a linear speed of 1.31 m/s. For root slices having mid-section diameters ranging from 45 mm to 55 mm, the peel removal efficiency ranged from 92% and 97.3%, while for root slices between 55 mm and 65 mm, the peel removal efficiency ranged from 95.3% and 100%. For the above tuber slice ranges, no breakage of roots was experienced during peeling. However for root slices with relatively larger diameters than those quoted above, the peel removal efficiency ranged from 15.2% to 82% and root breakage was observed to occur in some instances. In all cases, however, there were no losses of useful tuber flesh (Adetan *et al*, 2005).

3.2.7 Environmental Management

Lawn maintenance has always been a challenge in green areas within human communities. The need to provide ecologically-friendly and effective lawn mowing solutions is crucial for the well-being of humans and the planet as a whole. The work done in this area involved the development of a human-powered lawn mower blade system designed to cut tall grasses on small lawns in residential areas. The work entailed the design and fabrication of a reel-type mower blade system and a pedal-powered source of energy for the blade system. It also evaluated the performance of the fully-assembled unit. This was done with a view to providing an appropriate and affordable human-powered alternative for domestic lawn mowing involving tall grasses and weeds.

A reel-type mower blade system capable of cutting tall grasses and weeds was designed and fabricated. The system was based on the shear cutting principle to enable low-speed human-powered operation. A human-powered pedal-operated cycling mechanism incorporating a chain drive was used to power the machine as well as the cutting knives. Provisions were made for adjusting the height of the mower blade system (Plate 12). The mower blade system was tested on some overgrown grass plots within the University campus. Each test plot was measured to determine the total area within which cutting took place.

From the data obtained during the testing, the field efficiency and effective field capacity were determined. The blade system's cutting effectiveness and the quality of cut achieved by the unit were also studied and documented. The information gathered during testing was used to compare the performance of the fabricated system with other human-powered lawn mowing techniques.

Calculations gave the theoretical field capacity of the mower as 0.098 ha/h while field test results showed that the fabricated cutting system produced an effective field capacity of 0.0614 ha/h. These figures are clearly superior to the theoretical field capacity of 0.0247 ha/h obtained from the use of cutlasses for cutting. Results further showed that the unit performed in a manner comparable with the operation of standard reel mowers with similar effects in terms of quality of cut. Moreover, the unit's cutting system showed a substantial improvement over existing reel mower designs in its ability to cut on both the forward and reverse phases of its motion (Oladosu and Adekoya, 2014).

The study established that the designed blade system has the capacity to cut tall grasses and weeds. This device can therefore entirely eliminate the need for fuel-powered mowers on small residential lawns. The device can also be used for exercising the body during the mowing operation. Further work is presently being carried out on the machine to make it more functional.

3.2.8 Fatigue Behaviour of Locally-rolled Steels

Material selection is a very important aspect of machine design. This is because materials affect the service performance of machines. This is especially true in the selection of materials for the fabrication of rotating parts and structures that are prone to fatigue-induced failure.

In general, fatigue is the main cause of failure of machine components in mechanisms, structural functioning in aeronautics, naval and automotive industry as well as in civil engineering structures such as bridges, buildings, etc. Since fatigue failures occur suddenly without showing exterior plastic deformations, it follows that for many engineering applications, a comprehensive analysis of the elastoplastic deformation is necessary to ensure that accurate results are obtained from simulations in the process of designing or analyzing structures (As *et al*, 2008 and Heidari *et al*, 2009).

The Nigerian steel industry is dominated by private smelting and rolling mills from which mainly NST 37-2 steels (that represent about 75% of their volume) are produced. According to Balogun *et al* (2009), this particular grade of steel is produced from diverse raw materials that is mainly locally-sourced scraps. The indiscriminate use of the steel products, especially as machine elements without proper characterisation, is therefore a problem.

To alleviate the above problem, a joint research was undertaken by the Departments of Mechanical Engineering and Materials Science and Engineering. The work commenced with the characterization of NST 37-2 steel made at a local rolling mill from imported billets. Tests were carried out on required specimens to establish the baseline material properties of the steel in annealed, as-rolled, normalized and hardened tempered conditions. Fatigue tests were then carried out at 60%Su, 70%Su and 80%Su of the test material and fractographic examinations were eventually carried out on the specimens. Based on preliminary results, the steel material is recommended for use in low-cycle, quasi-static fatigue operations (Malomo *et al*, 2010 and Malomo *et al* 2011). Further work is being carried out on locally-rolled steels made from locally-produced billets that were manufactured from locally-sourced scraps.

3.3 Ergonomic Appraisal of Existing Machines

Ergonomics is the scientific discipline which is concerned with the understanding of the interactions among humans and other elements of a system. The objectives of ergonomics are those of achieving functional effectiveness of whatever physical equipment or facilities people use and of maintaining or enhancing human welfare or well-being (such as health, safety, and satisfaction) by appropriate design of equipment, facilities and environments (Adekoya, 1999).

3.3.1 Agricultural Tractors

Agricultural tractors, as the workhorse of mechanised farming, were ergonomically evaluated (Adekoya, 1993). Tractor brands used for the tests were Massey Ferguson (MF), David Brown (DB), Ford, Steyr, Fiat and John Deere (JD). Tractor models surveyed were MF 165 and 125; DB 990; Ford 5000 and 6610; Steyr 768, 8075, 8090, 8120 and 8130; Fiat 640 and 660; and JD 1120. Comparison of the anthropometric data of 31 tractor operators (from 11 agricultural organisations that were fairly spread across the country) with the design data of the above tractors showed that even though 96.8% of the operators said that the heights and widths of the seats were satisfactory, 46.7 and 43.3% of them experienced backaches and leg pains respectively during the cropping season.

According to Purcell (1980), discomforts such as backaches could be caused by (i) wrong angles for various tilts of the seat (i.e. wide deviations from the 5-10^0 from the horizontal, proposed by

Rebiffe, 1969); (ii) inadequate padding of the parts of the seat which come in contact with the ischial tuberosities (the two round knobs on the underside of the pelvis which bear most of the upper body weights while sitting); and (iii) bucket-shaped seats which tend to rotate the femur bones upwards, causing abnormal stresses in the hip muscles. The leg pains and backaches are therefore strongly suspected to have been caused by unsuitable seat designs and/or adjustments.

None of the tractors surveyed had a roll-over protective structure (ROPS), cab, or sun roof. Although there were no reported cases of tractor overturns by the operators, a roll-over protective structure is definitely desirable. Data made available to the US Consumer Product Safety Commission show that overturn of machinery was the most common fatal accident, and that agricultural tractors were involved in 99% of all equipment overturns. Three times as many persons died from farm tractor overturns as from any other fatal injury episodes (McKnight and Hetzel, 1985). Consequently, a retro-fitting of the existing tractors with roll-over protective structures (ROPS) was recommended. To this end, one of my postgraduate students is currently working on the design of ROPS for tractors being used in Nigeria.

3.3.2 *Molue* Buses

In public transportation, clearance at various levels is important for ingression and egression, for easy grasping and movement within the vehicle, and for adjusting the body properly for comfort (Woodson, 1972). Many passengers face some problems in getting on to the bus, going to the seat, in seat, going from the seat, and getting off the bus. Problems encountered by all bus passengers are worse for the elderly because of their reduced mobility (Gilmore, 1994). Therefore in public transportation, the scope for the application of ergonomics expertise is enormous and the effects seen in terms of improved safety and users' comfort, convenience and satisfaction are almost limitless (Brown, 1979).

Molue buses are the huge yellow locally-built commuter buses found mostly on Lagos roads (Plate 13). They ply some defined routes listed in Lagos State Government's Designated Bus Routes in Lagos State (Agbomeji, 2000). They are of two major sizes and are built on Mercedes Benz 911 or Bedford chassis. The big *molue* buses are recommended for 47 to 52 sitting passengers, while the small ones are recommended for 29 to 32 sitting passengers. However because of the acute shortage of commuter buses, the *molue* buses routinely carry more than the specified number of passengers with the extras standing crowded in the aisles and on the steps. This situation motivated the late Afrobeat maestro to release the popular song "44 sitting, 99 standing; suffering and smiling". Standing in the aisles and on the steps of *molue* buses make entering and exiting the bus to become more arduous.

Molue buses are built by roadside metal fabrication workshops, located mainly in Lagos and Ogun States, without reference to any formal design specifications. Because there are no specifications guiding the design and construction of these buses, their fabrications are based wholly on the whims and caprices of the technicians at the fabrication workshops. Therefore, no two *molue* buses are exactly the same even when built by the same workshop. This has resulted in a wide variety of *molue* buses on the roads, especially in Lagos.

In order to alleviate this problem, Ajayeoba and Adekoya (2009) initiated a research to carry out a comprehensive study of the problems of the design and construction of *molue* buses by the local metal fabricators. The ultimate goal of the research is to spearhead legislation on the standardization of the design and fabrication of *molue* buses. This is because currently, there are no generally-accepted design and fabrication standards for *molue* buses.

In this work, the anthropometric dimensions (stature, maximum body depth, maximum body breadth, buttock-knee length, buttock-popliteal length, popliteal height sitting, shoulder breadth, and shoulder height sitting) of some selected groups of male and female users of *molue* buses were measured. Design data (internal hand rail height, roof height, aisle length, aisle width, backrest-backrest frame height, backrest depth, backrest length, backrest width, seat length, seat width, backrest frame length, seat depth, seat frame-backrest height, seat height, seat depth, overall seat height, space between seat rows, and the relevant dimensions of the back seat) of both small and big *molue* buses were also measured (Ajayeoba and Adekoya, 2009; and Ajayeoba and Adekoya, 2012).

The data was analysed using percentiles (Hertzberg, 1972). Many shortcomings were discovered with respect to the design data resulting in discomfort for passengers. Based on the research result, the design data to accommodate the 95th percentile of the passengers were specified. There is a plan to collaborate with the Standards Organisation of Nigeria (SON) in order to standardise the design and fabrication of *molue* buses by local fabricators.

3.4 Machine Management

3.4.1 Agricultural Tractors

The workhorse of mechanised agriculture is the tractor, the evolution of which has accompanied changes in farm technology and sizes of farms. The tractor has progressed from its original primary use as a substitute for animal power to the present units designed for multiple uses. Tractors work for long periods without breakdowns if they are properly serviced. By service (or preventive maintenance) is meant cleaning, oiling, greasing, adjusting and similar tasks carried out on the tractor to keep it in operative condition and help maintain its efficiency (American Society of Agricultural Engineers, 1982). If the preventive maintenance is not carried out regularly, breakdowns occur, necessitating repairs. Repairs may also result from wear, accident, etc. Because agricultural operations have a time within which they have to be performed, breakdowns could prove to be economically disastrous to the farmer in mechanised agriculture.

The costs of owning and operating machinery in the business of farming are important to the farm owner or farm manager when making a decision on whether to buy or lease machinery or to hire work done by custom operators. One of the components in making this decision is the cost of maintenance. Engineers, mechanization specialists and economists have published very little data properly to estimate farm machinery maintenance costs in developing countries. Apparently, when such estimates are needed, data are taken from US or European experiences (Beppler and Hummeida, 1985).

Adekoya and Otono (1990) carried out research on the maintenance of agricultural tractors in established maintenance workshops in Lagos and Ibadan. These workshops served the then four contiguous States of Lagos, Ogun, Oyo (now Oyo and Osun) and Ondo (now Ondo and Ekiti). The workshops operated at the depot level of maintenance. The research data were obtained from the job cards of each tractor and the tractors were then grouped on the basis of the model and the year of purchase. All the tractors used were David Brown tractors. David Brown tractors were chosen for the study because they are popular and are among the first tractors to be imported into the country. The data were collected on a total of 144 tractors made up of the following numbers of different models: 50 DB 885, 56 DB 990 and 38 DB 1290. The data were made up mainly of the cost of disassembly, replacement and reconditioning of parts or units.

When these repair and maintenance costs (as a percentage of initial purchase price) were averaged over the years, the mean values of 10.94, 6.16 and 4.93% were obtained for DB 885, DB

990 and DB1290 respectively with an average maintenance cost of 7.3% of the cost price of the tractors. Comparison of this value (i.e. 7.3%) with values from previous work by Beppler and Hummeida (1985) shows that the (Nigerian) result averages 2-5.5 times the US and European values.

The result astounded us because tractors in Nigeria have an annual use of only about 500h (Food and Agriculture Organization, 1977). This number of hours of use is very low when compared with those in Europe and America. However, the higher maintenance costs for Nigeria could be explained by the high cost of imported spare parts, and the failure of most local tractor operators to carry out regular routine maintenance on the tractors, leading to frequent breakdowns which then necessitated repairs. Repairs also become necessary when the tractors are misused or abused by being used for jobs that they were not designed for. Given the fact that the data from the workshops did not include the cost of the routine maintenance carried out (on-site) by the tractor operators, the true cost of maintenance of agricultural tractors in Nigeria is probably higher than that obtained from the research.

3.4.2 Pumps

Pumps are machines used whenever water or some other liquid is to be raised from one level to another, taken from one tank to another, or circulated in a closed system. In all cases. energy is required to drive the pump in order to overcome the increase in level and/or friction in the pipes and fittings.

Pumps are second only to electric motors in the number of units in use worldwide. They have wide applications in water supply, sewage disposal, drainage, irrigation, fire services, chemical industry, petroleum industry, pulp and paper mills, food and beverage industries, mining, steel mills, hydraulic presses, refrigeration, heating and air conditioning, nuclear services, metering, solids pumping, and marine services.

A project that I am very proud to have been associated with was the Customised Training Workshops for Engineers and Technologists who were the staff of Water Corporations in Nigeria. The project was carried out under the National Water Supply Training Network of the National Water Rehabilitation Project, Federal Ministry of Water Resources and Rural Development, Abuja, from 1997 to 2002. It was coordinated by the National Centre for Water Resources, Kaduna. I was zoned to Southwest Nigeria . The Water Corporations which I serviced are shown in Table 4. The training programme was preceded by the writing of a training manual titled "Training Guide for Pump Design and Selection: Course Code 1010" (Adekoya and Hart, 1997).

Table 4: Training of water corporation engineers and technologies

S/N	Date	Organisation	Location	Topic
1	1998	Ekiti State Water Corporation	Ado-Ekiti	Preventive Maintenance of Pumps
2	1999	Water Corporation of Oyo State	Ibadan	Operation and Maintenance of Pumps
3	1999	Water Corporation of Oyo State	Ibadan	Pump Design and Selection
4	2001	Ogun State Water Corporation	Abeokuta	Pump Design and Selection
5	2002	Ondo State Water Corporation	Akure	Pump Design and Selection

4.0 CHALLENGES OF MACHINE DEVELOPMENT IN NIGERIA

In 1988/89, I was a part of a team that carried out a nation-wide survey of the status and challenges of agricultural and food machinery manufacture in Nigeria (Ngoddy *et al*, 1989). The survey showed that machines were being produced in Nigeria by four categories of organisations. These were (i) Research and Development Institutions mainly located in the engineering departments/faculties of the Research Institutes, Universities and Polytechnics. Many of them only produced, on order, prototypes of machines developed by them. Quantitatively, output was very small. Qualitatively, many of the prototypes being fabricated on demand still needed further development or value analysis for industrial application. (ii) Established manufacturers capable of undertaking machine development i.e. design (including value analysis) , production and testing. (iii) Cottage "manufacturers" which were credited with demonstrated ability to copy prototypes and/or commercial equipment with reasonable precision. (iv) Roadside "manufacturers", a group made up of all fabricators outside the preceding three categories.

The challenges being faced by machinery manufacturers were identified to include shortage of funds, lack of workshop or factory machinery and/or spare parts, high cost of production inputs, inadequate infrastructure, shortage of skilled manpower in design (especially value analysis), foundry, etc, and lack of adequate patronage.

It was concluded that for machinery manufacture to blossom in Nigeria, the country needed many established manufacturers who can take the prototypes developed by the R&D Institutions and carry out thorough value analysis or design for manufacture on them. One such company was Addis Engineering Limited, Isolo Industrial Estate, Lagos. The company took a license on the patent on "Device for mashing food" based on the principle of a machine developed then by Dr. Makanjuola (now Emeritus Professor) of the Department of Agricultural and Environmental Engineering of this University (Plate 14), and carried out further development (value analysis) of the idea to produce the highly successful yam pounding machine (Plate 15).

All over the world, academics in machine development traditionally stop their researches at the prototype stage. The ideas or principles of these machines are then further refined by the R&D Sections of manufacturing companies, such as Addis Engineering Limited in Nigeria and John Deere Incorporated (Moline, Illinois) USA. These companies have the capacity to take the ideas generated in universities and develop them into marketable products. To ensure that the university and researchers get rewarded, the ideas need to be patented. Thereafter, the patents are licensed or outrightly sold to the manufacturers.

What we lack in this country are the companies that are capable of carrying out value analyses on university prototypes. Until we have such companies, machine prototypes developed in universities and other R&D institutions will continue to gather dust.

5.0 MY CONTRIBUTIONS TO THE DEVELOPMENT OF ENGINEERING IN NIGERIA

Mr. Vice-Chancellor, the three major activities of an academic are Teaching, Research and Community Service. I have spent the last 38 years of my life doing all the above with respect to the development of engineering in Nigeria.

I have trained many generations of students in this University, and also at University of Lagos, Akoka; Covenant University, Ota; University of Ibadan, Ibadan; and Federal University of Technology, Akure; during my academic forays to those institutions as Visiting Professor or Adjunct Professor. Many of these former students are now established as professional engineers in the public and private sectors such as government agencies, oil and gas companies, manufacturing companies and universities in Nigeria and abroad. In academics, some of my former students have become professors both here and in other universities in Nigeria and abroad. As a matter of fact, two of my former students have not only become professors in this University, they have already delivered their inaugural lectures!

Administratively, I have had the opportunity of holding some positions of responsibility in the university. These include Head, Department of Agricultural Engineering (1991-1993), Head, Department of Mechanical Engineering (1995-1998, 2000-2003), Editor, Ife Journal of Technology, (2001-2007), Director, Central Technological Laboratories and Workshop, CTLW (2004-2007), and Director, Intellectual Property and Technology Transfer Office, IPTTO (2006-2012). I have served in various committees at the departmental, faculty and university levels.

In 1995, I transferred my services to the Department of Mechanical Engineering in order to assist in alleviating the problem of chronic shortage of academic staff in that department. Also, some young graduates of the department were recruited and sponsored abroad for further studies before and after 1995. As I stand before you today, there are at least five academic staff of the department with PhDs who have refused to return to the country after their studies in overseas universities in Europe and America.

One of my significant contributions to the department is the initiation of the takeoff of the postgraduate programme in 2002 during my second term as Head of Department. The programme had been approved by Senate since 1987, but could not take off because of the shortage of suitable academic staff. It was started, against all odds, by only two academic staff: my humble self and Prof. O. O. Mojola. The programme has since produced Ph.D. and M.Sc. holders, even as staff of the department. Through this singular act of starting the postgraduate programme, the problem of staff going abroad and not returning to the department was finally resolved.

Outside of the university, I have contributed my own quota to national development through consultancies, resource training and mentoring. I have been a member of several COREN and NUC Accreditation Teams to the Faculties of Engineering of Nigerian Universities including University of Nigeria, Nsukka (1991); University of Ibadan, Ibadan (1999); Federal University of Technology, Minna (2004); Abubakar Tafawa Balewa University, Bauch (2005); Ahmadu Bello University. Zaria (2005); Federal University of Agriculture, Makurdi (2005); and Federal University of Agriculture, Abeokuta (2012).

I have served as External Examiner for undergraduate and postgraduate degrees in Mechanical and Agricultural Engineering at several Nigerian Universities including University of Lagos, Akoka; University of Ibadan, Ibadan; Federal University of Technology, Akure; Federal University of Technology, Minna; Federal University of Agriculture, Makurdi; and Federal University of Agriculture, Abeokuta; and as Visiting Professor of Mechanical Engineering at Federal University of Technology, Akure (1999, 2010); University of Lagos, Akoka (1999-2000); and University of Ibadan (2007-2009).

I have been very active in my professional organisations. I have held and still hold many positions of responsibility in these organisations including Secretary, Nigerian Society of Engineers (NSE), Ile-Ife Branch (1985-1987), and Chairman, NSE Ile-Ife Branch (2004-2006). At the national level, I was Member, Engineering and Environment Committee (1987); Member, Investigation and Failure Analysis Committee (1991-1992); and currently Member, Continuing Education and Training Committee (2008-Date); Member: Engineering, Technology and Innovation Committee (2013-Date); Chief Examiner, Ile-Ife Examination Centre of the NSE (2010-Date); and Member, Monitoring Action Group on Agriculture, Water and Environment (2014-Date).

Professionally, I have served as an engineering expert in many capacities including as Consultant, National Centre for Agricultural Mechanisation, Ilorin (1986-1989); Resource Trainer, National Water Supply Training Network of the National Water Rehabilitation Project, Federal Ministry of Water Resources and Rural Development, Abuja (1997-2002); Consultant, National Economic Intelligence Committee (NEIC), Abuja (1998-1999); Consultant, Root and Tuber Expansion Programme, Federal Department of Agriculture, Ijebu-Ife (2001); and Consultant, Waste-to-Energy Project, Government of the State of Osun/Solargy Systems Africa (Nigeria) Limited (2013-Date). Plate 16 shows a typical waste-to-energy plant for converting municipal solid waste (MSW) to electricity by the incineration of the MSW.

My professional constituency has responded positively to these contributions. Consequently, I am a COREN-Registered Engineer; Fellow, Nigerian Institution of Agricultural Engineers (FNIAE); Fellow, Nigerian Institution of Mechanical Engineers (FNIMechE); Fellow, Nigerian Society of Engineers (FNSE) and Fellow, Nigerian Academy of Engineering (FAEng.).

6.0 CONCLUSIONS AND RECOMMENDATIONS

Mr. Vice-Chancellor, this inaugural lecture has been, in the main, a catalogue of some of my research activities. I have succeeded in carrying out the development of some machines that were subsequently commercialised and are therefore contributing to the improvement of the living standard of man. Others have potentials of being adopted.

I have contributed to the development of the engineering profession through consultancies, resource training, mentoring and active participation in the activities of my professional bodies.

Mr. Vice-Chancellor, I will end this Inaugural Lecture with a simple question and a corresponding simple answer. The question is "if man minus machines equals a labourer, what then is man plus machines?" My simple answer is that "man plus machines equals a productive worker"!

Therefore, my charge to employers (including this university) is that they should always provide their workers with the necessary machines/tools needed on the job. If and when that is done, it will be incumbent on the workers as operators/users of the machines/tools to operate them correctly and ensure that they are properly and regularly maintained. In this way, they will get long years of satisfactory performances from their machines/tools.

7.0 ACKNOWLEDGEMENTS

Mr. Vice-Chancellor, I thank the Almighty God for seeing me through my academic voyage and making it possible for me to finally present this inaugural lecture today. The date had been changed three times due to intramural and extracorporeal exigencies!

I thank the Department of Agricultural and Environmental Engineering for giving me an appointment in 1976, and the University for sponsoring me to the US for my Master and Doctoral studies from 1977 to 1982. I thank the University for allowing me to transfer to the Department of Mechanical Engineering in 1995. These experiences have positively impacted my life.

I thank my former teachers, former undergraduate and postgraduate students, co-researchers, professional colleagues, and friends for enriching my life. I thank my wife and children for their affection, patience and understanding.

I thank you all for your attention.

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