INDUSTRIAL ENGINEERING, DEVELOPMENT AND THE PRODUCTIVITY NEXUS IN SYNCHRONY

AN INUAUGURAL LECTURE, 2006

BY

A. E. OLULEYE

UNIVERSITY OF IBADAN

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An Inaugural Lecture delivered at the University of Ibadan

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by

A. E. OLULEYE
Professor of Industrial Engineering
Faculty of Technology
University of Ibadan
Ibadan, Nigeria

UNIVERSITY OF IBADAN

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The Vice-Chancellor, Deputy Vice-Chancellor (Administration), Deputy Vice-Chancellor (Academic), Registrar, Librarian, Provost of the College of Medicine, Dean of the Faculty of Technology, Dean of the Postgraduate School, Deans of other Faculties and of Students, Distinguished Guests, Ladies and Gentlemen.

It gives me great pleasure to give the Inaugural lecture for the 2005/2006 session on behalf of the Faculty of Technology. It is noteworthy that it is the first from the Department of Industrial and Production Engineering. Also, it is the first by an alumnus of the Faculty of Technology. About 25 years ago when I was contemplating a career direction, I met my friend, Abimbola Sangodoyin, now a Professor in the Department of Agricultural and Environmental Engineering. During one of our numerous discussions about what life held in store for us, he had broached the idea of 'helping' our alma mater. For me, the key question then was; how do you offer help, when you have only just begun? My decision to join the Faculty of Technology of this great University was made after discussions with two of my teachers; Professors E. B. Lucas and D. E. Osifo. In retrospect, what they discussed with me then can easily be referred to as 'a glimpse of the future'.

I was offered appointments by both the Department of Agricultural Engineering and the Department of Engineering Management (now Industrial and Production Engineering). I opted to join the latter, but my hands have never really left the plough of the former. In a way I have tried to locate an optimum position in the solution space.

In considering the topic for this lecture, my mind searched far and wide. I probably spent more time thinking about the topic than writing the lecture. As a young student at Government College, Ibadan, I learnt that Direction and Speed are different. While they are both important, they need to be handled independently and also in synchrony. In terms of direction, my aim is to educate on the discipline of Industrial Engineering while linking it to development and productivity, noting that all need to be in synchrony for any meaningful impact on the larger society's developmental aspirations.

This lecture is in four parts; the first is on the features of the Industrial Engineering discipline; the second on Development and the Productivity Nexus, the third deals with some of my contributions, while the fourth part concludes with some recommendations.

The Industrial Engineering Discipline

Industrial Engineering is the application of the principles of Mathematics, Physical Sciences, Social Sciences and Computing in the design, analysis, installation, control and operation of man-machine work systems with maximum productivity as the main criterion. A work system refers to the combination of people, technology and their interrelationship in such industrial operations as mineral exploration, extraction and distribution; construction, agro-allied and manufacturing. Others include such public and private service systems as healthcare, finance, transportation, maintenance, etc, (Hicks, 1977; IPE 2005).

Sometimes in the design and operation of machines and other contrivances, the man is made to adapt to the features of the machine. This usually places strictures on the operator's behaviour. However, one key attribute of Industrial Engineering training is to fit the machine to the man instead of the man to the machine. This way, the natural rhythm of the operator can be harnessed for enhanced performance. Also the capabilities of the man and his limitations are considered in the ultimate work system design.

Industrial Engineering is a relatively young discipline. Degree programmes were established only in the early 1900s. Since then, it has undergone very rapid development in both theoretical and practical concepts as well as integration into the powering of the economies of many nations..

Mr. Vice Chancellor Sir, it is noteworthy that, the University of Ibadan (UI) is the only university in the Nigerian university system running full-fledged undergraduate and postgraduate (B.Sc., M.Sc., and Ph.D.) programmes in Industrial Engineering. This has been so since 1984. Universities such as the University of Benin, Federal University of Technology Akure, Nnamdi Azikiwe University, Awka and the Federal University of Technology Owerri offer options in Industrial Engineering under some other engineering programmes.

The basic objectives of the University of Ibadan programmes include (IPE, 2005):

(1) educating and training students to have a broad engineering background to enable them to work successfully as industrial and production engineers in industries and the public service;

(2) equipping graduates of Industrial and Production Engineering with sufficient computing, communication and engineering management skills with the intent to enhance their professional growth, career leadership and global competitiveness;

(3) providing Industrial and Production Engineering graduates with sufficient knowledge and challenges of the discipline which will enable them to enter into and successfully complete postgraduate studies worldwide.

The development and running of the UI programme is based on the philosophy that rapid integration between academic studies and real-life applications in industries and social systems makes for a good industrial engineering programme. It is in following this philosophy that, in all core courses, students are encouraged to collect data and test engineering models in real-life situations.

The core industrial engineering courses can be classified into the following areas:

Production/Manufacturing. Production/manufacturing deals with the principles and techniques of the design and analysis of effective, efficient, safe, reliable and maintainable production systems. It includes such courses as Process Design, Production and Inventory Control, Quality Control, Maintenance System Design, Plant Layout and Location.

Operations Research. Operations research combines mathematical modelling techniques with the principles of optimization to identify the most effective and efficient components of a work system. Continuous Systems Optimization, Discrete Systems Optimization, Mathematical Programming, Network Flow Analysis, Queuing Theory and Engineering Statistics are some of the courses in Operations Research.

Engineering Management. Engineering management deals with the design, analysis and control of management models for complex engineering systems as the practices of engineering and of management may have grown hand in hand. It covers such courses as Engineering Economics, Replacement Theory, Technological Forecasting, Production Forecasting, Maintenance Management, Decision Theory, Engineering Organizations as well as Project Planning and Control.

Ergonomics and Human Factors. Ergonomics and Human Factors deals with the design of man–machine work systems with emphasis on worker relation to his general work environment (physical facilities, fellow workers and ambient conditions). Some of the courses in this area are Work Analysis and Measurement, Work–systems Design, Methods Engineering, Safety Engineering and Human factors Engineering.

System Analysis. System Analysis is the application of mathematical and computer modelling techniques to design and analyse complex systems. The areas covered include Information Systems, Simulation Computer and Communication Techniques.

Today, many industrial engineering programmes around the world are named to indicate a focus. Some current names include:

- Industrial Engineering
- Industrial and Systems Engineering
- Mechanical and Industrial Engineering
- Industrial and Information Engineering
- Industrial Engineering and Operations Research

- Industrial and Manufacturing Engineering
- Industrial and Management Systems Engineering
- Industrial Engineering and Information Systems
- Industrial Management Engineering
- Industrial Engineering and Industrial Management

This naming system is part of the adaptation of the discipline to cope with the challenges of the emerging digital world and the need to improve service delivery through enhanced productivity.

In summary, a graduate of Industrial Engineering is kitted to apply the skills acquired to the design, analysis, installation, control and operation of man-machine work systems with maximum productivity as the main objective.

Mr. Vice Chancellor Sir, in 1988, the Nigerian Institute of Industrial Engineers projected that about 3,000 Industrial Engineers would be required to service the Nigerian economy by the start of the 21st Century (NIIE, 1988). To date, far less than 1,000 are involved in the Nigerian economy. One would like to note that with an admission quota of about 60 students a year and an attrition rate of about 15%, it is doubtful if the real number of industrial engineers required to service the Nigerian Economy can be produced in the immediate future without some policy interventions.

Today, industrial engineers are involved in many areas of the Nigerian economy such as manufacturing, service, oil exploration, oil service, banks, academia and the armed forces amongst others. They continue to play allotted roles to enhance the standard of living of the larger society.

Productivity Systems and Development

While productivity is considered by some as the efficient use of resources to achieve set objectives (Alp and Murray, 1996; Prokopenko, 1987), others have defined it as a ratio of output to input (Heizer and Render, 1996; Swaim and Sink, 1985). Improving productivity helps to ameliorate the attendant inflationary pressures that drive the vicious cycle of increasing costs (Heizer and Render, 1996). It is noteworthy that increasing costs usually characterize the economies of developing countries, this in turn leading to a lowering of the standards of living (The Word Bank, 1993).

For any meaningful development therefore, organizations operating in developing countries must continuously endeavour to improve productivity in order to increase profitability on a long-term basis. It is of strategic importance if a competitive advantage is to be achieved (McTavish et al., 1996; Oluleye, 1987). In the case of the public sector; benefitability is the essence.

Productivity is a relationship (usually a ratio or an index) between quantities of outputs (goods and/or services produced by a given organizational system) and quantities of inputs (resources) utilized by that organization to produce same outputs (Swaim and Sink, 1985). Simply defined, it can be stated as:

Productivity = (output/input)

Once input and output measures are defined, productivity indices can be accurately obtained. However, it must be noted that there are other performance measures apart from productivity. These include (Swaim and Sink, 1985; Chase et al., 2003)

(i) Effectiveness
(ii) Efficiency
(iii) Quality
(iv) Quality of work life
(v) Innovation
(vi) Profitability
(vii) Price Recovery

Most organizations have a system designed to monitor, evaluate and control one or more of these performance measures. A productivity system is essentially a management control system. Many enterprises have concentrated on the monitoring of profitability and lately, quality. Only in more recent times has the need to monitor and control productivity been given critical consideration. Even in some more advanced countries like the United States of America, only about 30% of

their businesses had control systems for productivity in place as far back as 1980 (Sumanth, 1981).
Productivity is an important performance measure because it is indirectly linked to the standard of living of a nation in general.

Simply put, productivity can be expressed as:

$$\text{Productivity} = (\text{Profitability}/\text{Price Recovery})$$

where:

Profitability = (Output Value/Input value)
Productivity = (Output quantity)/ (Input quantity)
Price Recovery = (Output cost/Input cost)

The foregoing approach helps us to understand the perspective of productivity measures in mono-product or mono-service organizations. However, for multi-product, multi-input organizations, more esoteric models capture the same features by considering the interrelationships and relative contributions and values of both the inputs and outputs to obtain both partial and total factor measures of productivity (Grossman, 1993; Oluleye, 1998; Rao, 2000).

Many organizations are preoccupied with increasing their profitability. This may be achieved by increasing either the productivity or price recovery factor. Making gains through price recovery implies high profit margins, and thus high prices and an ultimate lowering of the level of standard of living. In order to avoid making profits through price recovery and thus lowering living standards, profits should instead be made through productivity. Large gains in productivity could in fact lead to a lowering of prices and thus enhance the general standard of living.

Within the framework of a productivity system, a productivity scheme must exist. The scheme represents a plan of action designed to improve the productivity of an organization.

It should include the following stages (Jamali, 1983):

(i) .Creating awareness about productivity
(ii) Productivity measurement
(iii) Productivity evaluation
(iv) Productivity planning

(v) Productivity improvement
(vi) Productivity control reporting

Conceptually, there are at least two major categories of productivity measures. They are:

(i) Static productivity ratios; and
(ii) Dynamic productivity indices

The productivity relationship is a static ratio when it refers to a 'snapshot' of a particular period in time. Dynamic productivity indices are concerned with successive measurements and compare one period with another. Many organizations substitute some other performance attributes for actual output and input measures required to obtain productivity ratios. These substitutes are called 'surrogate measures' because they are somewhat correlated with productivity.

Productivity systems differ mainly in the method of measurement. The method is a factor of the type of organization, or work being evaluated, nature of product or service, etc. However, whatever the measure adopted, it must necessarily represent input and output factors.

Arising from the definition, productivity ratios can be increased by any of the following actions:

(i) increasing output, but keeping input the same;
(ii) decreasing input, but keeping the output the same;
(iii) increasing output, but decreasing input

Therefore higher productivity may mean producing more with the same resources or producing at the same comparative level at lower cost. The latter is usually what most organizations attempt to achieve through cost reduction programmes, even though their objective is the increase of profitability. The adoption of new technology has also proven to be a potent weapon of increasing productivity to gain a competitive edge (Malpas, 2000).

Data on National Productivity indices are sparse. Many surrogate measures are utilized instead. Some of these have formed the basis of setting the Millenium Development goals. To enable a view of the current Nigerian situation, we consider the gross national income per capita as a surrogate productivity measure using comparative figures of some selected countries and regions (Table 1).

Table 1: Gross National Income per capita (GNI per capita), Year 2004

Country	GNI per capita ($)
Gabon	3060
Ghana	270
Nigeria	300
Botswana	3,010
South Africa	2,500
Egypt	1470
UK	25,510
USA	35,400
Japan	34,010
Germany	22,740
Canada	22,370

Source: The World Bank (2004)

It is evident that the figures for Nigeria and indeed all African countries show a lag far behind those of the European and North American regions. To catch up, the economies should be made to grow with the productivity as the growth pole.

Several factors limit productivity in Nigeria. These include (Prokopenko, 1987; Oluleye, 1999):

(i) lack of access to finance;
(ii) instability of government policy;
(iii) lack of consumable and spare parts;
(iv) energy constraints;
(v) materials supply chain problems; and
(vi) poor state of infrastructure.

These factors are usually external to the work system. It is the prerogative of the government to tackle these factors with ameliorating policies while organizations tackle internal performance impediments. Development has a productivity nexus.

The National Productivity Centre has been involved in creating the awareness on the need to improve productivity in the last 10 years. It superintends a productivity award scheme that is meant to encourage winners to strive for higher productivity. However, there is a need to institutionalize productivity measuring schemes as a means of ensuring that mandatory reports are made regarding the source of wealth created by the various sectors of the economy at both a global as well as on a firm level. This remains a challenge to the Nigerian economy if the oil-based economy is to be successfully diversified on the long run.

My Contributions

Over the years, I have been involved in research in the area of Production and Operations Management (POM) of Industrial Engineering. I have had a duality of interests in both manufacturing and service systems. Given the practical problem usually faced by POM practitioners in translating theory into practice, my focus has been to develop theoretical frameworks and decision support models for application in work systems. This has involved the development of algorithmic modules which form the platforms for Computer Integrated Manufacturing Systems (CIMS). In a way, they are necessary engines on which the diagnostic tools of productivity evaluation and monitoring are based for enhanced performance.

Given the time limitation imposed by an inaugural lecture such as this, I intend to summarize the main thrusts of my research in the following areas: Machinery Design, Service Operations, Operations Scheduling, Maintenance and Productivity Evaluation.

Machinery Design

The first engineering challenge that I faced was that of designing a rice thresher for use by the rural farmer (small-scale producer of less than 5 ha). The objective was to develop a simple and compact machine that threshes rice, limits losses and inexpensive to operate and maintain. This is against the backdrop that the traditional methods of trampling and hand beating of the rice crop have been known to lead to losses of 15–20%, of the threshed grain (Hopfen, 1977). Existing rice threshing machines also had problems of ease of haulage around the field due to their weight. The main objective was to design a thresher that would be portable and easily maneuvered around the field for enhanced operational output.

The thresher design by Oluleye and Igbeka (1984) had frames built from conduit pipes and sheet metal to limit the weight in order to achieve portability. A rope is normally tied to the thresher main frame conduit skids for easy movement across the field to threshing locations. This process replaces the traditional practice of bringing the grain to the thresher from long distances resulting in heavy losses. The drum was made from sheet metal and the beaters from bolts secured on to the drum by the use of nuts. The drum cover made of sheet metal minimizes grain losses normally attributed to scatter upon drum impact. The treadle made of mild steel bars provides the drive to the drum through the reciprocating action of a connecting bar. An inclined sheet guides the threshed rice on to a collecting tray. One useful feature of the machine is that maintenance is simple and inexpensive. Apart from the regular cleaning of the machine after use, greasing of the bearings using grease guns is the other critical function. These tasks require no special technical aptitudes (Oluleye and Igbeka, 1984). Figures 1 – 4 show some views of the rice thresher.

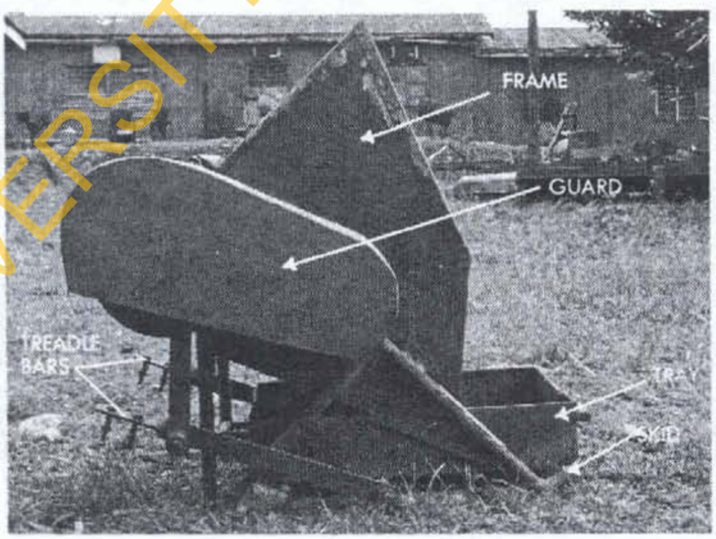

Fig. 1: Pedal Rice Thresher

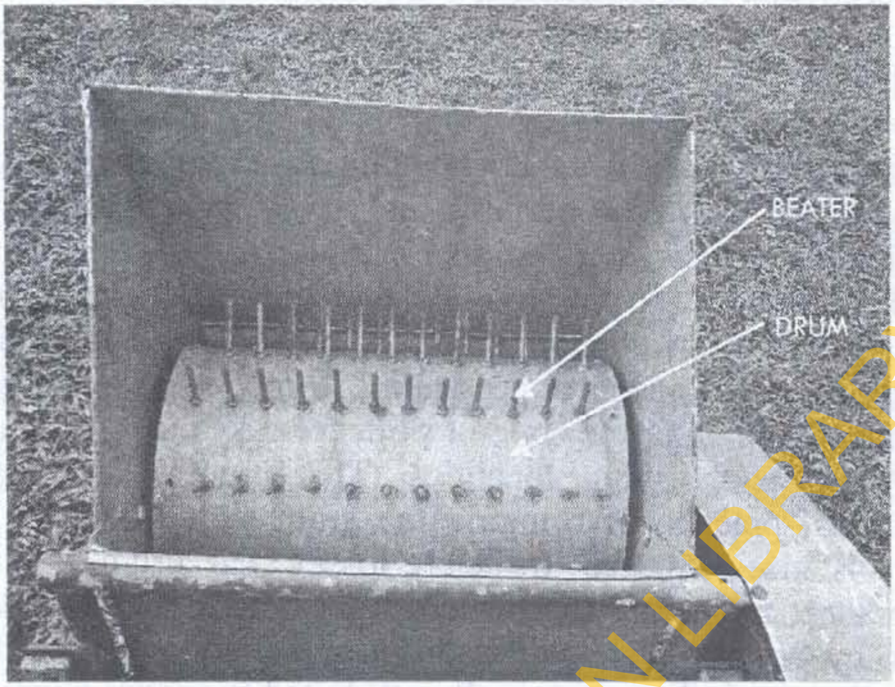

Fig. 2: Thresher Drum and Beaters

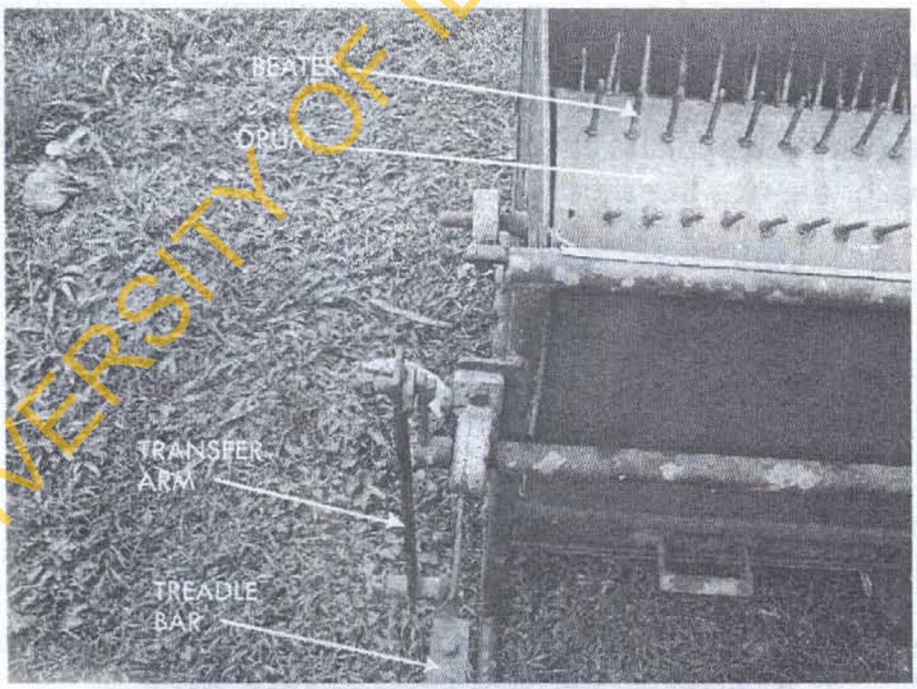

Fig. 3: Thresher treadle/Drum transfer arm

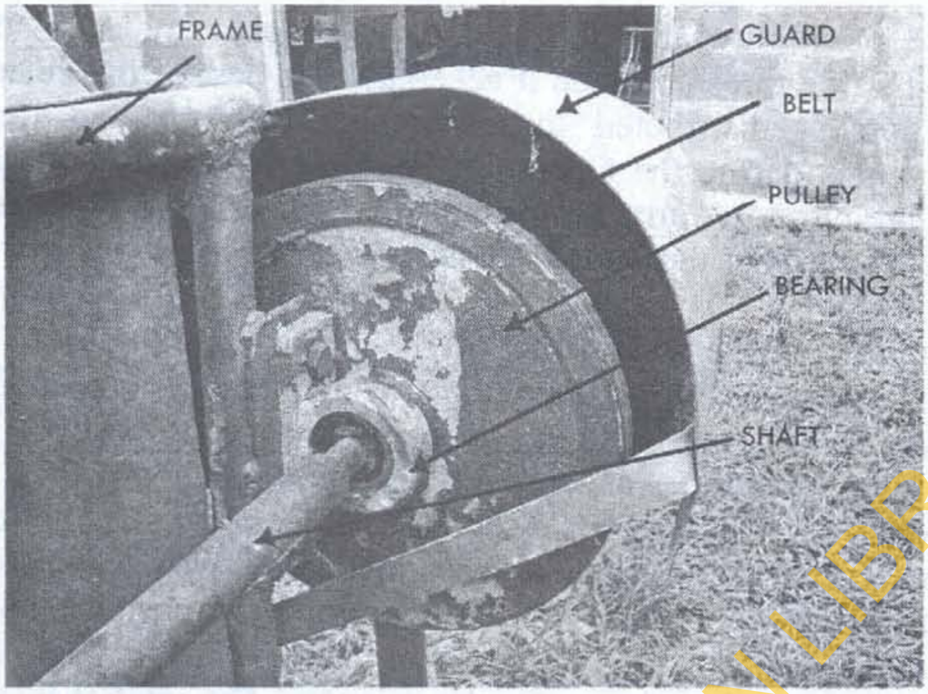

Fig. 4: Thresher Pulley Drive

Field tests showed that teams of three men taking turns at the thresher and gathering crops with each man spending 1 – 3 hours threshing was most sustainable. Treadle strokes of 64 – 69 strokes per minute produced sustainable threshing activity for over 90 minutes on a continuous basis.

Results showed that thresher output ranged between 72 – 79 kg/hr for crop of moisture content of 20.5 – 21.9% and cut grain/straw material length of 55 – 65 cm. The machine output compared favourably with the Musuhama and some other Japanese type threshers available in the Nigerian market (Table 2) (RNAM, 1980; Oluleye and Igbeka, 1982).

Table 2: Some Thresher Characteristics

Pedal Thresher Model	Weight (kg)	Output kg/hr
Musuhama	160	60
Japanese (Generic)	56	50
Oluleye and Igbeka	55	75.5

Sources: (a) RNAM, 1980
(b) Oluleye and Igbeka, 1982

The portability and high output achievable by using the prototype rice thresher made it acceptable as part of the coterie of equipment distributed to research institutions and local governments during the Operation Feed the Nation (OFN) and other agricultural programmes of the late 1970s and early 1980s. There was the added advantage of a cost reduction of 60%.

As part of the evaluation of the pedal rice thresher, an ergonomic analysis of its operation was carried out (Igbeka and Oluleye, 1986). The energy expenditure and the effect of operational posture was studied and compared to that of traditional hand threshing. Work rate and energy expenditure were measured using the heart rate method. Using ergometers with differing work loads for the operators, the corresponding heart rates were obtained. Calibration charts of heart rates and work rates were then drawn for the subjects. The relationship is given as:

$$HR = mW + Ro$$

HR = heart rate, m = slope, W = work rate, Ro = resting heart rate (was determined for each subject).

The established relationship was used to predict the work rates given corresponding heart rates after working the thresher. The average energy expenditure by weight of rice output was found to be 4.36 KJ/Kg compared to 5.18KJ/Kg for the hand threshing methods. The reduction in the energy requirement per unit weight of 19% was found to be significant ($p < 0.05$).

The bending posture assumed during the hand threshing process was found to be detrimental to health and body fitness. Most subjects complained of backache and waist pain. The operational posture essentially reduced the drudgery associated with the traditional threshing method, thus enabling the operator to work for longer hours (see Table 3).

Table 3: Machine output for different days of test

Day	Total Output (kg)	Duration of Test (hr)	Output (kg/hr)	Average Moisture Content
1	372.5	5	74.5	21.6
2	457.2	6	76.2	21.9
3	469.8	6	78.3	21.7
4	360.5	5	72.1	21.2
5	362	5	75.4	20.5
6	378	5	75.6	20.7
7	463.2	6	77.2	20.1
8	466.8	6	77.8	20.4
9	393	5	78.6	20.7
10	433.2	6	72.2	20.1

Service Operations

One of my first interactions with the detailed complexity of work systems was during my stint as the manager of the University of Ibadan petrol station. The petrol business is a high turnover, low profit margin one. Losses during the various handling stages of the product before reaching the consumer could be substantial for a dealer.

In our case, 70% of the turnover was from Premium Motor Spirit (PMS). However because of the low profit margin on petrol at that time (1.8%) the challenge of limiting handling losses became more daunting (Oluleye, 1986).

The possible handling losses were identified as:

(a) Short delivery of products by NNPC due to mal-functioning meters;
(b) Inaccurate dip stick measurements (ullage) during product delivery and subsequent operations;
(c) Possible tampering with product before delivery; and
(d) Leakage of underground tanks.

After a study of the possible loss areas, the calibration of both the delivery truck and the underground tanks was decided upon. The choice was based upon the observation that the methodology of using the opening stock, closing stock and totalizer meter readings was not a foolproof method of tracking the true value of product deliveries and pump sales. It was possible for errors in stock estimation to be carried over without detection. For a low profit-margin business, the effects are better imagined.

A recalibration exercise, which involved the use of flow meters and a correlation of the dip readings to the volume of product, was carried out. A key observation was that the intervals between which the attendants estimated stock and sales readings were too wide. It was possible for a dip stick reading (estimation) error of 1mm to lead to an error of 20 - 30 litres in a 30,000 litre underground tank (see Fig.5). By using shorter intervals of interpolation and assuming linearity over these intervals, the margin of error was cut down substantially by more than 98% using a computer algorithm that was developed for producing new calibration charts for both the tanker and the underground tanks.

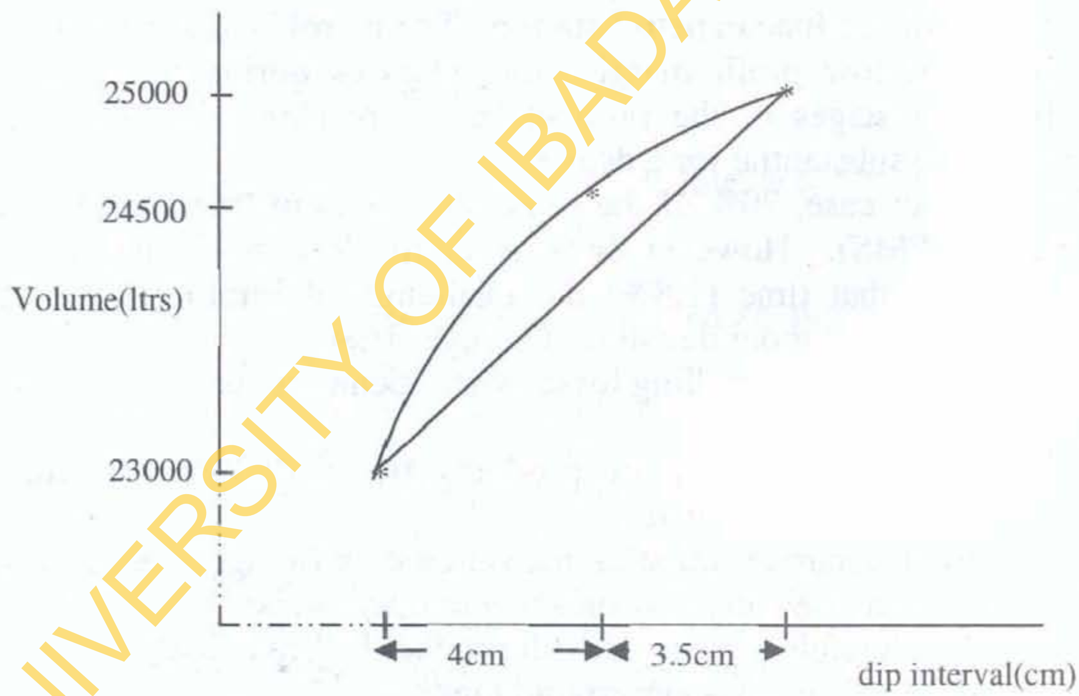

Fig. 5: Dip stick Intervals and Volumes for 30,000 litre tank

The adoption of the new methodology was to boost the turnover to more than ₦1million for the first time and increase profits by more than 136% within the first year.

Mr. Vice Chancellor Sir, over a three-year period, the station was able to operate profitably; altering the initial revenue profile to a point that consideration was given to opening up a second station on the Oyo – Ibadan road to tap the goodwill built up with customers who resided outside the University's immediate precincts. This experience brought into light the need to focus on the critical few in systems problem resolution. By solving only one of the four problems identified, operational performance and profitability were dramatically improved.

Operations and Project Scheduling

Given a set of tasks and resources, a related problem of sequencing and scheduling arises. Sequencing relates to defining the order in which the set of tasks pass through the set of processors, while scheduling is concerned with allocation of resources and determination of the times in which the tasks are to be performed. Usually, cost minimization or profit maximization is the primary objective. However, because of the complexity of the cost function, secondary criteria, which correlate strongly with costs, are often utilized. Common criteria include due date, in process inventory, machine utilization, maximum flow time, completion time of all jobs (makespan) and minimum lateness amongst others (French, 1982).

A vast number of scheduling problems remain intractable due to the computational complexity required to obtain optimal solutions. While solution approaches such as mathematical programming, branch and bound assure optimality, they usually require prohibitively long processing times to reach optimality. The search for practical solution procedures has encouraged the use of heuristic approaches which provide satisfactory solutions in good time. While not assuring optimality, good heuristics conserve expensive computer/human time while providing satisfactory results.

In order to appreciate the complexity of the general scheduling problem, consider the shop floor situation of scheduling 5 jobs on a line with 5 machines. There are $(5!)^5$ (360 million) possible schedules. An enumeration technique that evaluates 100,000 schedules per second on a computer will require over 69 hours bringing up the solution. This is a luxury, given that several of such problems would be handled in an operational setting.

Oluleye and Oyetunji (1999) studied the problem of scheduling a given number of jobs on a set of machines with the aim of minimizing the cycle time (makespan) of jobs. The desire to maximize the production and minimize the mean idle time of machines makes the makespan an acceptable measure of performance to many researchers.

Two heuristics (CDS and DAN) which had been known to perform fairly well (French, 1982) were selected. Three new heuristics were proposed—A1, 01 and 02 and tested against those selected from the literature. (see Tables 4, 5 and 6). The problem size n x m is used to represent the n job, m machine scheduling problem.

Table 4: Mean makespan of some problem sets for each heuristic (small–sized problems)

Problem Size	CDS	A1	01	02	DAN
5 x 3	371.37	385.82	392.94	370.02	
5 x 6	551.47	552.82	565.49	558.96	567.33
9 x 4	715.67	724.84	746.76	720.51	732.49
9 x 5	692.00	704.27	736.37	702.69	710.61
15 x 3	888.51	908.27	927.65	893.94	898.49
15 x 14	1096.45	1101.41	1137.06	1114.55	1125.27

Table 5: Mean makespan of some problem sets for each heuristic

Problem Size	CDS	A1	01	02	DAN
5 x 8	610.96	611.77	631.18	6.33.08	638.75
5 x 15	885.48	989.97	1004.59	996.46	1009.59
9 x 8	844.49	831.48	865.14	873.51	882.04
9 x 14	1149.49	1151.30	1180.40	1176.67	1991.04
15 x 9	1215.22	1179.85	1220.30	1261.26	1286.34
15 x 14	1518.24	1515.87	1569.12	1564.99	1583.83

Table 6: Range and mean of proportion of superior schedules for all problems

Heuristic	Range (%)	Mean
CDS	24.0-69.1	46.8
DAN	3.1-42.6	12.6
A1	26.6-64.0	44.0
01	11.7-21.7	14.6
02	8.8-62.0	25.6

It was observed that while the CDS heuristic obtained better solutions in respect of small-sized problems, the A1 heuristic obtained superior schedules for medium–sized problems (Tables 7 and 8). Statistical tests showed that the differences were significant ($p < 0.05$). Large–sized problems were not considered due to the prohibitive computer time requirement. Also, they are seldom encountered on the shop floor.

Table: 7 Mean range of proportion of superior schedules (small–sized problems)

	Number of machines				
Heuristics	**3**	**4**	**5**	**6**	**7**
CDS	69.1	45.7	49.4	46.0	54.0
DAN	42.6	27.14	19.9	13.7	15.7
A1	30.6	27.4	26.6	35.4	27.4
01	17.4	16.8	13.4	12.6	11.7
02	62.0	47.1	43.7	34.4	34.6

Table 8: Mean range of proportion of superior schedules (medium-sized problems)

	Number of Machines							
Heuristic	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
CDS	34.5	24.0	37.1	44.3	50.6	46.8	53.7	53.4
DAN	4.3	3.1	6.6	5.4	6.0	6.6	6.6	6.9
A1	62.6	64.0	60.6	58.6	48.6	47.4	42.6	41.7
01	13.1	21.7	14.6	16.6	14.0	13.1	13.4	11.7
02	10.0	8.8	12.6	11.14	15.4	16.9	17.4	19.1

The results show that while many research efforts have been geared towards obtaining heuristic procedures that produce satisfactory schedules for the general flowshop problem, what is required might be the resolution of a recognition problem. That is, problems can be classified using their complexity characteristic (number of machines) and appropriate heuristics that have been found to obtain superior schedules for each category utilized to obtain solutions. The CDS heuristic obtained superior schedules 52.8% of the time for small–sized problems as against 29.4% for the A1 heuristic, while the A1 heuristic obtained superior results 53% of the time for medium sized problems as against 43% for the CDS heuristic. The results show that while the CDS heuristic can be applied to solving small-sized problems, the A1 heuristic should be used in obtaining solutions to medium-sized problems. The other heuristics, 01, 02 and DAN obtained significantly inferior schedules. They should therefore be avoided in shop floor expediting.

The observation that solving recognition problems first before proceeding to select a solution method led to a study to develop predictive model equations for assessing the level of confidence in the expected results of some selected heuristics (Oluleye and Jolayemi, 2000). The CDS and A1 heuristics were evaluated alongside another proposed heuristic called A2. The results showed that the effectiveness of the heuristic was better defined as a function of the job size (see Tables 9 and 10) showing the values of the coefficient of determination. The key finding of the study was that if the structure of the problem is expressed as a function of the job size then, the most effective heuristic is easily determined by evaluating the predictive equations. This requires very little time, leading to savings.

Table 9: Regression equation for small job configuration ($2<n<7$ and $2<m<16$)

Heuristic	Regression Equation	Coefficient of Determination (R^2)	95% Confidence Limits of R	
			(Lower)	(Upper)
CDS	Y1=1.536 – 0.203J	0.998	0.99	1.0
A1	Y1=1.469 – 0.197J	0.999	0.99	1.0
A2	Y1=1.451 – 0.188J	0.999	0.99	1.0

Note: Y1 = Proportion of optimal makespan obtainable; J = number of jobs

Table 10: Regression equation for medium job configuration (6<n<16 and 2<m<16)

Heuristic	Regression Equation	Coefficient of Determination (R^2)	95% Confidence Limits of R	
			(Lower)	(Upper)
CDS	Y2=0.83 – 0.04J	0.91	0.94	0.99
A1	Y2=0.694 – 0.22J	0.70	0.78	0.94
A2	Y2=0.8217 – 0.033J	0.85	0.90	0.97

Note: Y2 = proportion of best makespan obtainable; J = number of jobs

As mentioned earlier, good scheduling heuristics give satisfactory solutions using minimal time related resources. Sometimes however, the optimal schedules are identifiable if the structure of the problem is well defined in respect of the job and machine size and relationships between the processing times of the jobs on the machines.

This observation was exploited by Oluleye and Awoniyi (1987) to propose a simple algorithm for solving the three-stage production process with a dominant second stage. With the second-stage processing times dominating those of the first and third stages; it was shown that once the second-stage processor starts operations, it encounters no idle times traceable to the order of jobs on the processors. Thus an optimal schedule is easily constructed directly without consideration of the other feasible schedules. This reduces the time required for determining an optimal schedule for a set of tasks that are simultaneously available.

The management of large-scale projects continues to be a challenge to most developing economies. Missed timelines and increasing cost variations are basic features of many projects. The pioneering work of Kelly (1961) in the development of the time-cost trade-off procedure for managing projects is worth noting. This procedure has undergone reviews by other researchers over time (Moder et. al., 1983; Russel, 1986). However, a key distinguishing feature between develop-ing economies and the developed is the inflation rate.

Time cost tradeoff models applied to most projects in the developed world treat the issue of inflation as not too significant in the variability of expected and final cost schedules. This is mainly due to the observation that inflation rates are low in such climes and are usually kept at single digits as a matter of policy. The same cannot be said of developing economies which boast of double-digit figures.

Jolayemi and Oluleye (1993) developed a model that decoupled equipment and material cost from that of labour using a discriminating inflation rate progression to track sectoral project cost escalations. Building on the time-cost trade-off models, it was shown that the standardized models would always underestimate actual project values in developing economies where inflation rates are high and mostly in double digits.

A strategy for limiting large-scale project costs was recommended. The key feature of the strategy is that if inflation is high, project costs and schedules are better kept under control by using crash-time values instead of standard times. The use of standard times underestimates the project costs leading to constant project cost reviews and variations in project implementation costs.

Maintenance System Evaluation

The maintenance function is usually seen as supportive of production and operational functions. It has both operational and cost objectives—equipment must of necessity be kept in acceptable operating conditions, they should be available most of the time and should serve for as long as possible. Also, maintenance expenditure should be minimized with a view to improving profit values.

Essentially, maintenance is a combination of actions carried out to retain an item in or restore it to an acceptable condition (Blanchard and Lowery, 1969; BSI, 1974). Usually a basic question arises; is the maintenance system effective? This can be answered against the backdrop of the system objectives. Maintenance performance is difficult to evaluate due to the problem of expressing outputs in tangible form. It is much easier to identify the outputs of the system as a whole or that of the production subsystem. The measurement of maintenance effectiveness enables an organization to monitor the use of allocated resources i.e. labour materials, machines, and capital among others.

While some performance measures individually focus on various aspects of the maintenance function, they do not give a sharp focus of the overall performance. This is the motivation for many researchers who have attempted to get composite values to represent the overall performance of the maintenance function (Duffuaa and Raouf, 1996). Conceptually, we could combine the measures into a single index. However, since data must first be obtained from the maintenance management information system (MMIS), it is important that one obtains as much relevant data as possible. Cycling (interdependence) effects arise when a measure or component factor is used more than once in composing an overall index. This implies a level of redundancy arising from duplicity. Ordinarily, measures used in composing indices should be independent.

Oluleye and Olajire (1999) presented a schema for identifying factors of relevance and outlined a guide as to their combinatorial feasibilities. In the development of the schema, we relied on the use of the nominal group technique (NGT). This technique utilizes a structured group approach to problem identification and solution development.

Based on the need to utilize the concept of a composite index to assess the maintenance function, Adeniyi and Oluleye (2003) studied the maintenance evaluation approaches adopted by some manufacturing companies in South Western Nigeria. The purposive sampling technique was used in order to include the dominant industries within the study area. Two companies were selected from each of Food, Beverages and Tobacco; Chemical and Pharmaceutical; Basic Metal, Iron and Steel; and Non-metallic Minerals sectors. Data were collected from the companies using questionnaires, interview, NGT interactions and review of existing records in the organizations. The companies focused more on measuring the performance of the production function to the detriment of the maintenance support function given the performance measures on which emphasis was placed (see Table 11). Indeed the key measures were related to availability, equipment effectiveness and quality of products. In order to get a balanced score card of the performance of the maintenance function, the following performance measures were utilized: work order turnover (WOTO), degree of planning (DP), and maintenance operation cost proportion (MOCP). A maintenance composite index (MCI) that denotes the effectiveness of maintenance was then computed from the values of WOTO, DP and MOCP to serve as a surrogate measure of maintenance productivity.

Table 11: Measures for evaluating production and maintenance in the companies studied

Performance Measure	**Number of companies applying measure for evaluating**	
	Production	**Maintenance**
Capacity Utilization (CU)	8 (100%)	5 (62.5%)
Line Utilization (LU)	1 (12.5%)	-
Performance efficiency (PE)	1 (12.5%)	-
Equipment availability (EA)	6 (75.0%)	3 (37.5%)
Rate of quality product (RQP)	4 (50.0%)	-
Percentage breakdown	-	2 (25.0%)
Work order turnover (WOTO)	-	3 (37.5%)
Degree of planning (DP)	-	3 (37.5%)
Maintenance operation cost proportion (MOCP)	-	3 (37.5%)
Overall equipment effectiveness (OEE)	-	-
Maintenance composite index (MCI)	-	-

While there was evidence of maintenance cost control in the organizations, this was not systematically applied for evaluating maintenance effectiveness in most of the investigated companies. Study results showed that the MCI obtained for the companies were found to be generally low (37 – 38%) as against the mean target of 78% set by the system operators. This is an indication that most of the companies had problems with:

- planning the maintenance function to focus on routine rather than emergency maintenance;
- getting work orders (repairs) done as quickly as possible; and
- keeping maintenance costs low.

The required intervention to bring the maintenance function and performance to par should therefore be in the highlighted areas.

Recently, Oke and Oluleye (2005) proposed a framework for determining maintenance effectiveness and monitoring the diagnostic interventions' alignment with system objectives while avoiding the deleterious effects of cycling redundancies that is usual in the development of composite performance indices. The framework allows system operators to develop measures that align with organizational objectives while leaning on experiential knowledge that is tacit but held captive by staff. It has the added advantage of helping to build realistic targets and goals for delimiting maintenance system performance.

Productivity Evaluation and Monitoring

Oluleye and Olajire (1999) conducted a study to assess the performance of two top production organizations. The selected companies were in the top 10% bracket considering their turn-over values in their sub-sector. It is notable that the two organizations were undergoing reforms as a response to dwindling profitability. Given this, it was decided that a key feature to be studied would be the separate effects of productivity and price recovery on profitability using the multi-factor American Productivity and Quality Centre model (APQC), (see Swaim and Sink, 1983; Rao, 2000) and a Computer based Productivity Reporting System (CPRS) developed by Oluleye (1998). Essentially, a set of matrix operations of the input and output values were utilized to determine profitability, price recovery and productivity indices.

Apart from materials and capital inputs, we also focused on labour input management as an important component of any performance improvement effort. It is noteworthy that these inputs constituted at least 65 percent of the costs in each organization. In order words, they were critical success determinants.

The first year was used as a base year to facilitate a proper tracking of trends during the reform period. A key observation was that both companies encountered profitability problems (see Table 12). The growth rates fell by about 2% for each. However, while Company I tried to improve on the profitability by raising productivity over the period by 3%, that for Company II fell by 6.2% (see Table 13).

Table 12: Profitability indices and growth-rates

Inputs	Profitability index	Growth-rate (%)
Company I		
Labour	1.03	11.9
Materials	0.61	-11.5
Capital	0.85	-3.6
Aggregate	0.97	-2.0
Company II		
Labour	1.35	10.3
Materials	0.83	-5.4
Capital	1.63	26.4
Aggregate	1.06	-2.1

Table 13: Productivity indices and growth-rates

Inputs	Productivity index	Growth-rate (%)
Company I		
Labour	1.32	7.2
Materials	1.10	1.4
Capital	1.13	1.0
Aggregate	1.17	3.0
Company II		
Labour	0.81	-6.3
Materials	0.90	-1.7
Capital	0.76	-8.6
Aggregate	0.81	-6.2

The results also showed that the long-term survival of both companies would continue to be in jeopardy as long as the price recovery component was the main focus of management intervention (see Tables 14 and 15). The reliance on price recovery is indicative that the products and services rendered are somewhat overpriced. This will inevitably lead to consumer resistance and ultimately a complete loss of the competitive edge.

Table 14: Regression of productivity and profitability indices

Regression equation		Coefficient of determination	Standard error
Company I			
1. Labour	Y = 0.96 + 0.05X	0.01	0.31
2. Materials	Y = 3.40 – 2.62X	0.59	0.18
3. Capital	Y = 1.39 – 0.48X	0.54	0.11
4. Aggregate	Y = 1.34 – 0.48X	0.46	0.12
Company II			
1. Labour	Y = 2.96 – 1.65X	0.75	0.15
2. Materials	Y = 1.77 + 2.88X	0.66	0.21
3. Capital	Y = 3.75 – 2.77X	0.53	0.54
4. Aggregate	Y = 1.12 + 0.07X	0.02	0.09

Note: X = Productivity Index; Y = Profitability index

Table 15: Regression of price recovery and profitability indices

Regression equation		Coefficient of determination	Standard error
Company I			
1. Labour	Y = 0.38 + 0.79X	0.59	0.20
2. Materials	Y = 0.07 + 0.91X	0.99	0.02
3. Capital	Y =0.42 + 0.55X	0.86	0.06
4. Aggregate	Y = 0.36 + 0.61X	0.89	0.05
Company II			
1. Labour	Y =0.55 + 0.46X	0.92	0.08
2. Materials	Y = 0.22 + 1.16X	0.97	0.06
3. Capital	Y = 0.45 + 0.50X	0.96	0.15
4. Aggregate	Y = 0.87 + 0.14X	0.21	0.08

Note: X = Price recovery index; Y = Profitability index

During the study, it was observed that the results only highlighted the possible input related interventions. This appeared to be a weakness in the intervention template. As a remedy to this, Anyaeche and Oluleye (2003) proposed a model that uses the input and output values based on matrix operations but with the results being both input and product related. The added advantage of this model is that interventions could be made not only by considering the values of productivity and profitability for the inputs alone but also for the products and services. This way, the decision of whether to discontinue a product line would be determined not only by the profitability values but by the productivity values also. This assists in curtailing any precipitate actions in the discontinuance of product lines given that access to capital and technical capacities are limited, at least in developing countries.

Concluding Remarks

Mr. Vice Chancellor Sir, it is easy to conclude this lecture with a plethora of recommended policy initiatives, but I hope to limit myself to a critical few.

The current NEEDS I document makes oblique reference to productivity especially as regards the manufacturing sector, but it fails to set a target for priming the sector. This should be amended under the NEEDS II document under review. It is when productivity and national economic growth rates are synchronized that meaningful development can be achieved.

The Nation needs to move away from talking about productivity to installing productivity schemes in the various sectoral work systems as a matter of policy with a view to measuring productivity and working towards its continuous improvement. In order to achieve sustainable development, the productivity nexus must be exploited and must be in synchrony.

More resources need to be deployed towards the training of engineering and technical personnel who would facilitate the installation of productivity schemes and perform diagnostic reviews for enhanced productivity. This group includes Industrial Engineers and other members of the engineering family who would work towards the technological development of the nation thereby enhancing the standard of living of the populace while building a great nation among the comity of nations. This is the veritable way for Nigeria to be great.

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Mr. Vice-Chancellor, I conclude by making a big confession. God has been good to me, and I give Him thanks.

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