OPERATIONS RESEARCH, MATHEMATICS AND SOCIAL SCIENCES: THE LINK

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BY

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DEDICATION

This Inaugural Lecture, like any of my works, is dedicated to the Almighty God who created me and has been taking care of me from cradle till today. Let the Glory and Honour Be Unto Him.

1.1 INTRODUCTION

This inaugural lecture as I see it is the foundation one in Operations Research. As a result it will be appropriate to devote a part of the lecture to explain what the discipline is all about and why management programmes and some professional bodies make some versions of it as compulsory courses to be offered.

I will also draw the attention of the role mathematics plays in operations research together with the usefulness of this discipline in social sciences. I am making an attempt to link these three areas, because, I am involved; just to use the words of a Nigerian elder statesman.

Fresh from having a good undergraduate degree in mathematics in 1970, I was preparing to have a career in that field. But that was not to be; I was literally "drafted" by University of Lagos to study an MBA in Quantitative Analysis in New York University in U.S.A. as an exchange scholar. (The scholarship was available and nobody was willing to take it because the programme was said to be a difficult one). Later on, I crowned it on with a PhD in the same field via an M. Sc. in operations from Department of Industrial Engineering and Management Science in Northwestern University.

After a PhD in field of Quantitative Analysis, I got employed into the Faculty of Social Sciences of University of Benin. Hence I can say that I am involved in these three areas.

Social science is a body of knowledge that deals with human society and man in his relation to other men, to the state, the family or any social group or institution to which he belongs. History, anthropology, sociology, economics, politics, geography can be regarded as social sciences. The economists will not hesitate to tell you that Business is an applied economics.

Perhaps that is why the Department of Business Administration is in the Faculty of Social Sciences.

Mathematics is the language and most potent tool of science. It is regarded as the "queen of sciences" it can be described as the study of numbers as related to space, time and motion. Many names have been given to mathematicians. They are called people who find trouble and create problems where apparently there are none. They are also described as people who engage in a subject in which they themselves do not know what they are talking about if though what they are talking about is true (Kenku, 1990).

Irrespective of the way mathematics is being ***portrayed***, what we do know is that the contemporary language of mathematics manipulates such basic notions as sets, functions and relations and describes constructions using them. Mathematics is usually laid out according to the following convention.

(a) **Definition:** This describes a new entity in terms of those that have been defined (or known) previously. For instance, in elementary geometry, a straight line is defined as the shortest distance between two points. Having defined a straight line, an angle is then defined as an inclination between two straight lines, or a triangle is a figure bounded by three straight lines.

(b) **Theorem:** This is a statement giving an answer to questions raised about these entities. For instance, having defined a triangle, we have a theorem, which states that the sum of angles in a triangle is 180 degrees.

(c) **Proof:** This gives a record of the manipulations necessary to convince that a theorem is a true statement.

The Need for Operations Research

The need for operations research started when man was driven from the Garden of Eden. Ever since, he had been confronted with numerous problems, difficulties and challenges, ranging from primitive farming to industrial revolution. This is because man's action or decision, no matter well intended will bring problem to himself, or to the other people or even to the society at large. Often new problems arise in an attempt to solve the existing ones. For instance, a person might buy a car to solve the problem of transportation; but in doing that he has created a problem of getting petrol to use, there is problem of maintaining the car, and so on. Sometimes, people come together in a group to form an association or corporate body with an objective to control financial and other resources available in order to achieve a set goal, and in the process several problems arise.

In many cases, a team of decision makers – ***MANAGEMENT*** either evolved or is created. Thus, social sciences then creeps in. However, in managing the affairs of modern business and government, managers need considerable assistance in coping with the complexity of their jobs. Unaided, the human mind cannot possibly weigh the manifold complexities involved in the development of a weapon, such as a bomb, the erection of a large office building or operation of an enterprise producing hundreds of products for diverse customer needs. A multitude of decisions go into scheduling of jobs, ordering suppliers, managing inventories, negotiating with contractors, hiring labour, pricing goods and planning production facilities. Furthermore, managers are constrained by or confronted with such uncertainties as the predictable tastes of consumers, the speculative nature of economic forecasts and research and development programmes. They are also constrained by government policies and actions of other competitors in the market. Thus, all too often, management must act largely on hunches and intuitions, wondering if the best decision was made. Hence managers need all the tools that are required to make a sound judgment. The major tool for an effective planning and for a good decision-making is ***Operations Research***.

1.2 THE CONCEPT AND NATURE OF OPERATIONS RESEARCH

The definition of operations research (OR) is quite wide and varied. This is because different schools of thought as well as operations research practitioners have argued consistently about the precise nature of their job. Nevertheless, the Operational Research Society of Britain, has adopted definition of O/R as follows:

"Operation is the application of the methods of science to complex problems arising in the direction and management of large system of men, machines, materials and money industry, business, government, and defense. The distinctive approach is to develop a scientific model of the system, incorporating measurements of factors such as chance and risk, with which to predict and compare the outcomes of alterative decisions, strategies or controls. The purpose is to help management determine its policy and action scientifically". (Stainton, 1977).

"Operations Research is an application of scientific method to problems arising in the operations of a system which may be represented by means of a mathematical model ad solving these problems by resolving the equations representing the system". (Huse, 1982). Also known as management science or

Quantitative Analysis, it is an approach that builds mathematical models and uses mathematical techniques to help organization solve complex problems.

From the definitions we found that some certain key words keep coming up. These are “scientific method”, “system”, “model”, “comparison”, and “decision making”. That is, these definitions tell us several essential features of O/R and they are:

i) Application of a model-based scientific approach,

ii) Systems approach to organization,

iii) The recognition of risk and uncertainty’

iv) Assistance to management decision making and control.

Some of these features will be discussed in this lecture. But before then let us look at a brief history of operations research.

2.1 BRIEF HISTORY OF OPERATIONS RESEARCH

The field of operations research can be said to have been in existence since the beginning of mankind. In ancient times, herdsmen sought methods of avoiding abnormal losses of their cattle. The concept of record keeping was believed to have been developed by them. For example, every morning as the sheep left the field, the herdsmen would drop one pebble into his pocket as each sheep passed out of the gate. On the animals’ return in the evening, they would be counted for by the reverse process until no pebbles were left in the pocket. Each pebble left in the pocket represented a lost sheep and action could be taken to find the animal.

In the 17th century, professional gamblers had sought ways of improving the chances of winning during gambling. As a result, they turned to Mathematicians to provide optimum strategies for various games of chance.

However, operations research really came to the fore and became established as a subject in its own right during World War II. For it was essential at that time to deploy resource in most economical and efficient ways. To ensure that this was done, a team of scientists was drawn together and instructed that they find solutions to pressing operational problems. The earliest group from Britain, then known as Blackett's circus, consisted of three psychologists, two mathematical physicists, one astrophysicist, one army officer, one surveyor, one general physicist and two mathematicians. (Glue and Thomas, 1968).

But when America entered the War, both the British and the American Military management called upon a large number of scientists to apply a scientific approach to dealing with military operations. In effect they were asked to research into military operations. Their efforts were alleged to be instrumental in winning the Air Battle of Great Britain, the Island Campaign in the pacific, the Battle of North Atlantic and so on. (Hillies and Lierberman, 1980).

Having enjoyed the euphoria success of operations research in the war, industries in Great Britain and America became interested in this new field. This was because, as the industrial boom came and specialization in organizations were again coming to the fore front, the truth then dawned on a number of people, including business consultants who had served on operations research teams, during the war, that these were basically the same problems but in a different context than had been faced by the military.

Thus O/R began to creep into industry, business and government. By 1951, it had already taken hold in Great Britain and in the process of doing so in the United States of America (Hiller and Lieberman, 1980). At the moment, operations research is widely in practice both in the public and private sectors of developed countries, like the U.S.A., U.K., Russia, France, Germany, Japan and so on. The applications of O/R are felt to some extent in developing countries such as India, South Korea, just to mention few. There are operations research societies backing its activities in these countries. In Nigeria, it has not gained ground yet, for not much of it is practiced now. However, there had been an attempt to bring it to the attention of the public. An Operational Research Society of Nigeria was formed in Lagos around 1983 it came up with one volume of its journal. The society is yet to be encouraged from either the private or public sector.

Having looked into brief history of operations, let us now touch, also, briefly the characteristics of O/R study.

2.2 CHARACTERISTICS OF O/R STUDY

Earlier on, four essential features of operations research were listed. Two important ones are discussed here. They are:

(a) the interdisciplinary approach, and

(b) systems view or orientation,

(a) A major characteristic of O/R studies is **interdisciplinary approach**. That is, O/R uses mixed teams of members of different discipline backgrounds. In other words, studies are conducted by mixed teams from diverse disciplines, such as economics, psychology, mathematics, sociology, history, engineering and other physical sciences. This might confirm the old adage which states that two heads are better than one.

The mixed teams approach has been existing since creation of the world. The Almighty God used it when He created man. For we were told that when God was creating the human being, he said "Let us create a man in our image…" (Gen 1:26) the words "us and our" connote a teamwork. But when one of this creature, Eve was confronted with a problem, she did not use this approach, hence a disaster in which we are today. For a team approach would have required Eve consulting Adam, who in turn would have consulted God, and a better solution would have been achieved.

The mixed teams approach has made operations research an outstanding new way of solving problems. This is because, prior to formal adoption O/R studies, management had always attempted to use the scientific method, had been thinking in quantitative terms and had been constructing models so that comparisons can be made. But the O/R interdisciplinary approach makes the difference; as already remarked, O/R employs teams of experts so that all aspects of a problem may be taken into account.

For instance, an industrial engineer may develop a new shop layout that will make it possible to produce greater output without any increase in either area or personnel. An O/R team working in the same plant might include representatives of several physical sciences, mathematics, and engineering, an economist, occasionally a sociologist, and psychologist. The team would therefore take into account not only the possibly of changing the layout in the various ways but the effect of all the other changes on the situation; namely, the future demand, the effect of changes on employees, the possibility of changing the design of the machines and the equipments and the various steps in the manufacturing process. All these variables and the relationships between them would be reduced to a mathematical model. Then the different possibilities and their effects on profitability would be analyzed through the use of a computer.

The lingering problems in the oil producing area of the Niger Delta of Nigeria, would have been reduced from the onset, if the oil companies operating there adopted an O/R approach. They, the oil companies, besides employing the services of engineers, geophysicists and perhaps economists and accountants, would in addition have a team of historians, anthropologists, sociologists and psychologists. This latter group would study the culture of the people in the area; their occupation, their behaviours and the effect the exploration of oil would have on their lives. O/R approach would explore alternative ways of living in the event of oil pollution. All this information would have been built into their profit models. Thus O/R team would have anticipated several problems that are possible before hand and prescribe solutions to them before the firms begin operations.

(b) **The systems view** as used in O/R pays attention to the interrelatedness of the components of the system, and to the interaction of the system with its environment. This is because, a system is a set of interacting variables, but each system is part of a larger system. For example, a single department is a system in which the variables include the procedures, the equipment, the organization structure, and the people. A change in procedures might make it necessary to get a new equipment or to change the organization structure in some way, and it might very well affect the attitude of the people in the department or make it necessary for them to learn new skills. Similarly, any change in any one of the variables is likely to affect the others, at least in a minor way. But a department is part of a larger system, that is of the company as a whole; and any change in it is likely to affect at least some of the variables in other departments. And, of course, the company itself is a part of the economy system. Hence a change in the company might affect other companies in the entire economy system of the nation.

Thus, rather than consider the effect of charges in variables in a single operation, O/R team would consider changes in variables in all operations, in the organization. This is because the optimum operation of one part of a system may not be optimum for some other parts. If a part of the system suffers a smaller level of attainment of its objectives when another part is optimized, the system is said to be sub-optimized. Thus, when a company in an attempt to maximize profit, cut off its production, reduce intake of raw materials and work forces, it might achieve its objectives, namely to maximize profit. But the entire economic system cannot be said to optimize when there are unemployment and few goods are made available to the public at higher prices. The story of Eve in the Bible is another example, where a single person's problem affected the entire universe.

2.3 OPERATIONS RESEARCH AND MATHEMATICAL MODELING: THE LINKS

A cardinal rule of the operations researcher is to build a model. The use of physical models is a common practice in industry. An architect uses small models to test new designs of a building. A model of new cars is common in vehicle industry; scale models are often used in studying plant layout. Each model is a symbolic picture that represents certain aspects of a real thing. Models can be though of a formalized way of doing things.

The distinguishing features of operations research are its uses of the applications of mathematics to real-life situations. This is the process of **mathematical modeling**. By this we mean the process of translating a real problem from initial context into a mathematical description, which is the mathematical model. That is, Operations Research links mathematics with social sciences. This mathematical problem is then solved, and the resulting mathematical solution must be translated back into original context.

In general, mathematical model may take the following form:

Optimize $E = f(x, y)$

Subject to $g_k(x, y) \geq 0$

Where

E = objective measure of the system's performance or effectiveness (objective function).

x = $(x_1, x_2, \ldots x_n)$ is a vector of the system variables that are subject to control (controllable or decision variables)

y = $(y_1, y_2, \ldots y_n)$ is a vector of the system variables that are not subject to control (uncontrollable or environmental factors variables)

f = is appropriate functional relationship, that is, it expresses the relationship between variables.

g_k = are the k conditions or constraints that the associated with system performance, in most cases they set limits for the controllable variables.

A model can be deterministic or stochastic depending on the nature of the controllable inputs.

The main stages in the modeling process can be summarized in the following steps, as shown in Figure 1.

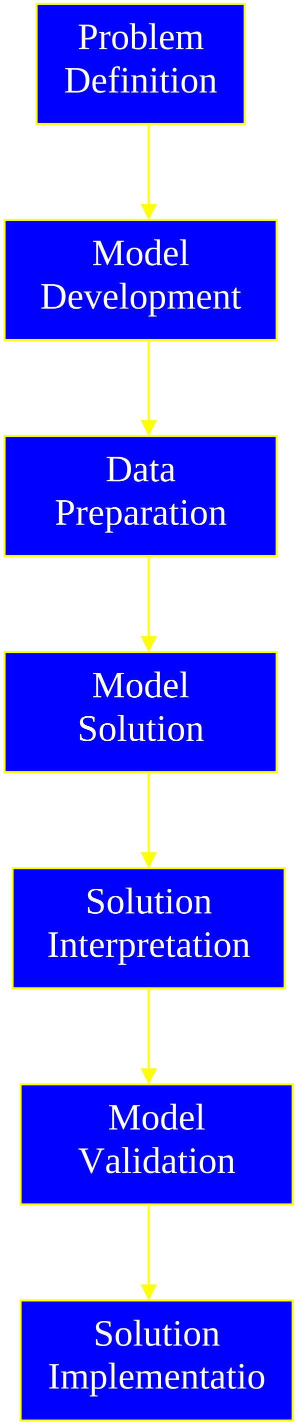

Fig. 1 Steps in Mathematical Modeling

1. Identification of or formulation of the real problem
2. Model development – formulation of the mathematical problem
3. Data preparation or collection of data
4. Model solution or solving of the mathematical problem
5. Interpretation of the solution of the mathematical problem
6. Model validation
7. Implementation of final solution and the use of the model to explain, predict, to make decision or design.

In the above process, steps 1, 5 and 7 represent the real world, while steps 3 and 4 the mathematical world; firstly the problem is simplified and formulated and secondly the mathematically solution is translated back into the real world situations. That is, the links between social sciences and mathematics are found in steps 3 to 4.

In a straight forward modeling process, one can move from step 1 to step 7 in a sequence, but most modeling is not straightforward. Hence one can go from step 6 back to step 2 when model formulated is not adequate. Or one may have to move from step 4 to step 2 when the mathematical problem is either too complex to solve or it has no solution with regards to the assumption made.

Although the above sequence is by no means standard, it seems generally acceptable. Below are brief explanations of these steps:

1. The first step requires a definition of the problem. From the viewpoint of operations research, this indicates three major aspects. They are:
   (a) an exact description of the goal or the objective of the study;

(b) an identification of the decision alternatives of the system; and

(c) a recognition of the limitations, restrictions, and requirements of the system (Taha, 1976)

2. The second step deals with the model construction. Depending on the definition of the problem, the O/R team should decide on the most suitable model for representing the system. Such a model should specify quantitative expression for the objective and the constraints of the problem in terms of its decision variables. At times, the resulting model might fit into one of the common mathematical models, and in this its solution can be obtained by using corresponding mathematical techniques. If the mathematical relationships of the model are too complex to allow analytic solutions, a **simulation** may be more appropriate. Some cases may require the use of a combination of mathematical, simulation, and **heuristic** models.

3. The third step is the collection of data to be used in the model. Many models fail to achieve their purpose because of inaccurate or incomplete and biased data. Here the accountants and perhaps the engineers in O/R team are required to provide the information in quantitative forms to the model. The data involved are the uncontrollable variables or the parameters.

4. The fourth step deals with solving the model. In mathematical models this is achieved by using well-defined optimization techniques and the model is said to yield an optimum solution. If simulation or heuristic models are used, the concept of optimality is not well defined and the solution in these cases is used to obtain approximate evaluation of the measures of the systems.

5. The fifth step is that of interpreting the mathematical solution back into the original content. At times O/R team may be carried away by using the notations used in solving the mathematics in reporting back the solution. Such practices are to be discouraged, since the customers you are providing the solution to may not understand your technical terms.

6. The sixth step calls for the checking the validity of the model. A model is valid if, despite its inexactness in representing the system, it can give a reliable prediction of the system performance. A common method for testing the validity of a model is to compare its performance with some past data available for the actual system. You may ask yourself "does the mathematical solution of your model make any sense". I tell you a "class room example". In our MBA programme where I teach statistical analysis, we normally go down to elementary topics before moving up to harder ones. In teaching frequency distribution, we discuss topics such as methods of location like quantities, deciles and percentiles. Rather than asking the student to compute specific percentiles and so on, I bring some managerial decision problems. One specific example has to do with the age distribution of workers in an organization. The age ranges from 18 years to 65 years. The first question I asked was to determine the minimum age of permanent staff if the youngest ten percents of the group were casual workers. The answer of course is P_{10} which happened to be 26 years. When I then asked that management wanted to retire five percent oldest workers in the organization, I was given the answer of 23 years. The question then is, how can some enter the organization at the age of 26 years and retire at the age of 23? Is this model valid (what the students did was to compute p_5 instead of p_{95}). Even though O/R models are computer oriented, we have to check the soundness of the

programmed logic so that the model's structured components can be verified before undertaking experimentation with the models.

7. The final step in mathematical modeling deals with the implementation of the tested results of the model. The burden of executing these results lies primarily with the operations researchers. This would basically involve the transaction of these results into detailed operating instructions issued in an understandable form to the individuals who will administer and operate the system after its execution.

2.4 MODELS AND ASSUMPTIONS

One needs to dwell a little on this area, because of sarcastic remarks non-operations practitioners make about models and theories. Models can be though of a formalized way of doing things. (Agbadudu, 1996). All models have a set of assumptions with which they operate. An **assumption** is a principle that is accepted to be correct without proof. Therefore, whatever good results or achievements obtained from a model depend on the fact that any of the assumptions for the model have not been violated. Once one or any of the assumptions is violated the model will not work. For instance, in our country, Nigeria, a motorist is supposed to keep to the right lane while driving, that is, we are talking of a right-hand drive model. The underlying assumption here is that all vehicles will keep to the right lane. But when this consumption is violated, the result is traffic hold up, accidents and so many unpleasant happenings. This is because if a vehicle or set of vehicles decides to take left lane instead of the right one, it or they are bound to cause confusion to oncoming vehicles in the opposite direction. Majority of the accidents happening on Nigeria roads are as a result of violation of this right hand drive model.

Also, a four-year degree programme in a university assumes, among other things, that a student that enrolls in that programme will pass all the prescribed tests or examinations for each level or year, for him or her to graduate in the fourth year. If the student skips, at least, one of the examinations or tests in a particular year, he or she cannot graduate in the fourth year. At times, one or more assumptions to a model can be relaxed or changed. You will still get a result. But this result will be different from the first result when original assumptions were not changed. For instance, in our own days, to enroll in a university degree programme, one needs to have five credits in West African School Certificate (WASC) or equivalent in one sitting. Nowadays, that assumption or condition had been relaxed or changed to five credits in two sittings. People still graduate from universities with this condition, but is the result still the same as we had earlier?

Mathematical model like any other model will have a good result if its assumptions are not violated. Being a scientific approach to solving problems and acquiring knowledge, it hinged on, among other assumptions that nature is orderly and regular. This assumption indicates that there is regularity and orderliness in the universe and its operation. This is because, events do not occur haphazardly. It is assumed that night follows day, rainy season follows dry season, the moon and the earth move on their regular path. This observable regularity and orderliness indicates that nature is orderly and therefore could be empirically studied and understood (Oyibo, 1992). The assumptions about nature are useful in planning. But if nature seems to violate one of these assumptions, we may be in for a big problem or a disaster. For if, dry season follows dry season, there will be draught, and farmers may not be able to produce enough food and hence, famine.

3.1 THE LINKS: SOME EXAMPLES

To a majority of students of elementary mathematics about two decades or so back, the phrase **Applied Mathematics** means that branch of physics called Mechanics. This was not only because **Mechanics** was taught to them, but also because it constituted a major part of the contents of books on Applied Mathematics. In addition, the impression tended to be created that mathematical expressions and equations were important only in physics, chemistry, and more especially engineering courses. So, it was not a surprise in the early 1960's that most students of social sciences and business, when asked to take mathematics as one of their degree courses, tended to wonder why they should offer that subject. They also questioned the wisdom behind it. The popular question then was "why should we take mathematics? Now, put it in these ways: Has mathematics anything to do with business and social sciences? Or, what are the uses of mathematics in business? Is there any link between mathematics and social sciences?

We shall give two reasons why those questions were asked, and devote the remaining section to two basic examples. First, at that time, those who were in business or social sciences, were being asked to take some mathematics courses offered in the Department of Mathematics. For instance, in the 1976/78 academic year at the University of Lagos, Part I (or year two) students in the Faculty of Social Sciences were required to register for a Mathematics course taught to the preliminary (Advanced Level) students of the Faculty of Science. This being a regular course in the department of Mathematics, was tailored to the needs of Faculty of Science students and tended to include little or no business and economic applications of the materials covered in class. Instead, most of the examples were drawn from science and engineering. Consequently, students from the Social Sciences were very often at a loss. As one of them put it, “all we have been studying here is XYZ”.

Secondly, as stated by Agbadudu (1978), business of management mathematics was not one of the conventional commercial subjects like Banking, Accounting and Marketing. It was introduced into business on an ad hoc basis. Hence, it was used where useful and fitted as best it could in the business curriculum without formal expression in the existing organizational framework.

As for the question of whether mathematics is relevant in the business and social science world, we would say, as we have argued earlier (Agbadudu, 1972) that even pure or abstract mathematics can be applied to any field of knowledge. It is used very often by management in the decision making process.

Two Basic Examples

One of the mathematics that is normally introduced to students of Social Sciences is **matrix and matrix algebra.** The general application of matrix is the **matrix equation:** AX = B.

It is shown that if the inverse A exits then the solution to that equation is

$$X = A^{-1}B.$$

One of the earlier applications of matrix equation in physical sciences or engineering is Kirchhaff’s Voltage Law. It states that:

"The algebraic sum of the RI voltage drops in one direction around a loop equals the algebraic sum of the voltage sources in the same direction around the loop"

In other words,

$$RI = V$$

where the voltage V is measured in volts, the Resistance R in ohms and the current I in amperes. Assuming inverse of R exists, then the current, I is given as

$$I = R^{-1}V.$$

Yet another application in this area is the Hooke's Law in Physics. It is about a horizontal elastic beam being supported at each end and is subjected to forces at various points. In terms of matrix equation

$$AX = B,$$

This law can be written as

$$DF = Y.$$

Where

D = is the flexibility matrix

F = vector of forces that beam is subjected to, and

Y = is a vector listing the amounts of deflection of the beam.

Assuming the inverse of D exists then

$$F = D^{-1}Y.$$

The inverse of D is the ***stiffness matrix***. More and more examples in physical sciences and engineering can be given. As a result, one would feel that there was no links between mathematics and social science.

However that picture changes in this area of matrix equation, around 1949, when an economist, and a Harvard Professor Wassily Leontif introduced input-output models. The professor came out with these models with assumptions which include that each economy can be broken into n sector (or industries) with each sector producing one product. And that an output in one sector can be or an input in another sector (including the sector itself). There are some outputs that are used outside the industries. In the simplest form, he came out with an equation

$$X = Y + D$$

Where X is the vector of output in each sectors, Y is the vectors of inputs required in the industries and D is the vector of final demand, output used outside industries, such export and household demands. Further assumption shows

$$Y = AX$$

where A is the **consumption matrix**. Hence the above equation becomes

$$X = AX + D \qquad \text{or} \qquad X - AX = D$$

which is

$$(I - A)X = D$$

Solving we have $$X = (I - A)^{-1} D.$$

The inverse of I – A is the **matrix of interdependence**. This is the matrix describing the final linkage of one sector with another, an important tool in economy planning.

In that year (1949) when the professor was doing this work, he came out with 500 sectors of U.S.A. economy. But because the faster computer then which was Mark II, could not handle 500 equations, he had to aggregate this to 42 sectors so that 42 equations could be solved. It took 56 hours by the computers before a solution came. (Lay, 1997).

This work has thrown the door open for several research works in this area. One of my earlier PhD students, Dimowo worked in this area, applying to the model to the Nigerian economy. Still using Nigeria data you can get more information on this in (Agbadudu, Ogunrin and Ighomerho, 2004).

Input-output models have brought an avalanche of research in the use of matrix equations in social sciences. These applications include accounting where variant of models in **Reciprocal Cost Allocation** and in economics, model of **Balance of Trade** are used. These are abound in current literature as can be seen in (Agbadudu, 1998).

Another major area of mathematics that is taught to students of social sciences students in **calculus**. In differential calculus, various applications in physics and engineering are abound. For instance, we are told that derivative of distance with respect to time gives **velocity (v)**, and that if you differentiate distance second time with respect to distance you obtain **acceleration** (A). In other words,

$$\frac{ds}{dt} = V \quad and \quad \frac{d^2s}{dt^2} \quad = \quad A$$

Going a little further you are introduced to some Newton's laws and Kepler's laws. For instance, Newton's second law as applied to a particle of constant mass m can be written as

$$\mathrm{F} = \mathrm{m}\frac{dv}{dt}$$

Where F is force, v, velocity and t, time. With some examples given this area, one will feel attain that there is no link between calculus and social sciences.

However, what operations research practitioners see here is rate of change. This is **marginal analysis**. The question here is how can this powerful mathematical tool be linked to social sciences? The answer lies among other things, at the rate of change in revenue, cost, utility and so on. For if you differentiate revenue with respect to output you have marginal revenue, if you differentiate cost with respect to output you get marginal cost, and so on.

Going further, the economists were able to demonstrate, using calculus that if the motive of a firm is to maximize profits, then this is achieved when marginal revenue equals marginal cost. They further tell you that when cost is minimized it is equal marginal revenue. Other results include the situation optimal utility obtained, when the ratio of the prices of two goods concerned equals the ratio of their marginal utility.

A lot of works has been done in these areas of calculus, which yield fruitful results. For instance, making use of the marginal analysis approach, together with Kahn-Tucker conditions, I was able to demonstrate that if an organization is to stay in business, it has to equate its demand with production output (Agbadudu 1985). With the aid of differential calculus I also came with a tax model of pay as you use (Agbadudu, 1983).

4.1 BENEFITS OF USING THIS LINK: OPERATIONS RESEARCH

When operations research models are properly utilized by the organization, their advantages are numerous. A very relevant one is that it provides a frame of reference for considering problem confronting the organization; that is, the O/R model indicates gaps which are not apparently immediate. Upon testing the model, the character of the failure might give a clue to the model's deficiencies.

Some of the greatest advances in science might have resulted from the failure of a particular model.

From a cost and time point of view, a complex problem can be expressed in a mathematical model that will allow the organization or the individual to change parameters without undertaking actual construction of the project. For example, the use of a model can avoid a placement of plants and warehouses which does not best meet the present and future needs of customers. The results can be obtained with a relatively short time as opposed to waiting a much longer time for the completion of the project and actual day-to-day operations.

Once a problem is expressed in mathematical notation and equation form, there is the advantage of the manipulative facility of mathematics. Thus we can insert different values of the parameters into the mathematical model and study the behaviour of the system. If properly undertaken, statements about the sensitivity of the system to a change in any of the variables can be made. Also, the symbolic language offers advantages in communication since it allows a precise statement of the problem as opposed to a long verbal description.

Operations research models, which allow one to predict based upon past or present information can be utilized for training purposes. This allows trainees to see the results of their decisions with having to make the actual decision. By using a model, a wrong decision on their part will affect the organization's actual position. Models also allow the trainees to examine cause and at relationships that may not readily be apparent.

Mathematical models have the ability to expose the abstraction in a problem. That is, in considering a complex world, the individual is made to select those attributes and concepts that are applicable. The model indicates what data should be collected to deal with the problem quantitatively, and a computer can be used to manipulate the major variables and factors of the model, which facilitates an understanding of the effect each has on the other.

It is more difficult to cheat conclusion with mathematical model. The results of a mathematical debate are precise and depend only on the initial assumptions. For a given set of assumptions, the mathematical conclusion are accurately expressed, and their results cannot be argued. It is the assumptions that can and should be criticized. Also with a mathematical description, it is possible to arrive at optimal solutions which would not be obvious without analysis.

Embracing operations research discipline widens one's thinking horizon. That is, one can reason beyond one's nose. Thus, when an action is taken, one will be able to know that there will be several possible reactions, and hence could prepare for any one of them. Operations research, via some theories, enable us understand that certain phenomena are normal and usual. One can also detect abnormality in an organization very fast. For instance, sometimes in the 1980's a Department presented final results in the Faculty Board, with a candidate having a first class. The candidate's GPA was 5.08. A colleague of mine, who was my student then, detected this abnormality immediately, and I agreed with him. The argument was that, since a maximum point for a course was 5.0 there was no way an average would be greater than a maximum point. The mistake was later discovered.

For instance, when you have a crowd such as we have today, there is a possibility that someone now has a headache, has just lost a relation a few weeks or months back and so on.

I serve as an examiner in a public Examination Board. Each year we gather together to award marks; the process was usually done manually. However, at the era of I.T the secretariat staff experimented with computer, which was good. In the first set of results, a colleague with O/R discipline detected a mistake. He saw in the results, that there were many students with 100 percent in the English column. This was not possible, for, in the English paper, there were three essays to write, a comprehensive section, and so on, and there was no way a candidate could have scored a 100 percent. The programme was checked and mistakes discovered. One can give other examples.

At the elementary stage, when we teach courses in O/R, students are normally exposed to subjects like calculus, matrix algebra, linear programming, basic statistics, and so on. It is not that upon graduation they will be "differentiating" or "integrating" functions in their respective places of work. Rather such subjects aid them in their thinking and making a sound decision. For instance, if someone presents a set of data in a form of percentage, all you need to do, is to check whether the percentage add up to 100; if not, any analysis based on it is wrong. In all organizations, O/R team can devise a measure to monitor whether that organization is doing well or not. Thus, there are a lot of benefits to be achieved here.

However, benefits may not be always achieved because of the following reasons:

a) inaccurate, incomplete or biased data
b) wrong choice of model
c) inaccurate or incomplete specification of variables
d) poor interpretation and/or implementation of results

Otherwise the power of mathematical modeling (in O/R) to ensure efficient utilization of finance, time, labour and materials is well noticeable in any organization.

4.2 SOME CONTRIBUTIONS IN THIS DISCIPLINE

My contributions to operations research can be categorized into two folds. First, it has to do with a few people I have introduced into this discipline by the fact that I supervised their PhD in this area. The second one, is some works I have done here so far.

4.3 SOME Ph. D SUPERVISION

The following people had been introduced to operations research by their Ph.D thesis, which I have supervised. They are:

1. Dr. Edward N.S. Shiwa of the University of Dar-es-salaam, Tanzania. We used Goal Programming Techniques. It was deterministic model.
2. Dr. F.A. Dimowo – We used input-output with Linear Programming method, also a Deterministic model.
3. Dr. S. Uynimadu – His work was Bi-matrix and Game theory. This can be regarded as Stochastic model.
4. Engineer Dr. Y. Lawal of NIFOR – His work was on maintenance and Reliability. This was strictly on Stochastic model.
5. Dr. (Mrs.) M. I. NWOYE – Her work was on production, a mixture of Deterministic and Stochastic models.
6. Dr. J. A. Alumonal – Factor Utilization Problem – stochastic models.
7. Dr. Aigbokhabholo Oziegbe – Production Functions; a mixture of Deterministic and Stochastic models.
8. Dr. R.O. Akingunmola – Finance Problems; Stochastic models.

Others that might fall into this category, because I was involved in the sense that I was co-supervisor (or second supervisor) include:

a) Dr. B.A. Agbanofoh – Marketing problem; Deterministic and Stochastic models.
b) Dr. G.C. Eheduru – Computer programming; this was a mixture of Deterministic models and Stochastic models.
c) Dr. A. Amadasu – Finance problem: Linear Programming Technique, Deterministic model.
d) Prof. R. O. Abiola – Marketing problem; Deterministic and Stochastic models.
e) Dr. R. Iyasere – Finance Problem; a mixture of Deterministic and Stochastic models.

4.4 OTHER FORMS OF CONTRIBUTION

Few of my works are mentioned here. There is a major one that I regarded as a break-through, (Agbadudu and Balachandran, 1998) and is briefly described here.

The work is on linear programming problem on large scale system. For, different management applications have been successfully modeled as large-scale linear programming (LP) models in more than three decades now. Agbadudu (1977) has specifically shown that applications relative to plant location, maintenance scheduling, assembly line balancing, machine loading, capital budgeting and capital rationing problems to be modeled as large-scale linear programmes. But these models usually contain a special structure in the constraint matrix that can be exploited computationally. It was shown that these constraints have special forms that are referred to as **generalized upper bounding** (GUB) and **variable upper bounding** (VUB) constraints in addition to the conventional constraints common to any LP model. We say that an LP model is defined to have a GUB constraint if it has a constraint of the form:

I. $$\sum_{iES_j} x_i = 1 \quad for \quad j = 1,2,\ldots,m_2$$

furthermore, if an LP model has a constraint of the form

II. $$x_j \leq x_k$$

We say that LP model has a VUB constraint.

What we did was to propose a methodology for solving an LP models that contains both GUB and VUB constraints. Specifically we were concerned with linear programming problems of the following form

Maximize Cx

Subject to: wx = p(m_1 rows)

$$\sum_{iES_j} x_i = 1 \quad for \quad j = 1,2,\ldots,m_2 \text{ (}m_1\text{ rows)}$$

$$x_j \leq x_k$$

The existing literature has shown methodologies for resolving LP problem either the first set of m_1 constraints and the third set of m_3 constraints, but not both. Their approaches had been one working basis. Our method was for two working basis to accommodate both GUB and VUB constraints.

After two theorems and a collary we were able to demonstrate that it was possible to have a – two working or reduced basis. The method was found to be more superior to the existing ones where s_j is an index set of GUB constraint.

This theory was first introduced in ORSA/TIMS Georgia conference of 1978. After two decades of perfection it has now been accepted as truth, and it appeared in a chapter of an advanced text book of operations research in U.S.A. (see Agbadudu and Balachandran, 1998).

This work strictly is a deterministic model. Other deterministic models include (Agbadudu, 1987), where I worked on inventory model with negative costs; (Agbadudu and Donwa, 2000) where we looked into common overhead allocation via linear programming model. As for stochastic models, one can highlight an example or more here. They include (Agbadudu, 1984) where I estimated market share of three major barks in Benin City, (Agbadudu, 1985), where I looked into price control and roadside petrol sellers in Nigeria, and (Agbadudu and Ogunrin, 2006) where we examined why Aso-Oke is always used by people.

5.1 ACKNOWLEDGEMENTS

Words are usually insufficient to express gratitude for assistance of various kinds one has in life time, but all the same one has to say thank you. First, I must thank the Almighty God who is my creator, and who has taken the trouble to take care of me from the cradle up till now.

He takes the credit for all the success I achieved in my life, and therefore I give Him all the Glory. I also thank all of you who are present in this inaugural lecture.

I also acknowledge the role of the following people played in my lie too, even though they are no more living. they are my parents, Chief Agbadudu Okrakpotsa and Mrs. Ajendono Okrakpotsa who paid my school fees in the secondary school, instead of building a “block house”, my Uncle Mr. Akpolophi Okrkpotsa who translated my primary school readers each time I had a new lesson; my older brother, Mr. Victor U. Awarien for accommodating me while I was in the college and my first cousin, Mr. Daniel A. Okrakpotsa – Kameta for helping out occasionally with school fees. I note the role played by Prof. O. J.

Fagbemi, former Head of Department of Mathematics, University of Lagos who introduced me into Quantitative Analysis, and Alhaji Fatai Durotimi-Etti who not only found me admission into a university, he made sure I got a scholarship along with it. I dedicate one of my textbooks to him.

As for the living, I wish to thank first, my wife, Mrs. Alero Emily Agbadudu and our children Doro and Ejiro for their understanding and constant encouragement. I dedicated my economics textbook to her (my wife).

It is not possible to name here friends and acquaintances who have made the past few years enjoyable and interesting even during those times which were particularly frustrating. Special thanks are given to Profs. A. Akerele, A.G. Onokerhoraye and P. O. Sada for their conviction in my humble ability and worth. I dedicated my statistics textbook to these gentlemen.

I wish to thank my PhD supervisor, Prof. V. Balachandran of Northwestern University, Evanston, Illinois, U.S.A. and Prof. F. Murphy of New York University, New York for helping out in my graduate degree programmes.

Many thanks go to all the Vice-chancellors that had been in power since I have been working in the University of Benin for more than 26 years now. I am grateful to Prof. Adamu-Baike, who, employed me as a senior lecturer and made me Head of Department of Business Administration in 1981 when I was just under two years here. I am also grateful to Prof. Grace Alele-Williams who re-affirmed the action taken by her predecessor, by appointing me in 1988, again as the Head of Department of Business for two years. I was then an Associate Professor. I thank too. Prof. A. G. Onokerhoraye who confirmed the actions taken by his two predecessors, by appointing me in 1997, the Head of Department of Business Administration when I was already a Professor. I am grateful to the Almighty God that during the reign Prof. A.R. Anao, I dabbled into the politics of deanship in the Faculty of Social Sciences, and God said I won. He, God, stood by me during the turbulent years I was the Dean of the Faculty.

I thank the incumbent Vice-chancellor Prof. E.A.C. Nwaze who, inspite of the way I was portrayed by his immediate predecessor he still finds me worthy to be appointed as Head of Department. I thank him for his peaceful reign.

It is difficult to mention all the names of relations, friends and acquaintances who in one way or the other, have been useful to me. To mention few names, more, I wish to thank Professors Otakpo and Ogunde, and Dr. Chiegwe for our adult jokes. To Prof. F.C. Okafor, I thank him for being among those who supported me during deanship days in the Faculty. I am grateful to the youths who came to my rescue when I was attacked by armed robbers in October 2002. I wish to use this opportunity to apologize for anyone I might have offended. This becomes necessary for it is difficult to please everyone at all times. One incident, I remembered was a situation where a senior lecturer attended an interview for a position of an associate professor and scored two, out of five, in interview performance. As H.O.D, I objected to his being given that position. That didn't go well with my immediate boss. This matter was reflected in a recent publication. I thank all the staff: academic and non-academic of my department and my faculty, and indeed the entire University. I also thank all the students, undergraduate and postgraduate that I have taught in the following universities. Bayero University Kano; Bendel State University, now AAU, Ekpoma, Delta State University, Abraka, Federal University of Technology, Akure; University of Lagos and University of Benin. May the Almighty God bless you all.

Finally I thank our supreme God who created all of us.

6.1 CONCLUSION

One aspect of activity of human being, whether he is by himself or in an organization, is decision-making exercise. I have tried in this lecture to show that the discipline operations research, is a useful tool for that exercise. That is, it links mathematics with social sciences even though O/R came to force as a subject of its own after the second World War, it has gained prominence in all areas of economic system of a nation. The developed countries adopted it both in the private and public sectors. This is because the major problems that may confront an organization from time to time include the following:
(1) Allocation; (2) Inventory; (3) Routing; (4) Replacement; (5) Queuing; (6) Sequencing and coordination; and (7) Search

But these types of problems are susceptible to O/R solutions via its techniques, like linear and non linear programming, game theory, network analysis, dynamic programming, statistical analysis, and so on. The reasons why O/R is useful here is because of its major characteristics which are as follows;

- examines the functional relationship from a systems overview;
- utilizes the interdisciplinary approach;
- adopts the planned approach;
- uncovers new problems to study.

6.2 RECOMMENDATION

The study of operations research in higher institutions in Nigeria should be more embracing, by establishing a department of its own. The current practice now is to offer some course in O/R in the Departments of Buisness

Administration, Economics, Mathematics, Production Engineering, and Computer science. What I advocate here is that there should be a degree awarding programme both at the undergraduate and post graduate levels for O/R.

In this way its pact will be felt both in the industry and in the government circles, as the graduates in this field will be forced to practice their trades where they are employed.

Government should establish Operations Research Department or a division in the presidency. At the moment, we have office of statistics; I feel this is not adequate, because majority of its activities has been devoted to gathering data and a little of model building in general. Hence a department of operations research, with office statistics as a section will be of better use to the society.

Private and public sectors should adopt this discipline in a formal way not only by establishing an office for it, but should use its research and findings. Finally, I believe, since truth cannot be suppressed, decisions made with O/R will actually set people free. Thank you.

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ABOUT THE AUTHOR

Professor Amorosu Burutu Agbadudu was born in Omosomo-Ewu Urhobo to Chief Agbadudu Okrakpotsa and Mrs. Ajenadono Orakpotsa of the blessed memory. He started his primary school at C.M.S school, Omosomo-Unurhie, Ewu in 1954 and after two double promotions, he finished in 1958. In 1959 there was this debate or argument whether he should attend secondary modern school which was in vogue at the time or college that had a longer duration. The young Agbadudu chose college and he was sent to an elder brother in Lagos for college education. The brother got him admitted into Lagos City College which he felt was cheaper and the parents could afford. So, he attended the Lagos City College from 1960-1964 where he got his School Certificate. In 1965, he got admission to the Federal School of Science with a Federal Scholarship to read his A-level, which he finished in 1967. The same year, he got another Federal scholarship to read mathematics at the University of Lagos where he graduated in 1970 with a second class upper and won the Dean's prize as the best graduating student in the faculty. In 1971, the University of Lagos persuaded him to go for M.B.A Quantitative Analysis in New York University, U.S.A., an American scholarship as an exchange scholar. He finished the programme in 1972. A year later, he got a teaching assistance to study Operations Research at the Department of Industrial Engineering and Management Science, Northwestern University, Evanston, Illinois, U.S.A., where he obtained M. Sc. in Operations Research. In 1974, the government of the defunct Mid-Western Nigeria gave him another scholarship to study for his PhD at Kellogg Graduate School of Management, Northwestern University. He obtained a PhD in Managerial Economics and Decision Sciences.

Professor Agbadudu's teaching career in tertiary institutions started in 1976. He was a part-time instructor both at Illinois Institute of Technology (IIT) where he taught Operations Research, and Chicago State University where he taught Economics. He took up a full time teaching job at Bayero University, Kano in October, 1977 as Lecturer I. After a brief stay at the Centre for Management Development (CMD) in Lagos, he was appointed a senior lecturer by the University of Benin in 1979. He rose to the position of full Professor in October, 1989.

A two-term Dean of Faculty of Social Sciences (2000 – 2004), Professor Agbadudu had been Head of Department of Business Administration on four different occasions. He has taught courses from undergraduate to post-graduate programmes in the University of Benin and six other universities. He has supervised more than 200 (two hundred) M.B.A projects and supervised 13 (thirteen) PhD students that have graduated. His teaching at the University of Benin spanned several departments. They are Business Administration, Accounting, Economics & Statistics, Production Engineering and Mathematics. He has over 40 publications to his credit. They include ten textbooks currently being used in tertiary institutions, some chapters in textbooks and papers in scholarly journals published locally and internationally.

Professor Agbadudu has served as external examiner to the University of Dar-es-Salaam, in Tanzania, University of Ghana Legon, Ghana and several Nigerian Universities that include A.B.U. Zaria, University of Lagos and University of Jos. He is also an examiner in statistics for the Nigerian Civil Service Examination conducted by Administrative staff College of Nigeria (ASCON), Topo Badagry. He has served as team leader of N.U.C accreditation exercise. He was a member of Council, College of Education Warri.
Professor Agbadudu has been a member of several committees in the University. They include Housing Committee, Central Entrance Examination,

Budget Estimate Committee, A & P Committee Academic and Non Academic, and many others.

He is a member of Operational Research Society of Nigeria, Member, Statistical Association of Nigeria. He is also a member of Nigerian Academic of Management, and Member of New York Academy of Science. He was awarded Justice of Peace in 1996. Professor Agbadudu is married with children.

SYNOPSIS

Human endeavour no matter well intended always brings problem to the society. Operations Research uses mathematical technique to solve individual or organizational complex problems. It is the link between mathematics and social sciences. This discipline, unlike conventional subjects like marketing, finance, accounting and so on was introduced into social sciences curriculum without formal expression in the existing organizational frame work.

There had been a notion that mathematics was not relevant to social sciences. This was because when the discipline was taught, the impression was that it was only useful to physical sciences. Two basic examples, one from matrix algebra and the other from calculus to buttress situations where applications of mathematics are used in physics and engineering. However, towards the middle of the twentieth century, Operations Research practitioners had found out one could link these branches of mathematics to social sciences. They use it in planning national economy, accounting, and the behaviour of firms. They were able to demonstrate, including the author, that even pure or abstract mathematics can be applied to any field of knowledge, socials being one of them. The linking is achieved through mathematical modeling, a process where a real problem is first defined, and then a mathematical version of the problem is formulated and solved. The mathematical solution is checked to see whether the solution is valid. Various mathematical models with given assumptions were introduced, and many Ph. D students, who had graduated from university of Benin, taken advantages of Operations Models were mentioned.

Some of the contributions of the author were highlighted and one that he considered as breakthrough Linear Programming with Variable Upper bounding (VUB) and Generalized Variable Upper Bounding (GUB) was discussed. It was found to be more superior to the existing models in this area.

The author recommended among other things for government to pay more attention to this discipline. A division or department of O/R should be established, even in the Presidency.