Nature and Scope of operations research

What is an Operation Research

Operations Research is the science of rational decision-making and the study, design and integration of complex situations and systems with the goal of predicting system behavior and improving or optimizing system performance.

Operations Research has been defined so far in various ways and still not been defined in an authoritative way. Some important and interesting opinions about the definition of OR which have been changed according to the development of the subject been given below:

Operations research is the application of the methods of science to complex problems in the direction and management of large systems of men, machines, materials and money in 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 alternative decisions, strategies or controls. The purpose is to help management in determining its policy and actions scientifically.

- Operational Research Society, UK

The application of the scientific method to study of operations of large complex organizations or activities, it provides top level administrators with a quantitative basis for decisions that will increase the effectiveness of such organizations in carrying out their basic purposes.

- Committee on OR of National Research Council

Operations research is the systematic application of quantitative methods, techniques and tools to the analysis of problems involving the operation of systems.

- Daellenbach and George, 1978

Operations research is essentially a collection of mathematical techniques and tools which in conjunction with a systems approach, is applied to solve practical decision problems of an economic or engineering nature.

- Daellenbach and George, 1978

Operations research utilizes the planned approach (updated scientific method) and an interdisciplinary team in order to represent complex functional relationships as mathematical models for the purpose of providing a quantitative basis for decision-making and uncovering new problems for quantitative analysis.

- Thierauf and Klekamp, 1975

This new decision-making field has been characterized by the use of scientific knowledge through interdisciplinary team effort for the purpose of determining the best utilization of limited resources. **– H A Taha**

Operations research, in the most general sense, can be characterized as 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 operations with optimum solutions to the problems. **- Churchman, Ackoff and Arnoff, 1957**

Operations research has been described as a method, an approach, a set of techniques, a team activity, a combination of many disciplines, an extension of particular disciplines (mathematics, engineering, and economics), a new discipline, a vocation, even a religion. It is perhaps some of all these things.

- S L Cook, 1977

Operations research may be described as a scientific approach to decision-making that involves the operations of organizational system.

-*F* S Hiller and G 1 Lieberman, 1980

Operations research is a scientific method of providing executive departments with a quantitative basis for decisions regarding the operations under their control.

- P M Morse and G E Kimball, 1951

Operations research is applied decision theory It uses any scientific, mathematical, or logical means to attempt to cope with the problems that confront the executive, when he tries to achieve a thorough-going rationality in dealing with his decision problems. **- D W Miller and M K Star, 1969**

Operations research is a scientific approach to problem-solving for executive management. **— H M Wagner**

As the discipline of operations research grew numerous names such as operations analysis, systems analysis, and decision analysis, management science, quantitative analysis, decision science were given to it This is because of the fact that the types of problems encountered are always concerned with 'effective decision', but the solution of these problems do not always involve research into operations or aspects of the science of management.

From all above opinions, we arrive at the conclusion that whatever else 'OR' may be, it is certainly concerned with optimization problems. *A decision, which taking into account all the present circumstances can be considered the best one, is called an optimal decision.*

THE HISTORY OF OPERATIONS RESEARCH

It is generally agreed that operations research came into existence as a discipline during World War II when there was a critical need to manage scarce resources. However, a particular model and technique of OR can be traced back as early as in World War I, when Thomas Edison (1914-15) made an effort to use a tactical game board for finding a solution to minimize shipping losses from enemy submarines, instead of risking ships in actual war conditions. About the same time A.K. Erlang, a Danish engineer, carried out experiments to study the fluctuations in demand for telephone facilities using automatic dialing equipment. Such experiments were later on were used as the basis for the development of the waiting-line theory.

Some groups were first formed by the British Air Force and later the American armed forces formed similar groups, one of the groups in Britain came to be known as Blackett's Circus. This group, under the leadership of Prof. P. S. Blackett was attached to the Radar Operational Research unit and was assigned the problem of analyzing the coordination of radar equipment at gun sites. The efforts of such groups, especially in the area of radar detection are still considered vital for Britain in winning the air battle. Following the success of this group similar mixed-team approach was also adopted in other allied nations,

After the war was over, scientists who had been active in the military OR groups made efforts to apply the operations research approach to civilian problems related to business, industry, research development, etc. There are three important factors behind the rapid development of using the operations research approach.

These are:

(i) The economic and industrial boom after World War II resulted in continuous mechanization, automation and decentralization of operations and division of management functions. This industrialization also resulted in complex managerial problems, and therefore the application of operations research to managerial decision-making became popular.

(ii) Many operations researchers continued their research after war. Consequently, some important advancement was made in various operations research techniques. In 1947, he developed the concept of *linear programming,* the solution of which is found by a method known as *simplex method.* Besides linear programming, many other techniques of OR, such as statistical quality control, dynamic programming, queuing theory and inventory theory were well-developed before the end of the 1950.

(iii) Greater analytical power was made available by high-speed computers. The use of computers made it possible to apply many OR techniques for practical decision analysis.

During the 1950s there was substantial progress in the application of OR techniques for civilian activities along with a great interest in the professional development and education of OR. Many colleges and universities introduced OR in their curricula. These were generally schools of engineering, public administration, business management, applied mathematics, economics, computer science, etc.

Today, however, service organizations such as banks, hospitals, libraries, airlines, railways, etc., all recognize the usefulness of OR in improving efficiency. In 1948, an OR club was formed in England which later changed its name to the Operational Research Society of UK. Its journal, *OR Quarterly* first appeared in 1950. The Operations Research Society of America (ORSA) was founded in 1952 and its journal, *Operations Research* was first published in 1953. In the same year, The Institute of Management Sciences (TIMS) was founded as an international society to identify, extend and unify scientific knowledge pertaining to management. Its journal, *Management Science,* first appeared in 1954.

At the same point of time Prof R S Verna also set up an OR team at Defense Science Laboratory for solving problems of store, purchase and planning. In 1953, Prof. P. C. Mahalanobis established an OR team in the Indian Statistical Institute, Kolkata for solving problems related to national planning and survey. The OR Society of India (ORSI) was founded in 1957 and it started publishing its journal *OPSEARCH* 1964 onwards. In the same year, India along with Japan became a member of the International Federation of Operational Research Societies (IFORS) with its headquarters in London.

The other members of IFORS were onwards UK, USA, France and West Germany.

A year later, project scheduling techniques - Program Evaluation and Review Technique (PERT) and Critical Path Method (CPM) - were developed as efficient tools for scheduling and monitoring lengthy, complex and expensive projects of that time. By the 1960s OR groups were formed in several organizations. Educational and professional development programmes were expanded at all levels and certain firms, specializing in decision analysis, were also formed.

The American Institute for Decision Sciences came into existence in 1967. It was formed to promote, develop and apply quantitative approach to functional and behavioural problems of administration. It started publishing a journal, *Decision Science,* in 1970.

Because of OR's multi-disciplinary character and its application in varied fields, it has a bright future, provided people devoted to the study of OR can help meet the needs of society. Some of the problems in the area of hospital management, energy conservation, environmental pollution, etc., have been solved by OR specialists. This is an indication of the fact that OR can also contribute towards the improvement of the social life and of areas of global need. However, in order to make the future of OR brighter, its specialists have to make good use of the opportunities available to them.

APPLICATIONS OF OPERATIONS RESEARCH

Some of the industrial/government/business problems that can be analyzed by the OR approach has been arranged by functional areas as follows:

Finance and Accounting

- Dividend policies, investment and portfolio management, auditing, balance sheet and cash flow analysis

- Claim and complaint procedure, and public accounting
- Break even analysis, capital budgeting, cost allocation and control, and financial planning
- Establishing costs for by-products and developing standard costs

Marketing

- Selection or product-mix, marketing and export planning
- Advertising, media planning, selection and effective packing alternatives
- Sales effort allocation and assignment
- Launching a new product at the best possible time
- Predicting customer loyalty

Purchasing, Procurement and Exploration

- Optimal buying and reordering with or without price quantity discount
- Transportation planning
- Replacement policies
- Bidding policies
- Vendor analysis

Production Management *(Facilities planning)*

- Location and size of warehouse or new plant, distribution centers and retail outlets
- Logistics, layout and engineering design
- Transportation, planning and scheduling

Manufacturing

- Aggregate production planning, assembly line, blending, purchasing and inventory control
- Employment, training, layoffs and quality control
- Allocating R&D budgets most effectively

Maintenance and project scheduling

- Maintenance policies and preventive maintenance
- Maintenance crew size and scheduling
- Project scheduling and al location of resources

Personnel Management

- Manpower planning, wage/salary administration
- Designing organization structures more effectively
- Negotiation in a bargaining situation
- Skills and *wages* balancing
- Scheduling of training programmes to maximize skill development and retention

Techniques and General Management

- Decision support systems and MIS; forecasting
- Making quality control more effective
- Project management and strategic planning

Government

- Economic planning, natural resources, social planning and energy
- Urban and housing problems
- Military, police, pollution control, etc.

MODELS AND MODELLING IN OPERATIONS RESEARCH

Models do riot, and cannot, represent every aspect of reality because of the innumerable and changing characteristics of the real-life problems to be represented. However, a model can be used to understand, describe and quantity important aspects of the system and predict the response to the system to inputs. In other words, a model is developed in order to analyze and understand the given system for the purpose of improving its performance as well as to examine the behavioral changes of a system without disturbing the ongoing operations. For example, to study the now of material through a factory, a scaled diagram on paper showing the factory floor, position or equipment, tools, and workers can be constructed. It would not be necessary to give details such as the color of machines, the heights of the workers, or the temperature of the building. In other words, for a model to be effective, it must be representative of those aspects of reality that are being investigated and have a major impact on the decision situation. A system can easily be studied by concentrating on its key features instead of concentrating on every detail of it. This implies that the models attempt to describe the essence of a situation so that the decision-maker can study the relationship among relevant variables quickly to arrive at a holistic view.

The key to model building lies in abstracting only the relevant variables that affect the criteria of the measures-of performance of the given system and in expressing the relationship in a suitable form. However, a model should be as simple as possible so as to give the desired result. On the other hand, over simplifying the problem can also lead to a poor decision. Model enrichment is accomplished through the process of changing constants into variables, adding variables, relaxing linear and other assumptions, and including randomness. The top three qualities of any model are:

- The validity of the model, i.e., how the model will represent the critical aspects of the system or problem under study,
- The usability of the model, i.e., whether a model can be used for the specific purposes, and
- The value of the model to the user.

Besides these three qualities, other qualities of interest are (i) the cost of the model and its sophistication, (ii) the time involved in formulating the model, etc.

More important than the formal definition of a model is tile informal one that applies to all of us, a tool for thinking and understanding before taking action. We use models all the time, even though most of them are subjective. For example, we formulate a model when (a) we think about what someone will say if we do something, (b) we try to decide how to spend our money, or (c) we attempt to predict the consequences of some activity (either ours someone else's or even a natural event). In other words, we would not be able to derive or take any purposeful action if we did not form a model of the activity fast. OR approach uses this natural tendency to create models. This tendency forces to think more rigorously and carefully about the models we intend to use.

In general models are classified in eight ways as shown in Table 1.1. Such a classification provides a useful frame of reference for modelers.

1. Function	4. Degree of certainty	7. Degree of closure
• Descriptive	• Certainty	• Closed
• Predictive	• Conflict	• Open
• Normative	• Risk	8. Degree of quantification
2. Structure	• Uncertainty	• Qualitative
• Iconic	5. Time reference	• Mental
• Analog	• Static	• Verbal
• Symbolic	• Dynamic	• Quantitative
3. Dimensionality	6. Degree of generality	• Statistical
• Two-dimensional	• Specialized	• Heuristic
• Multidimensional	• General	• Simulation

Table 1: Model classification scheme

I. Classification Based on Structure

1. Physical models

These models provide a physical appearance of the real object under study, either reduced in size or scaled up. Physical models are useful only in design problems because they are easy to observe, build and describe_ For example, in the aircraft industry, scale models of a proposed new aircraft are built and tested in wind tunnels to record. the stresses experienced by the air frame. Since these models cannot be manipulated and are not very useful for prediction, problems such as portfolio selection, media selection, production scheduling, etc., cannot be analyzed with the help of a physical model. Physical models are classified into the following two categories.

(i) Iconic Models

Iconic models retain some of the physical properties and characteristics of the system they represent. An iconic model is either in an idealized form or is a scaled version of the system. In other words, such models represent the system as it is, by scaling it up or dower (i.e. by enlarging or reducing the size). Examples of iconic models are blueprints of a home, maps, globes, photographs, drawings, air planes, trains, etc.

Iconic models arc simple to conceive, specific and concrete. An iconic model is used to describe the characteristics of the system rather than explaining the system. This means that such models are used to represent a static event and characteristics that are not used in determining or predicting effects that take place due to certain changes in the actual system. For example, the color of an atom does not play any vital role in the scientific study of its structure. Similarly, the type of engine in a car has no role to play in the study of the problem of parking.

(ii) Analogue Models

These models represent a system by the set of properties of the original system but does not resemble physically. For example, the oil dipstick in a ear represents the amount of oil in the oil tank; the organizational chart represents the structure, authority, responsibilities and relationship, with boxes and arrows; and maps in different colors represent water, desert and other geographical features. Graphs ultimo series, stock-market changes, frequency curves, etc., may be used to represent quantitative relationships between any two properties and predict how a change in one property affects the other. These models are less specific and concrete but are easier to manipulate and are more general than iconic models.

2. Symbolic models

These models use symbols (letters, numbers) and functions to represent variables arid their relationships for describing the properties of the system. These models are also used to represent relationships that cart be represented in a physical form. Symbolic models can be classified into the following two categories,

(i) **Verbal Models**

These models describe a situation in written or spoken language. Written sentences, books, etc., are examples of a verbal model.

(ii) **Mathematical Models**

These models involve the use of mathematical symbols, letters, numbers and mathematical operators to represent relationships among various variables of the system for describing its properties or behavior. The solution to such models is then obtained by applying suitable mathematical techniques.

The relationship among velocity, distance and acceleration is an example of a mathematical model. In accounting, the cost-volume-profit model is also an example of a mathematical model.

Symbolic models are precise and abstract and can be analyzed and manipulated by using Laws of mathematics. The models are more explanatory rather than descriptive.

II. Classification Based on Function or Purpose

Models based on the purpose of their utility include the following types:

1. Descriptive models

Descriptive models characterize things as they are the major use of these models is to in the outcomes or consequences of various alternative courses of action. Since these models check the consequence only for a given condition (or alternative) rather than for all conditions, there is no guarantee that an alternative selected with the aid of descriptive analysis is optimal. These models are usually applied in decision situations where optimizing models are not applicable. They are also used when the final objective is to define the problem or to assess its seriousness rather than to select the best alternative. These models are especially used for predicting the behavior of a particular system under various conditions. Simulation is an example of a descriptive technique for conducting experiments with the systems.

2. Predictive models

These models indicate the consequence, if this occurs, then that will follow. They relate dependent and independent variables and permit the trying out, of the 'what if' questions. In other words, these models are used to predict *the outcomes of* a given set of alternatives for the problem. These models do not have an objective function as a part of the model of evaluating decision alternatives.

For example, $S = a+bA+cI$ of is a model that describes how the sale *(S)* of a product changes with a change in advertising expenditure (A) and disposable personal income (I), Here, *a, b* and c are parameters whose values must be estimated. Thus, having estimated the values of *a,* b and *c,* the valve of advertising expenditure (A) can be adjusted for a given value of I, to study the impact of advertising on sales. In these models, however, one does not attempt to choose the best decision alternative, but can only have an idea about *the* possible alternatives available to him.

3. Normative (or Optimization) models

These models provide the `*best'* or 'optimal' solution to problems, subject to certain limitations on the use of resources. These models provide recommended courses of action, For example, in mathematical programming; models are formulated for optimizing the given objective function, subject to restrictions on resources in the context of the problem under consideration and non-negativity of variables. These models are also called *prescriptive models* because they prescribe what the decision maker ought to do.

III. Classification Based on Time Reference

1. **Static models**

Static models represent a system at a particular point of time and do not account for changes over time. For example, an inventory model can be developed and solved to determine an economic order quantity for the next period assuming that the demand in planning period would remain the same as that today.

2. **Dynamic models**

In a dynamic model time is considered as one of the variables, and it accommodates the impact of changes that take place due to change in time. Thus, sequences of interrelated decisions over a period of time are made to select the optimal course of action in order to achieve the given objective. Dynamic programming is an example of a dynamic model.

IV. Classification Based on Degree of Certainty

1. **Deterministic models**

If all the parameters, constants and functional relationships are assumed to be known with certainty when the decision is made, the model is said to be deterministic. Thus, in such a case where the outcome associated with a particular course of action is known, i.e. for a specific set of input values, there is a uniquely determined output which represents the solution of the model under conditions of certainty. The results of the models assume single value. Linear programming models are examples of deterministic models.

2. **Probabilistic (Stochastic) models**

Models in which at Least one parameter or decision variable is a random variable are called probabilistic (or stochastic) models. Since at least one decision variable is random therefore, an independent variable, which is the function of dependent variable(s), will also be random. This means consequences or payoff due to certain changes in the independent variable cannot be predicted with certainty. However, it is possible to predict a pattern of values of both the variables by their probability distribution.

Insurance against risk of fire, accidents, sickness, etc,, are examples where the pattern of events is studied in the form of a probability distribution.

V. Classification Based on Method of Solution or Quantification

1. Heuristic models

These models employ some sets of rules which, though perhaps not optimal, do facilitate solutions of problems when applied in a consistent manner.

2. Analytical models

These models have a specific mathematical structure and thus can be solved by the known analytical or mathematical techniques. Any optimization model (which requires maximization or minimization of an objective function) is an analytical model.

3. Simulation models

These models also have a mathematical structure but are not solved by applying mathematical techniques to arrive at a solution. Instead, a simulation model is essentially a computer-assisted experimentation on a mathematical structure of a real-life problem in order to describe and evaluate its behavior under certain assumptions over a period of time.

Simulation models are more flexible than mathematical ones and can, therefore, be used to represent a complex system that otherwise cannot be represented mathematically. These models do not provide general solution like those of mathematical models.

OPERATIONS RESEARCH MODELS IN PRACTICE

There is no unique set of problems that can be solved by using OR models or techniques. Several OR models or techniques can be grouped into some basic categories as given below. In this book, a large number OR models have been discussed in detail. Here, only introductory descriptions of these models are given.

- **Allocation models**

Allocation models are used to allocate resources to activities in such a way that some measure of effectiveness (objective function.) is optimized. Mathematical programming is the broad term for the OR techniques used to solve allocation problems.

If the measure of effectiveness such as profit, cost, etc., is represented as a linear function of several variables and if limitations on resources (constraints) can be expressed as a system of linear equalities Or inequalities, the allocation problem is classified as a linear programming problem. But if the objective function of any or all of the constraints cannot be expressed as a system of linear equalities or inequalities, the allocation problem is classified as a non-linear programming problem.

When the solution values or decision variables of a problem are restricted to being integer values or just zero-one values, the problem is classified as an integer programming problem or a zero-one programming problem, respectively.

A problem having multiple, conflicting and incommensurable objective functions (goals) subject to linear constraints is called a goal programming problem. If the decision variables in the linear programming problem depend on chance the problem is called a stochastic programming problem.

lf resources such as workers, machines Or salesmen have to be assigned to perform a certain number of activities such as jobs or territories on a one-to-one basis so as to minimize total time, cost or distance involved in performing a given activity, such problems are classified as assignment problems. But if the activities require more than one resource and conversely, if the resources can be used for more than one activity than the allocation problem is classified as a transportation problem

- **Inventory models**

  Inventory models deal with the problem of determination of how much to order at a point in time and when to place an order. The main objective is to minimize the sum of three conflicting inventory costs. The cost of holding or carrying extra inventory, the cost of shortage or delay in the delivery of items when it is needed and the cost of ordering or setup. These are also useful in dealing with quantity discounts and selective inventory control.

- **Waiting line (or Queuing) models**

  These models have been de loped to establish a trade-off between costs or providing service and the waiting time of a customer in the queuing system. Constructing a model entails describing the components of the system: Arrival process, queue structure and service process and solving for the measure of performance like average length of wailing lime, average time spent by the customer in the line, traffic intensity, etc. of the waiting system.

- **Competitive (Game Theory) models**

  These models are used to characterize the behavior of two or more opponents (called players) who compete for the achievement of conflicting goals. These models arc classified according to several factors such as number of competitors, sum of loss and gain, and the type of strategy which would yield the best or the worst outcomes.

- **Network models**

  These models are applied *to* the management (planning, controlling and scheduling) of large scale projects. PERT/CPM techniques help in identifying potential trouble spots in a project through the identification of the critical path. These techniques improve project coordination and enable the efficient use of resources. Network methods are also used to determine time cost trade off resource allocation and help in updating activity time.

- **Sequencing models**

  The sequencing problem arises whenever there is a problem in determining the sequence (order) in which a number of tasks can be performed by a number of service facilities such as hospital, plant etc., in such a way that some measure of performance, for example, total time to process all the jobs on all the machines, is optimized.

- **Replacement models**

  These models are used when one must decide the optimal time to replace an equipment for one reason or the other for instance, in the case of the equipment whose efficiency deteriorates with time or fails immediately and completely. For example, in case of an automobile, the user has own measure of effectiveness. So there will not be one single optimal answer for everyone, even if each automobile gives exactly the same service.

- **Dynamic programming models**

  Dynamic programming may be considered as an outgrowth of mathematical programming, in solving the optimization of multistage (sequence of interrelated decisions) decision processes, The method slams by dividing a given problem into stages or sub problems and then solves those sub problems sequentially until the solution to the original problem is obtained.

- **Markov-chain models**

  These models are used for analyzing a system which changes over a period of time among various possible outcomes or states. The model, while dealing with such systems, describes transitions in terms of transition probabilities of various states. These models have been used to test brand loyalty and brand switching tendencies of consumers, where each system state is considered to be a particular brand purchase.

- **Simulation models**

  These models are used to develop a method for evaluating the merit of alternative courses of action by experimenting with a mathematical model of the problems where various variables are random, That is, these provide a means for generating representative samples of the measures of performance variables. Thus, repetition of the process by using the simulation model provides an indication of the merit of alternative cowˉse of action with respect to the decision variables,

- **Decision analysis models**

  These models deal with the selection of an optimal course of action given the possible payoffs and their associated probabilities of occurrence. These models arc broadly applied to problems involving decision-making under risk and uncertainty.

OPPORTUNITIES AND SHORTCOMINGS OF THE OPERATIONS RESEARCH

The use of quantitative methods is appreciated to improve managerial decision-making_ However, besides certain opportunities, OR approach has not been without its shortcomings. The main reasons for its failure are due to unawareness on the part of decision makers about their own role, as well as the avoidance of behavioral/ organizational issues while constructing a decision model. A few opportunities and shortcomings of the OR approach are listed below,

Opportunities

- It compels the decision-maker to be quite explicit about his objective, assumptions and his perspective to constraints,

- It makes the decision-maker very carefully consider exactly what variables influence decisions.
- Quickly points out gaps in the data required to support workable solutions to a problem.
- Its models can be solved by a computer, thus the management can get enough time for decisions that require quantitative approach.

Shortcomings

- The solution to a problem is often derived either by making it simpler or simplifying assumptions and thus such solutions have limitations.
- Sometimes models do not represent the realistic situations in which decisions must be made.
- Often the decision maker is not fully aware of the limitations of the models that he is using.
- Many real world problems just cannot have an OR solution.