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AN INTRODUCTORY NOTE TO OPERATION RESEARCH.

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INRODUCTION

The first operations research group in the United Arab Republic has been established in the National Planning Commettee to study planning problems in different fields. Since operations research (O.R.) is new to the U.A.R., some explanation of its nature and the role it can play in the progress of the country is quite important. a simple definition of O.R. (given by R.L. ACKOFF) is:

"O.R. is the application of scientific methods, techniques, and tools to problems involving the operations of a system so as to provide those in control of the system with optimum solutions to the problems".

The "system" referred to above is in most cases a man-machine system. It can be a multi-man or a complex machine system. The system may be in an industrial, business, government or military organization.

This definition may not show the reader exactly the distinctive features of O.R., its scope, or methods this paper is directed toward the clarification of these points.

HISTORY OF OPERATIONS RESEARCH:

Shortly after the beginning of world war 11, the british Anti-Aircraft Command asked a professor in University of Manchester called M. Blackett to study the optimum use of the newly invented radar equipment. In order to solve the problem Blackett formed a research group from scientists of the folliwng specialities: physiology, mathematical physics, astrophysics, general physics, surveying, mathematics, and an army officer. This group was the nucleus of operations research groups in the British Army Mavy, and Air Force.

The main characteristics of these groups were:

1. They contained scientists of varied backgrounds.
2. They studied system problems in a scientific way, taking the whole system into consideration.
3. They used the team approach in tackling the problems.

Some of the problems that were studied during the war are presented as examples below

1. Results of antisubmarine attacks from the air were dissatisfactory. Changes in either the altitude of the bombers or the size of the depthbomb lid not give any substantial improvement. It was observed during the study that the submarines were attached while they were on or near the surface of water. The bombs, however, were set to explode at 100′ under the water, while their lethal range was 20′ only and therefore the chance of their causing a significant damage to the U.Boats was very slim. The research group recommended that the anti-submarine bombs be set to explode at a depth 20′-25′ below the surface of water. The bombing efficiency was reported by the Royal Navy to increase 400% and by the R.A.F. to increase 700%.

2. One of the questions confronting the Royal Navy was:-

"What is the optimum size of a merchant convay for minimum losses and minimum patrol requirements ? "As the patrol increased, losses decreased. But it was not possible to provide more patrolling airplanes or ships. The only controllable variable was the size of the convay. It was found from past data that when the convay was less than 45 ships the average loss was 2.6%, while the losses for conveys larger than 45 ships were only 1.7% Large convays were then recommended, which resulted in reduced losses

3. A similar study was carried out after the British attaked Germany. The study revealed that as the number of attacking airplanes increased the losses decreased. This result led to the first aerial attack consisting of 1000 airplanes which the Royal Air Force in 1942. After the U.S.A. entered the war, operations research groups were formed in the American Armed Forces similar to those in England, The following is an example of one of the studies made by those groups:-

The problem was to find whether a ship attacked from the air should take a straight or zigzag course. A straight course will help the anti-aircraft guns to hit the attacking airplanes, while a zigzag course will give a greater change of avoiding the enemy's fire. Using past data, it was found that large ships should follow a zigzag path, while small ones should go on a straight line. Later operations showed the ships which followed this rule were hit 29% of the time, while those which did not were hit 47% of the time.

The studies made during the war, although carried out in a more or less scientific way, yet the techniques and the mathematical models used were not as developed as they are now in the field of operations research.

Civilan Operations Research:

After the war, O.R. Continued its activities in the military field both in England and in the United States. Government, industrial, and business organizations, aware of the profits gained by military O.R., began to utilize the services of O.R. specialists. Some of the O.R. activities were already performed by consulting agencies in industrial engineering, accounting, market research, etc.. although the approach was different. In Great Britain, O.R. found applications in planning the policy of food production, imports and distribution for the government, and in planning for increased efficiency of production especially in nationalized industries. In the United States, civilian application of O.R. did not start as quickly, because the cometition between companies stood in the way of expenditures on research in a new field and because of the cometition of consulting agencies claiming to perform the same functions of O.R. However, O.R. started in some industries related to the military field, such as the aircraft industry. Later, many other concerns recognized the importance of the new field and made great use of its services. Presently, there are in the U.S.A. thousands of scientists O.R. Several universities give undergraduate courses in O.R. leading to the B.S. Degree, and a few give graduate courses toward the M.S. and the ph. D. degrees, and some offer special short courses for those interested in the field, such as executives. Active operations research societies have been established in the U.S.A.; U.K. and France and an international society was formed with these societies as members. Several studies in O.R. and applications of it to practical problems have been made in Canada, Norway, Sweden, Denmark, Holland, Belgium, Italy, Germany, Austria, Spain, Turkey, Poland, Japan, and India.

CHARACTERISTICS OF OPERATIONS RESMARCH:

The following question may arise, "What are the characteristics of operations research that would necessitate its consideration as a new area of inquiry?" Such areas as industrial engineering, economics, statistics, market research, etc., deal with about the same type of problems as operations research. The distinction, however, lies in the following arguments:

1. - Application of science to operational problems:

Operations research took the scientist from his laboratory out in the field. The scientist used his tool, the scientific method, for the solution of practical problems involving complex man-machine systems. His approach to any problem was generally to gather data, analyze them, construct models, solve them, apply the solutions, and check them. A specialist in any one of the above mentioned fields would tend to apply previously constructed devices and formulas for the solution of the problem at hand. For example, in order to prepare a production schedule for a set of machines in a factory an industrial engineer would resort to the Gantt chart or any one of the more modern machine loading devices. An O.R. analyst, on the other hand, would define the problem, determining exactly the objectives to be attained, and then he would gather the necessary data, and work abstractly using perhaps, sequencing or scheduling models, or developing new models to solve the problem. The operations research solution. although it may be more expensive to find is more likely to realize better gains.

2.- Science and Recommendations for Action

The classical function of science is the understanding of existing phenomena. This understanding helped in better predictions of the behavior of these phenomena. Operations Research used the scientific method to recommend courses of action to the decision-makers, after knowing their criteria for good solutions, that is, their objectives and values. In other words, operations research as a science tells what <u>ought</u> to be done, not only what <u>is</u> happening. Actually science has taken a step further and is examining the set of values that the decision-makers may have.

3.- The "Whole System" Approach

An operations research approach to any problem does not confine itself to the study of the particular division of the organization directly concerned with the problem. Instead, O.R. studies the whole system with the purpose of realizing its main objectives, even if this working under optimum in any one of the different divisions. For example, a study originally directed to determine the optimum inventory levels in a manufacturing company may lead to the scheduling of production during the succeeding few months, or to an intensive market research to find if a price cut in certain periods of the year may tend to reduce the total cost of production and inventory.

4.- The Team Work

The whole system approach of O.R. requires diversified knowledge in different fields on the part of the analysts. As was previously mentioned, some problems required the experience of mathematicians, physicists, psychologists, and electrical engineers Teams were then established containing men from these and other disciplines. This became a characteristic of O.R. The research team usually comprises people with varied backgrounds. When a consulting agency works for an organization, a research team is established containing members from the consulting agency who offer the experience in O.R., and members from the organization who provide help in collecting data, and in understanding the operations of the organization. The latter group acquires experience in O.R. through their work with the other members, and they may form a permanent O.R. group later.

STEPS OF AN O.R. STUDY

The operations research approach to a problem follows the same outline of any scientific investigation. Roughly this is:

1.- Formulating the problem

This involves defining the objectives of the decision-makers and their criteria for an optimum or best policy. The limits on the scope of the study are determined in this step, but may be changed (expanded or tightened) later during the investigation. Ameasure of effectiveness is established to determine the degree to which a solution satisfies the objectives of decision makers.

2.- Collection of data:

All the facts relevant to the problem should be gathered. These may be obtained from records, reports and correspondance, but in most cases interviews with concerned persons or specialists are important. Sampling may be resorted to at this stage. Note that the main objective of the collection of data at this stage is only for the purpose of providing enough information to construct the mathematical model and not to apply it.

3.- Constructing a mathematical model to represent the system under study.

As in any other field of science, a model is built to represent the system. In its broadest sense, a model is a simply field replioa of subject under study, constructed because of certain features in it that makes the study easier on it than on the original subject. A model can be physical or abstract. Physical models represent the subject of study by material component, such as drawings, solid scale models, and analogues. Abstract models employ words and symbols as a means of representation. This class of models, especially mathematical type, are favored, especially in the field of O.R. because of their ease of manipulation, and the facility generalizations can be made with them. They also have minimum material requirements.

The general classes of mathematical models now used operations research studies are: programming models, probability and statistical models, an important class of the latter is queuing processes, also inventory models, sequening models, and competitive processes. A more detailed discussion of these models of Operations research".

The effectiveness of the system under study is described as a function of the variables in it, both the controllable and the uncontrollable. Variables of either type may be subject to random variations, linear or nonlinear restrictions, or may be under the control, or partial control, of a competitor. The type of mathematical model used depend on which of these conditions obtain. One or more of the above mentioned may be applicable to the system, or else completely a new mathematical model may have to be built.

After the model is constructed, a solution is found for it. A solution will satisfy the system's requirements and maximize its effectiveness. A solution may be analytic, numerical, or experimental. The data are fed directly in the analytic colution whenever one exists. Such solutions exist for simple inventory and queuing models. In models which has numerical solutions, such as linear programming, the data are fed in the original formulation of the problem and specified procedure is carreid out on these data until a final solution is obtained. In some cases, where neither analytic non-numerical solutions exist, such as in complex queuing situations, experiments are conducted, feeding random inputs, with known distributions, and observing the outcome at succeeding stages of process.

4.- Testing the Model :

The model is tested with fresh data or with past data that were not used in the construction of the model. A model is tested for truth and validity: It is true when it describes the system with acceptable accuracy, and it is valid when all the statements included in it are logically consistent.

The solution of the model may be tested experimentally by comparing the decisions it gives with alternative decisions. A sensitivity test may be carried out to detect the effect of a specified change in one of the variables (controllable or uncontrollable) on the effectiveness of the system. Statistical methods may be used when the variables are subject to random fluctuations.

A procedure should be specified by which the system is tested against variations that may redner the model or the solution derived from it inapplicable. Statistical quality control techniques may be used here.

5.- Implementation :

Recommendations for actions given by the O.R. team are generally executed by persons whose knowledge of mathematics is limited. Therefore the results of the study should be translated to a language familiar to them. The decision rules should be simple in order that they may be usable.

In practical application of the recommendations, factors sometimes appear that were not taken into account before. These must be considered and necessary abjustments should be made.

If the control apparatus detects any significant changes in the system, modifications in the model should be made to make it applicable to the new situations.

The implementation step of an O.R. study is of atmost importance and is part of the responsibility of the O.R. team. The job of this team is not finished until they make sure that the system starts running according to their recommendations, (after having the approval of the top executives), and that everyone who is responsible for the execution of the recommendations knows exactly what he is supposed to do. Some times a permanent team in the organization takes up the responsibility of supervising the implementation after the consulting group withdraws.

APPLICATIONS OF O.R.:-

Operations research have found applications in diverse fields of activity. The following problems are examples of civilian studies

1. The optimum utilization of resources to satisfy different economic activities

2. Industrial problems:
   - Inventory control
   - Scheduling
   - Equipment policy
   - Balancing of capacities

3. Distribution:
   - Effectiveness of advertizing
   - Market research for : needs, price forecasts, etc....

4. Transportation:

   - Routing for minimum distance travelled
   - Design of networks

A. Detailed Example:

The following is a simplified review of an industrial operations research study, in which the author of this report participated:

A cetain metal-producing company was worried about the high investment in semi-finished ingot inventory relative to its total capital investment. The question imposed to the O.R. team was, "Is this inventory level too high? and if it is, what is the opitmum level?"

The O.R. team discovered that the inventory level was high mainly because of the large lead time between receiving the raw materials and producing the ingots. This period had an average of one month. It was not possible to cut this time down through the reduction of raw material order lead time, or through the elimination of some of the quality control aperations or the reduction of time required for them.

The second stage of the study was to analyze all the costs relevant to the inventory and find the levels of the controllable variables that would minimize the total of these costs. Since the demand on inventory was variable, but predictable, the alternatives to meet it were:

1) To produce at a constant level and keep an inventory at the periods of low demand to be used at the periods of high demand.

2) To plan a variable production schedule to meet the expected variable demand:

   a) by using a variable laber force having men when needed and firing them afterwards.

   b) by maintaining a constant labor force and working it overtime when necessary.

3) A combination of the above alternatives.

   The costs involved with these alternatives are:

   1) Cost of labor on regular time = c_r/manhour on regular time.
   2) Cost of overtime premium = c_o/manhour at overtime.
   3) Cost of hiring = c_h/manour hired.
   4) Cost of layoff (firing) = c_f/ manhour laid off.
   5) Cost of maintaining ingot inventory =c_1/unit stored
   6) Cost of raw material.
   7) Cost of supplies.
   8) Cost of maintenance.
   9) Cost of administrative and sales overhead, depreciation, and other fixed costs.
   10) Cost of excess work force (i.e., unproductive time) = c_r/manhour wasted.