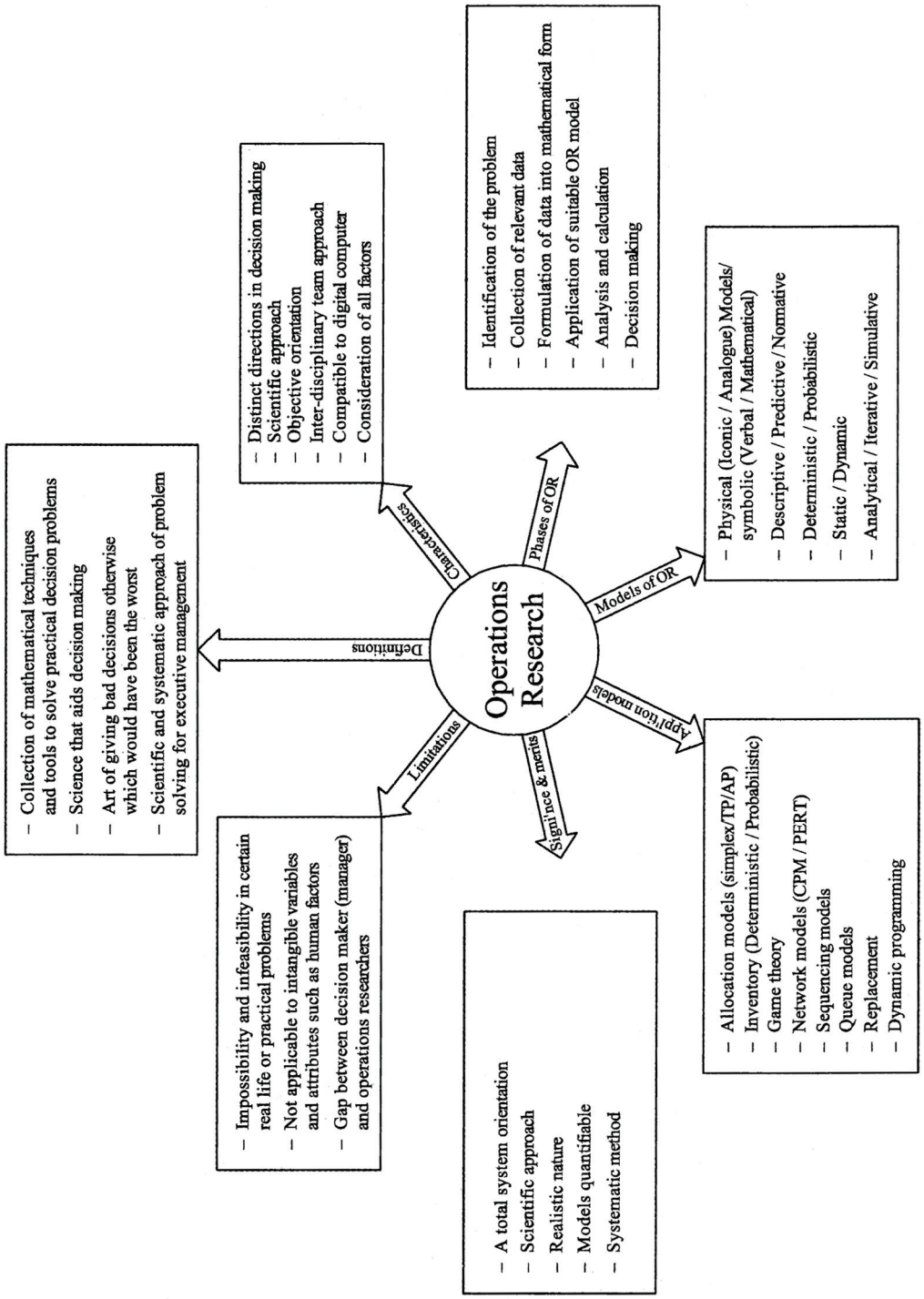
1 Chapter

Operations Research – An Overview

CHAPTER OUTLINE

CHAPTER AT A GLANCE



1.0 *Introduction*

"Science that aids decision making is Operations Research which is tested and implemented through appropriate modelling."

We take several decisions in our daily life. Most of these decisions are taken by common sense. But the decisions taken by mere common sense sometimes may mislead or confuse us. Also, such decisions may neither provide any evidential support nor stand on any scientific base. Therefore, it has become necessary for managers and engineers to believe in the science that provides the evidential support and scientific base.

Operations Research (OR) is one such science that provides better solutions to the managers, engineers and any practitioners with better solutions. This science came into existence during World War II. Though it was first employed for military operations, its applications are extended to any field on the earth in some form or other.

Thus OR is considered as the science that deals with decision making and this book deals with formulating, analysing, testing and application of various OR models.

1.1 *Origin and Development of OR Models*

The term, "*Operations Research*" was first coined by Mc Closky and Trefthen in 1940 in a small town, Bowdsey of United Kingdom.

The name operations research was given to this subject because it has started with the *research* of (military) *operations*. During world war - II, the military commands of UK and USA engaged several teams of scientists to discover tactical and strategic military operations. Their mission was to formulate specific proposals and to arrive to the decisions that can optimally utilize the scarce resources to acquire maximum possible level of effective results. In simple words, it was to uncover the methods that can yield greatest results with little efforts. Thus it has gained popularity and was called "*an art of winning the war without actually fighting it*".

Following the end of the war, the success and encouraging results of British teams have attracted industrial managers to apply these methods to solve their complex problems. The first method in this direction was simplex method (LPP) developed in 1947 by G.B. Dantzig, USA. Since then several scientists have been developing this science in the interest of making operations to yield high profits or least costs.

Now, this science has become universally applicable to any area such as transportation, hospital management, agriculture, libraries, city planning, financial institutions, construction management and so forth. In India, many industries have been realising the advantages by implementing the OR models.

A few to quote in this regard are Delhi Cloth Mills, Indian Airlines, Indian Railways, Hindustan Liver Ltd., (HLL), Tata Iron & Steel Co., (TISCO), Fertilizer Corporation of India (FCI), Life Insurance Corporation (LIC) of India etc.

1.2 *Operations Research : Some Definitions*

Because of the wide scope of applications of operations research, giving a precise definition is difficult. However, a few definitions of OR are as under.

- *Operational 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 change and risk, with which to predict and compare the outcome of alternative decisions, strategies or controls. The purpose is to help management in determining its policy and actions scientifically.* Operations Research Society, UK
- *Operations Research is concerned with scientifically deciding how to best design and operate man - machine systems usually requiring the allocation of scarce resources.* Operations Research Society, America

Apart from being lengthy, the definition given by Operational Research Society of UK, has been criticised because it emphasizes complex problems and large systems, leaving the reader with the impression that it is a highly technical approach suitable only to large organisation. The definitions of OR society of America contains an important reference to the allocation of scarce resources. The key words used in the above definitions are *scientific approach, scarce resources, system and model.* The British definition contains reference to optimisation, while the American definition quietly slips in the word, best. A few other definition which are commonly used and widely acceptable are as follows :

- *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, are applied to solve practical decision problems of an economic or engineering nature.* Daellenbach and George, 1978

These two definitions project another view of OR as the collection of models and methods which have grown up largely independent of one another.

- *Operations Research utilizes the planned approach (updated scientific method) and an interdisciplinary providing a quantitative basis for decision making and uncovering new problems of quantitative analysis.* Thierauf and Klekamp, 1975
- *This new decision making field has been characterised by the use of scientific knowledge through inter disciplinary team effort for the purpose of determining the best utilisation of limited resources.* H.A Taha, 1976

These two definitions refer to the inter disciplinary nature of OR. However, one of the best definitions, given by Churchman, Ackoff and Arnoff, is as follows :

- *Operations Research, in the most general sense, can be characterised 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
- *Operation 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
- *OR is the art of giving bad answers to problems to which otherwise worse answers are given.* T L Saaty, 1958
- *Operations Research may be described as a scientific approach to decision making that involves the operations of organisational system.* F S Hiller and G J Lieberman, 1980
- *Operations Research is a scientific method of providing executive departments with a quantitative basis for decisions under their control.* P M Morse and G E Kimball
- *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 through - going rationality in dealing with his decision problems.* D W Miller and M K Stan
- *Operations Research is a scientific approach to problems solving for executive management.* H M Wagner

As the discipline of operations research grew, many other names such as Optimization Techniques, Operation Analysis, Systems Analysis, Decision Analysis, Management Science were given to it. However, each of these emphases the quantitative approach to the analysis and solution of management problems.

1.3 *Phases (or Steps) of Operation Research Method (Modelling)*

About four to five decades ago it would have been difficult to get a single operations researcher to describe a procedure for conducting OR project. But today, every engineer and manager are presenting the procedure in different ways as suits to their situations. However, the procedure for an OR study generally involves the following major phases :

Phase - I : Formulating the problem
Phase - II : Fitting a Suitable 'OR' model
Phase - III : Analysis and Deriving the solutions from the model
Phase - IV : Testing the Model and its solution
Phase - V : Sensitivity analysis and Controlling the solution
Phase - VI : Decision making and Implementing the solution

Phase - I : *Formulating the Problem :*

To find the solution of a problem, the problem must be formulated in the form of an appropriate model. This requires the following information.

1. Who has to take the decision?
2. What are the objectives?
3. What are the ranges of controllable variables?

4. What are the uncontrolled variables that may affect the possible solutions?
5. What are the restrictions (or) constraints on the variables?
6. What are other conditions or nature of variables?

The formulation should be considerably careful while executing this phase because a wrong formulation cannot give a right decision (solution), and even may be disastrous in some cases.

Phase - II : ***Fitting a Suitable 'OR' Model :***

The next phase of the investigation is concerned with the searching of suitable OR model in an appropriate form which is convenient for analysis. It requires the identification of both static and dynamic structural elements. The OR model consists of the following three important basic factors.

1. Decision variables and OR parameters;
2. Constraints (or) restrictions;
3. Objective function.

Various models are discussed in the next sections (1.4 & 1.5)

Phase - III : ***Analysis and Deriving the Solutions from the Model :***

The third phase involves in the computation of those values of decisions variables that maximise or minimise the objective function. Such solution is called an optimal solution which is always in the best interest of the problem under consideration.

Phase - IV : ***Testing the Model and its Solution :***

After computing and deriving the solution from the model, it is once again tested as a whole for the errors if any. A model may be said to be valid if it can provide a reliable prediction of the system's performance. A good practitioner of Operations Research believes that his model be applicable for a longer time and thus updates the model time to time by considering the past, present and future specifications of the problem.

Phase - V : ***Sensitivity*** Analysis and Controlling the Solution :

The fifth phase establishes controls over the solution with desired degree of satisfaction. The model requires immediate modification as soon as the controlled variables (one or more) change significantly, otherwise the model goes out of control. This action is often referred to as sensitivity analysis. As the conditions are constantly changing in the world, the model and the solution may not remain valid for a long time. Therefore it leaves a lot of scope for further improvement along with controlling.

Phase - VI : ***Decision Making and Implementing the Solution :***

Finally, the tested results of the model are implemented to work. This phase is primarily executed with the co-operation of operations Research experts and those who are responsible for managing and operating the systems. However, this job is more concerned with the production dept of executors of the model. Moreover, it essentially requires to take into confidence, the willingness and belief of the people who implement it or involve in it.

1.4 *Operation Research Models : Classification*

OR model is a representation of a real life situation. OR models can be studied by classifying in many ways. These are discussed here below :

1.4.1 *Classification Based on Structure*

1. **Physical** Models : **These models give a physical appearance of the real object either in reduced form or scaled up. These are further divided into two categories.**

   (a) ***Iconic*** Models : ***These are representations in either idealised form or a scaled version. (i.e., enlarging or reducing in size) of real objects. e.g., Blue prints, Globe, Photographs, Drawings, Templates etc.***

   (b) ***Analogue*** Models : ***These models represent a system by a set of properties different from that of the original system, and physically do not resemble. After attaining solution, it is re-interpreted in terms of original system. e.g., frequency curves, flow charts, organisation charts etc.***

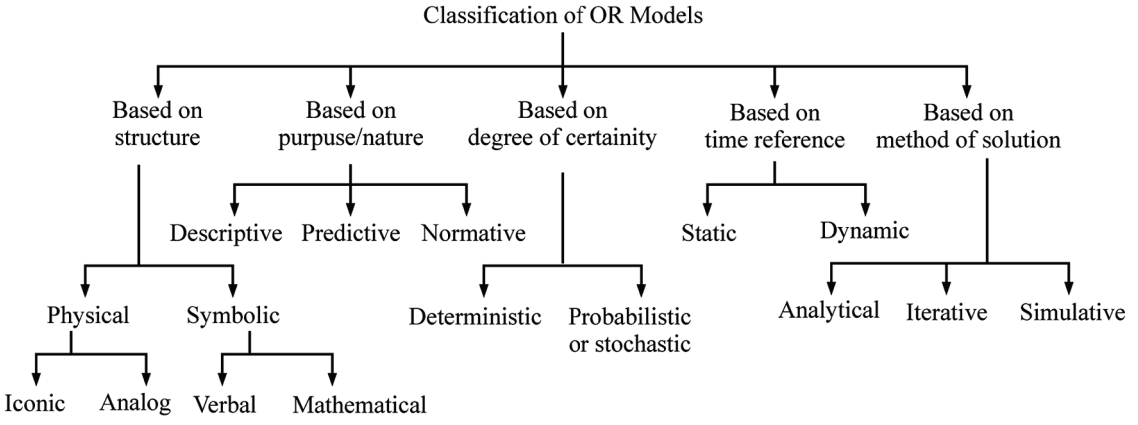


FIGURE 1.1 : CLASSIFICATION OF OR MODELS

2. **Symbolic** Models : **These models use symbols in the form of letters, mathematical operators or any other symbols to represent the properties of the system. These are often described in two types.**

   (a) ***Verbal*** Models : ***These models are used to describe a situation in written or spoken language in the form of letters, words and sentences.***

   (b) ***Mathematical*** Models : ***These models use mathematical symbols, letters, numbers and mathematical operators to represent relationship among various variables of the system to explain its behaviour and properties.***

1.4.2 *Classification Based on Purpose and Nature*

1. **Descriptive** Models : **The reports of surveys, questionnaire results, inferences of the observations etc., are used in such models to describe the situation. These also include the models such as plant layout diagram, block diagram of an algorithm etc.**

2. **Predictive** Models : **These models are results of the quiery such as "what will follow if this occurs or does not occur?" e.g. Preventive maintenance schedules.**
3. **Normative Model** (or Optimisation Models) : **These models are designed to provide 'optimal' solution to the problems subject to certain limitations on the use of resources or meeting the requirements or at the conditions that normally exist.** *e.g.* **Linear Programming Problem.**

1.4.3 *Based on Certainty*

1. **Deterministic** Model : **If all the parameters of decision variables, constants and their functional relationship are known (or assumed to be known) with certainty, then the model is said to be deterministic. e.g. Certain inventory models, games with saddle points.**
2. **Probabilistic** (or Stochastic) Model : **This is the model in which at least one parameter or decision variables is a random variable. e.g. Probabilistic inventory models, games without saddle points, queuing models.**

1.4.4 *Based on Time Reference*

1. **Static** Model : **These models present a system at a specified time, which do not account for changes over certain period of time. e.g. Replacement of machines when money value is not changing with time.**
2. **Dynamic** Model : **Time is considered as one of the variables and the impact of changes generated by time is accounted while selecting the optimal course of action. e.g. Machine replacement model when money value is changing with time.**

1.4.5 *Based on Method of Solution*

1. **Analytical** Model : **These have a specific mathematical structure and hence can be solved by analytical or mathematical techniques. e.g. Any optimisation model, such as inventory models, waiting lines etc.**
2. **Iterative** Models : **In these models, the solution is obtained from the conclusion of previous step. e.g. Simplex method for LPP, dynamic programming.**
3. **Simulation** Models : **Though these models have a mathematical structure, they can not be solved by applying mathematical techniques. Instead, a simulation model is essentially a computer assistant experimentation on a mathematical structure of a real life problem under certain assumptions over a period of time. e.g. Monte-Carlo simulation, use of random numbers, forecasting models etc.**

1.5 *Application Models of Operations Research*

Basic Operation Research Application Models are discussed here below

1. **Allocation** Models : **Allocation models are used to allocate resources to activities in such a way that sum measure of effectiveness (objective function) is optimized. e.g. Linear Programming Problem (Simplex, Transportation, Assignment etc.,) and Non–linear programming.**

2. **Inventory** Models : **Inventory models are used to determine how much to order and when to place an order so as to optimize the inventory costs such as order cost, carrying cost, shortage cost etc.,**
3. **Competitive** (Game Theory) Models : **These models are used to characterize the behaviour of two or more opponents (called players) who compete for the achievement of conflicting goals. These models are classified according to number of competitors, sum of loss and gain and type of strategy.**
4. **Network** Models : **These models are applied to management (planning and scheduling) of large scale projects, PERT/CPM help in identifying trouble spots in a project by critical path and to determine time-cost trade off, resource allocation and updating of activity times.**
5. **Sequencing** Models : **This arises whenever there is a problem in finding a sequence or order in a number of tasks performed by a number of service facilities. Here, the total time to process all the jobs on all the machines is optimized.**
6. **Waiting Line** (Queuing) Models : **These are used to establish a trade off between cost of providing service and the waiting time of a customer in queuing system by using the probabilities and averages.**
7. **Replacement** Models : **To decide the optimal time to replace equipment, for instance when equipment deteriorates or fails, these models are applied.**
8. **Dynamic** Programming Model : **These may be considered as an out growth of mathematical programming, which involves optimization of multi stage, inter–related decision process.**
9. **Markov** Chain Models : **Used for analysing a system which changes over a period of time among various possible out comes or states.**
10. **Monte-Calro** Simulation : **Simulation is a quantitative procedure, which describes process by developing a model of that process and then conducting a series of organised experiments to predict the behaviour of the process over time. To find out how the real process would react to certain changes, we can produce these changes in our model and simulate the reaction of the real process to them.**

1.6 *Significance and Applications of OR in Industrial Problems*

The Operations Research approach becomes very significant in industrial problems particularly, when the resouces are scarce or/and when a balance is to be brought between conflicting goals where there are many alternative courses of actions available to the decision maker. Let us consider one such example given below.

Suppose, a decision has to be taken regarding inventory management. The objective of production manager is based on quality of material and availability on time. While a finance manager thinks on the line of minimising the costs. Therefore he would prefer to order a party who can supply at lowest costs or can offer some discount. The materials manager wishes to safeguard production from stockouts and against demand fluctuations etc. Therefore he would like to order in such way. But the stores manager will be particular about accommodating them in his stores and other related problems in protecting the materials while storage and so on. Thus all

these managers are trying minimise the cost or maximise profit to the organisation. Though every manager is thinking in the interest of organisation growth, their objectives vary according to their specification.

In view of the situations like above a manager has to derive the decisions which should consist.

1. A total system *orientation*
2. Scientific *approach*
3. Realistic *nature*
4. *Models should be able to be expressed quantitatively.*
5. Systematic *method.*

OR is the science that is embedded with suitable blend all the above features.

Thus, OR can play a significant role in bringing a balance among different interdisciplinary people to managerial problems.

Some Areas of Applications :

1. Design of aircraft and aerospace structures for minimum weight.
2. Finding the optimal trajectories of space vehicles.
3. Design of civil engineering structures like frames, foundations, bridges, towers, chimneys and dams for minimum cost.
4. Optimum design of linkages, cams, gears, machine tools and other mechanical components.
5. Selection of machining conditions in metal cutting processes for minimum production cost.
6. Design of material handling equipment like conveyors trucks and cranes for minimum cost.
7. Design of pumps, turbines and heat transfer equipment for maximum efficiency.
8. Optimum design of electrical machinery like motors, generators and transformers.
9. Optimum design of electrical networks.
10. Shortest route taken by salesman visiting different cities.
11. Optimum production planning, controlling and scheduling.
12. Analysis of statistical data and building empirical models from experimental results to obtain the accurate representation of the physical phenomenon.
13. Optimum design of chemical processing equipment and plants.
14. Design of optimum pipe line networks for process industries.
15. Selection of site for an industry.
16. Inventory control to minimise inventory costs such as ordering cost, carrying costs, shortage costs etc.
17. Planning of maintenance and replacement of equipment to reduce the operating costs.
18. Allocation resources of services among several activities to maximise the benefit.
19.

Controlling the waiting and idle items and queuing in production lines to reduce the costs.

20. Planning the best strategy to obtain maximum profit in the presence of competitor.

1.7 *Characteristic features of Operations Research Model (or Merits of Operations Research Models)*

Some significant features of Operations Research Model are given below.

1.7.1 *Distinct Direction in Decision Making*

Operations Research model provides a clear and distinct direction to the managers in decision making and problem solving. A major premise of Operations Research is that decision making irrespective of the situation involved, can be considered as a general systematic process.

1.7.2 *Scientific Approach*

Operations Research employs scientific reasoning to its problems. Therefore the managers can confidently implement their decisions. Even if they fail after taking a decision provided by Operations Research, they will have scientific and evidential basis to plead in their support.

1.7.3 *Objective Orientation*

Operations Research is oriented to locate the best possible or optimal solution to the problem. As the approach itself is embedded with setting of the goal or objectives, it becomes easy to use this as a measure to compare the alternative courses of action.

1.7.4 *Inter - Disciplinary Team Approach*

Operations Research is inter disciplinary in nature and therefore needs a team approach. It is a blend of the aspects of various disciplines such as economics, physics, physiology, sociology, anatomy, engineering, technology, mathematics, statistics and management. This feature keeps Operations Research on the common berth to all sectors of people and builds an espirit-de-corps. It can also provide a solution acceptable to all the people.

1.7.5 *Compatible to Digital Computer*

Perhaps the use of digital computer has become an integral part of the Operations Research approach to decision making. There are several software packages developed with the help of Operations Research approach to problems with high volume and complexive in nature.

1.7.6 *Consideration of All Factors*

Operations Research takes into account of the goals (objective function) of the organisation with all bottlenecks or hurdles (constraint set) and the feasibility (conditions of variables). This feature provides a manager to take a decision that can keep himself or his organisation on a competitive edge.

1.8 *Limitations (Demerits) of Operations Research*

Operations Research, though widely used has got certain limitations. These are given below :

1.8.1 *Impossibility and Infeasibility*

Operations Research takes care of all the factors in choosing the best alternative. In modern society and in real life these factors are numerous and establishing relation among these is either impossible or infeasible in many cases. Thus many problems will be left unsolved.

1.8.2 *For Intangible Situations*

Operations Research can provide solution to those problems in which all the factors can be quantifiable. But it can not provide any solution to intangible variables and attributes which are qualitative in nature such as a human factors etc.

1.8.3 *Distance Between Managers (Decision Maker) and Operation Researcher*

Operations Research is specialist's job and requires the knowledge of mathematics, statistics etc. The researcher thus may not be aware of the business problem and the aspect of flexibility cannot be clarified by him.

At the same time the managers may fail to understand the complex working of the OR. Some times they may not even find time to notice any misconceptions. Thus there is a large gap built up between one who provides solutions and one who uses them. This leads to confusion and poses lot of problems during implementation or practice. Therefore it may result in utter failure even with a successful formula.

Review Questions

1. Discuss the phases of Operations Research.

2. Discuss the characteristics and limitations of Operations Research.

[Mech. 96, 95/C, 97/S, 98/P, 99/C]

3. Discuss the types and characteristics of models used in Operations Research. **[CSE - 98/S]**

4. What are the different types of models used in Operations Research? Mention general methods of solving Operations Research models. **[Mech. 95/S, 96/S, CSE 96, 98]**

5. Explain engineering applications to optimization techniques. **[EEE 95, 97, 98/S]**

6. "Operations Research provides bad solutions, otherwise which would have been the worst." Comment.

7. Discuss the merits and demerits of Operations Research models.

8. Discuss the strengths and weakness of Operations Research approach.

9. Discuss the significance of OR in solving managerial problems. **[CSE 2000]**

10. Explain the characteristic features of OR **[CSE 2000/S]**

11. Write short note on 'General methods of solving OR models' **[JNTU - Mech./Prod./Chem. - 2001/S]**

12. Write critical essay on the definition and scope of OR **[JNTU - CSE/E.Com. E 2001]**

13. Define Operations Research **[OU - MBA - 90, Dec. 95, Sep 2001,]**

14. State three distinguishing characteristics of OR **[MBA - OU - May 91 Dec. 2000, Sep. 2000]**

15. Explain the role of OR in management decision making **[MBA - OU - March 99]**

16. What is "team approach" in OR **[MBA - OU - July 2000]**

17. Write any three definitions of OR **[MBA - OU - Nov. 94]**

Objective Type Questions

1. Which of the following models does not use probabilities.

   (a) inventory models (b) game theory models
   (c) queuing models (d) linear programming

2. Which of the following belongs to Operations Research model classified on the basis of time reference.

(a) predictive model (b) normative model
(c) dynamic model (d) simulation

3. In which of the following models, we do not use alphabet

(a) mathematical model (b) descriptive
(c) verbal (d) none of the above

4. Deterministic models are based on

(a) time frame (b) degree of certainty
(c) method of solution (d) nature or purpose of use

5. Iconic model uses

(a) scaled version (b) expectation
(c) synergy (d) time reference

6. The Operations Research model represents a system, but does not physically resemble the components of the system is

(a) iconic (b) analogue (c) symbolic (d) normative

7. Game theory without saddle points belongs to _____ model of OR

(a) static (b) dynamic (c) deterministic (d) probabilistic

8. Replacement models when money value not changing with time can be considered as

(a) static (b) dynamic (c) probabilistic (d) simulative

9. Which of the following is not a strength of Operations Research.

(a) objective orientation (b) distinct decision making
(c) team approach (d) gap between the user and OR model designer

10. Which of the following is not a limitation of Operations Research.

(a) qualitative aspects
(b) gap between decision maker and model maker
(c) involvement multiple constraints
(d) scientific approach

11. The Operations Research widely employed in marketing problems is

(a) goal programming (b) game theory
(c) dynamic programming (d) linear programming

12. "If this occurs, what will follow?" This question is connected with _____ model.

(a) normative (b) iconic (c) predictive (d) descriptive

13. The scaled version of a real object is _____

(a) iconic model (b) descriptive
(c) normative model (d) static model

14. Find odd man out.

(a) iconic model (b) verbal model
(c) mathematical model (d) probabilistic model

15. The failures of decisions based on Operations Research modeling to managerial problems is attributed to

(a) model makers ignorance (b) managers inefficiency
(c) decision makers fault (d) understanding between decision maker and model maker

16. In which of the following, deterministic models are not found.

(a) games and competitive strategies (b) inventories
(c) waiting line models (d) replacement models

17. Plant layout diagram is an example as best fit in

(a) probabilistic model (b) dynamic model
(c) descriptive model (d) simulative model

18. Demand forecasting can be fit as an example of

(a) static model (b) simulative model
(c) deterministic model (d) symbolic model

19. Consider these following two groups :

1. Degree of certainty	( )	A.	Iterative
2. Time reference	( )	B.	Normatives
3. Application	( )	C.	Stochastic
4. A method of solution	( )	D.	Verbal
5. Symbolism	( )	E.	Static

The correct matching is

(a) 1-C, 2-E, 3-B, 4-D, 5-A (b) 1-C, 2-E, 3-B, 4-A, 5-D
(c) A-4, B-3, C-4, D-1, E-2 (d) A-3, B-4, C-2, D-5, E-1

20. Operations Research models can not work in the case of

(a) tangible variables (b) quantitative factors

(c) human factors (d) decision maker knows OR.

21. Match the following:

1. Iconic model	( )	A. Explanation
2. Dynamic model	( )	B. Words × letters
3. Predictive model	( )	C. Changes with time
4. Stochastic model	( )	D. Expectation through clues
5. Verbal model	( )	E. Scaled version
6. Descriptive	( )	F. Comparative
		G. Involvement of risk

Fill in the Blanks

1. The scaled version of a real object can be termed as _____ model of Operations Research.
2. Operations Research problems take into consideration of the objective function, constraints and _____.
3. According to Saaty " Operations Research is choosing _____ decision otherwise which would have been _____.
4. The goodness or optimality of an Operations Research problem is checked by _____.
5. The static and dynamic models of Operations Research are based on _____ reference.

Answers

Objective Type Questions :				
1. (d)	2. (c)	3. (d)	4. (b)	5. (a)
6. (b)	7. (d)	8. (a)	9. (d)	10. (d)
11. (b)	12. (c)	13. (a)	14. (d)	15. (d)
16. (c)	17. (c)	18. (b)	19. (d)	20. (c)

Match the Following :		
1. (e)	2. (c)	3. (d)
4. (g)	5. (b)	6. (a)
Fill in the Blanks :		
1. iconic	2. conditions of variables	3. the bad, the worst
4. objective function	5. time	