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Introduction to Operation Research

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1.1 Introduction

The subject operations research is a branch of mathematics - especially applied mathematics used to provide a scientific base for management to take timely and effective decisions to their problems. It tries to avoid the dangers of taking decisions merely by guessing or by using thumb rules. Management is a multidimensional and dynamic concept. It is multidimensional because management problems and their solutions have consequences in several dimensions, such as human, economic social and political fields. As the manager operates his system in an environment, which will never remain static, hence is dynamic in nature. Hence any manager, while making decisions, considers all aspects in addition to the economic aspect, so that his solution should be useful in all aspects. The general approach is to analyze the problem in economic terms and then implement the solution if it does not aggressive or violent to other aspects like human, social and political constraints.

1.2 History of OR

No science has ever been born on a specific day. Operations research is no exception. Its roots are as old as science and society. Though the roots of OR extend to even early 1800s, it was in 1885 when Frederick W. Taylor emphasized the application of scientific analysis to methods of production, that the real start took place.

During World War II, the military management in England called on a team of scientists to study the strategic and tactical problems of air and land defense. This team was under the direction of Professor P.M.S. Blackett of the University of Manchester and a former naval officer. ***"Blackett's circus"***, as the group was called, included *three physiologists*, *two mathematical physicists*, *one astrophysicist*, *one army officer*, *one surveyor, one general physicist*, and *two mathematicians*. Many of these problems were of executive-type. The objective was to find out the most effective allocation of limited military resources to the various military operations and to the activities within each operation. The application included the effective use of the newly invented radar, allocation of British Air Force Planes to missions and the determination of best patterns for searching submarines. This group of scientists formed the first OR team.

The name operations research (or operational research) was apparently coined in 1940 because the team was carrying out research on (military) operations. The encouraging results of these efforts led to the formation of more such teams in British Armed Services and the use of such scientific teams soon spread to Western Allies - the United States, Canada, and France. However this science of operations research originated in England, the United States soon took the lead. In the United States, these OR teams helped in developing strategies for mining operations, inventing new flight patterns and planning of sea mines.

Post - World War II: Immediately after the war, the success of military teams attracted the attention of industrial managers who were seeking solutions to their problems. Industrial operations research in the U.K. and U.S.A. developed along different lines. In the U.K. the critical economic situation required a drastic increase in production efficiency and creation of new markets. Nationalization of a few key industries further increased the potential field for OR. Consequently OR soon spread from military to government, industrial, social and economic planning.

Today, the impact of operations research can be felt in many areas. This is shown by the ever-increasing number of educational institutions offering this subject at degree level. The fast increasing number of management consulting firms speaks of the popularity of the subject. OR activities have spread to diverse fields such as hospitals, libraries, city planning, transportation systems, crime investigation, etc. Some of the Indian organizations using OR techniques are Indian - Airlines, Railways, Defence Organizations, Fertilizer Corporation of India, Delhi Cloth Mills, Tata Iron and Steel Co., etc.

1.3 Definitions of Operation Research

Many definitions of OR. have been suggested from time to time. Some of the different definitions are:

1. OR. is an experimental and applied science developed to observing, understanding and predicting the behavior of purposeful man-machine systems and OR. workers are actively engaged in applying this knowledge to practical problems in business, government, and society.

   OR. Society of America
2. OR. is a scientific method of providing executive departments with a quantitative basis for decision regarding the operations under their control.

   Morse and Kimbal (1946)
3. OR. is a management activity pursued in two complementary ways – one half by the free and bold exercise of commonsense untrammeled by any routine, and the other half by the application of a repertoire of well established pre-created methods and techniques.

   Jagjit Singh (1968)
4. OR. is the application of scientific methods, techniques, and tools to problems involving the operations of systems so as to provide these in control of the operations with optimum solutions to the problem.

   Churchman, Acoff, Arnoff (1957)
5. OR. is a scientific approach to problem-solving for executive management.

   H.M. Wagner
6. OR. may be described as a scientific approach to decision making that involves the operations of an organizational system.

   Hiller and Lieberman
7. Operations Research is the art of winning wars without actually fighting.

   Aurther Clarke
8. Operations Research is the art of giving bad answers to problems where otherwise worse answers are given.

   T.L. Satty

1.4 Characteristics of OR

From the definitions of OR following characteristics can be extracted out.

1. Use of Interdisciplinary Teams

OR involves many numbers of variables and constraints. For a single person, it is not possible to understand and analyze justifiably. Hence people from various disciplines are required to understand the OR problem, who applies their special knowledge acquired through experience to get a better view of cause and effects of the events in the problem and to get a better solution to the problem. This type of team approach will reduce the risk of making wrong decisions.

2. Complete System Orientation

A business may be considered as a system having various sub-systems. The decision made by any subsystem will have its effect on other sub-systems. When dealing with OR problems, one has to consider the entire system, and characteristics of subsystems, the inter-relationship between sub-systems and then analyze the problem, search for a suitable model and get the solution for the problem. Hence it can be concluded that OR is a Systems Approach rather than an individual approach.

3. Involvement of Scientific Method

Various scientific methods are involved in OR to solve different kinds of problems. Scientific methods are based on derived logics and empirical relations from past experience. So the application of scientific methods leads to logical and sequential results, which are not depending on irrelevant assumptions.

4. Improvement in Quality of Decisions

OR provides various alternatives and let the user to select an optimal choice. This will definitely help him in making better and quick decisions. Hence, the quality of a decision can be improved.

5. Uncovering Hidden Problems

Sometimes, during solving the adopted problem, new problems are uncovered. These problems are mostly overlooked. For example, the excess inventory provides flexibilities in managing the orders but on other hands, it hides many problems related to manufacturing, human, finance, etc. As an uncovered problem can also affect the existing problem, it is very essential to solve these problems using different OR techniques.

1.5 Phases of OR

An OR study is rooted in teamwork, where the OR analysts and the client work side by side. The OR analysts' expertise in modeling must be complemented by the experience and cooperation of the client for whom the study is being carried out.

The principal phases for implementing OR in practice include

1. Definition of the problem.
2. Construction of the model.
3. Solution of the model.
4. Validation of the model.
5. Implementation of the solution.

1. Definition of the problem

Problem definition involves defining the scope of the problem under investigations. This function should be carried out by the entire OR team. The aim is to identify three principal elements of the decision problem: (1) description of the decision alternatives, (2) determination of the objective of the study, and (3) specification of the limitations under which the modeled system operates.

2. Construction of the model

Model construction entails an attempt to translate the problem definition into mathematical relationships. If the resulting model fits one of the standard mathematical models, such as linear programming, we can usually reach a solution by using available algorithms. Alternatively, if the mathematical relationships are too complex to allow the determination of an analytic solution, the OR team may opt to simplify the model and use a heuristic approach, or they may consider the use of simulation, if appropriate. In some cases, mathematical, simulation, and heuristic models may be combined to solve the decision problem.

3. Solution of the model

The model solution is by far the simplest of all OR phases because it entails the use of well-defined optimization algorithms. An important aspect of the model solution phase is *sensitivity analysis.* It deals with obtaining additional information about the behavior of the optimum solution when the model undergoes some parameter changes. Sensitivity analysis is particularly needed when the parameters of the model cannot be estimated accurately. In these cases, it is important to study the behavior of the optimum solution in the neighborhood of the estimated parameters.

4. Validation of the model

Model validity checks whether or not the proposed model does what it purports to do - that is, does it predict adequately the behavior of the system under study? Initially, the OR team should be convinced that the model's output does not include "surprises". In other words, does the solution make sense? Are the results intuitively acceptable? On the formal side, a common method for checking the validity of a model is to compare its output with historical output data. The model is valid if, under similar input conditions, it reasonably duplicates past performance. Generally, however, there is no assurance that future performance will continue to duplicate past behavior. Also, because the model is usually based on careful examination of past data, the proposed comparison is usually favorable.

5. Implementation of the solution

The objective of OR is not only to produce reports but to improve the system performance so the results of the research must be implemented. For this, the solution obtained above should be translated into an operating procedure which can be easily understood and applied by those who control the operations. Changes needed in present procedures and resources must be clearly indicated and should be implemented. After the solution has been applied to the system, OR group must study the response of the system to the changes made. The solution obtained should, therefore, be continuously reviewed, modified and updaed according to the changing situation.

1.6 Scope of OR

When we broaden the scope of OR, we find that it has really been practiced for hundreds of years even before World War II. Whenever there is a problem of optimization, there is scope for the application of OR. Its techniques have been used in a wide range of situations:

1. In Industry

In the field of industrial management, there is of a chain of problems starting from the purchase of raw materials to the dispatch of finished goods. The management is interested in having an overall view of the method of optimizing profits. In order to make a decision on a scientific basis, the OR team will have to consider various alternative methods of producing the goods and the return in each case. OR study should also point out the possible changes in the overall structure like the installation of a new machine, the introduction of more automation, etc. OR has been successfully applied in industry in the fields of production, blending, product mix, inventory control, demand forecast, sale and purchase, transportation, repair and maintenance, scheduling and sequencing, planning, scheduling and control of projects and scores of other associated areas.

2. In Defence

OR has a wide scope for application in defense operations. In modern warfare, the defense operations are carried out by a number of different agencies, namely airforce, army, and navy. The activities performed by each of them can be further divided into sub-activities viz. operations, intelligence, administration, training and the like. There is thus a need to coordinate the various activities involved in order to arrive at optimum strategy and to achieve consistent goals. Operations research, conducted by a team of experts from all the associated fields, can be quite helpful to achieve the desired results.

3. Planning

In both developing and developed economies, the OR approach is equally applicable. In developing economies, there is a great scope of developing an OR approach towards planning. The basic problem is to orient the planning so that there is maximum growth of per capita income in the shortest possible time, by taking into consideration the national goals and restrictions imposed by the country. The basic problem in most of the countries in Asia and Africa is to remove poverty and hunger as quickly as possible. There is, therefore, great scope for economists, statisticians, administrators, technicians, politicians, and agriculture experts working together to solve this problem with an OR approach.

4. Agriculture

OR approach needs to be equally developed in the agriculture sector on a national or international basis. With the population explosion and consequent shortage of food, every country is facing the problem of optimum allocation of land to various crops in accordance with climatic conditions and available facilities. The problem of the optimal distribution of water from the various water resources is faced by each developing country and a good amount of scientific work can be done in this direction.

5. Public Utilities

OR methods can also be applied in big hospitals to reduce waiting time of outdoor patients and to solve the administrative problems. Monte Carlo methods can be applied in the area of transport to regulate train arrivals and their running times. Queuing theory can be applied to minimize congestion and passengers' waiting time. OR is directly applicable to business and society. For instance, it is increasingly being applied in L.I.C. office to decide the premium rates of various policies. It has also been extensively used in petroleum, paper, chemical, metal processing, aircraft, rubber, transport and distribution, mining and textile industries. OR approach is equally applicable to big and small organizations' For example, whenever a departmental store faces a problem like employing additional sales girls, purchasing an additional van, etc., techniques of OR can be applied to minimize cost and maximize the benefit for each such decision.

Thus we find that OR has a diversified and wide scope in the social, economic and industrial problems of today.

1.7 Limitations of OR

The magnitude of Computations:

OR tries to find out optimal solution taking into account all the factors. In modern society, these factors are enormous and expressing them in quantity and establishing relationships among these require voluminous calculations which can only be handled by machines.

Non-Quantifiable Factors:

OR provides a solution only when all elements related to a problem can be quantified. All relevant variables do not lend themselves to quantification. Factors which cannot be quantified, find no place in OR Models in OR do not take into account qualitative factors or economical factors which may be quite important.

Distance between Manager and Operations Research:

OR being a specialist's job requires a mathematician or a statistician, who might not be aware of the business problems. Similarly, a manager fails to understand the complex working of OR. Thus there is a gap between the two. Management itself may offer a lot of resistance due to conventional thinking.

Money and Time Costs:

When the basic data are subjected to frequent changes, incorporating them into the OR models is a costly affair. Moreover, a fairly good solution at present may be more desirable than a perfect OR solution available after sometimes.

Implementation:

Implementation of decisions is a delicate task. It must take into account the complexities of human relations and behavior. Sometimes resistance is offered only due to psychological factors.

1.8 Operations Research and Decision Making

Operations research or management science, as the name suggests, is the science of managing. As is known, management is most of the time making decisions. It is thus a decision science which helps management to make better decisions. The decision is, in fact, a pivotal word in managing. It is not only the headache of management; rather all of us make decisions.

Decision-making can be improved and, in fact, there is a scope of large scale improvement. The essential characteristics of all decisions are

a) Objectives,
b) Alternatives,
c) Influencing factors (constraints).

Once these characteristics are known, one can think of improving the characteristics so as to improve upon the decisions itself.

For, example, if you have to reach at an exam centre within time, using various modes of conveyance. You have three conveyance modes. First is to go alone in own car, second is to go by city bus and the third one is to go in sharing car among friends. If you choose the first conveyance mode than you will definitely reach the exam centre on time, but it will be definitely costly. If you choose the second conveyance mode, it will be least costly, but it might take more time in traveling, so you might get late at the exam centre. If you choose to travel by sharing among friends, it will let you reach within time, as well as it will be both economical compared to the first options. Although the destination was reached by using any conveyance mode, the best option is to select the third alternate, which is economical and object-oriented.

It is scientific quantification used in OR, which helps management to make better decisions. Thus in OR, the essential features of decisions, namely, objectives, alternatives and influencing factors are expressed in terms of scientific quantifications or mathematical equations. This gives rise to certain mathematical relations, termed a whole as a mathematical model. Thus the essence of OR is such a mathematical model.

However, with the advance of science and technology, decision-making in business and industry has become highly complex and extremely difficult. The decision-maker is not only faced with a large number of interacting variables, which at times do not lend themselves to neat quantitative treatment but also finds them too numerous and dynamic. Above all he has to take into consideration the action of the competitors over which he has no control. This complexity of decision-making make made the decision-makers look for various aids in decision-making. It is in these situations that operations research comes to our help.

The managers today make full use of the OR techniques in various functional areas. It has been realized beyond doubt that intuition alone has no place in decision-making since such a decision becomes highly questionable when it involves the choice among several alternatives. OR provides the management with much-needed tools for improving the various decisions.