CHAPTER

1 Basics of Operations Research

The main purpose of this book is to provide the reader with basic concepts of operations research (abbreviated to OR). The subject is so vast that in any introductory text, such as this, the discussion of various topics has got to be limited. Complete volumes have been written on some of the topics discussed here. Attempt has been made to present a variety of material within a limited structure. References are indicated at the end to provide the reader with exhaustive treatment of the different topics.

This chapter provides an overall view of the subject of operations research. It covers some general ideas on the subject, thus providing a perspective. The remaining chapters deal with specific ideas and specific methods of solving OR problems.

1.1 DEVELOPMENT OF OPERATIONS RESEARCH

(i) *Pre-World War II:* 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 Ferderick W. Taylor emphasised the application of scientific analysis to methods of production, that the real start took place. Taylor conducted experiments in connection with a simple shovel. His aim was to find that weight load of ore moved by shovel which would result in maximum of ore moved with minimum of fatigue. After many experiments with varying weights, he obtained the optimum weight load, which though much lighter than that commonly used, provided maximum movement of ore during a day. For a "first-class man" the proper load turned out to be 20 pounds. Since the density of ores differs greatly, a shovel was designed for each ore so as to assume the proper weight when the shovel was correctly filled. Productivity rose substantially after this change.

Another man of early scientific management era was Henry L. Gantt. Most job-scheduling methods at that time were rather haphazard. A job, for instance, may be processed on a machine without trouble but then wait for days for acceptance by the next machine. Gantt mapped each job from machine to machine, minimizing every delay. Now, with the Gantt procedure it is possible to plan machine loadings months in advance and still quote delivery dates accurately.

In 1917, A.K. Erlang, a Danish mathematician, published his work on the problem of congestion of telephone traffic. The difficulty was that during busy periods, telephone operators were unable to handle the calls the moment they were made, resulting in delayed calls. A few years after its appearance, his work was accepted by the British Post Office as the basis for calculating circuit facilities. The formulae he developed on waiting time are of fundamental importance to the theory of telephone traffic.

The well-known economic lot size model is attributed to F.W. Harris, who published his work on the area of inventory control in 1915.

1.3 CHARACTERISTICS OF OPERATIONS RESEARCH

The various definitions of operations research presented in section 1.2 bring out the essential characteristics of operations research. They are

(*i*) its system (or executive) orientation,
(*ii*) the use of interdisciplinary teams,
(*iii*) application of scientific method,
(*iv*) uncovering of new problems,
(*v*) improvement in the quality of decisions,
(*vi*) use of computer,
(*vii*) quantitative solutions, and
(*viii*) human factors.

Let us consider each of these in some detail.

1.10 APPLICATIONS OF VARIOUS OR TECHNIQUES

Operations research at present finds extensive application in industry, business, government, military and agriculture. Wide variety of industries namely, airlines, automobiles, transportation, petroleum, coal, chemical, mining, paper, communication, computer, electronics, etc. have made extensive use of OR techniques. Some of the problems to which OR techniques have been successfully applied are:

1. **Linear programming** has been used to solve problems involving assignment of jobs to machines, blending, product mix, advertising media selection, least cost diet, distribution, transportation, investment portfolio selection and many others.
2. **Dynamic programming** has been applied to capital budgeting, selection of advertising media, employment smoothening, cargo loading and optimal routing problems.
3. **Inventory control** models have been used to determine economic order quantities, safety stocks, reorder levels, minimum and maximum stock levels.
4. **Queuing theory** has been helpful to solve problems of traffic congestion, repair and maintenance of broken-down machines, number of service facilities, scheduling and control of air traffic, hospital operations, counters in banks and railway booking agencies.
5. **Decision theory** has been helpful in controlling hurricanes, water pollution, medicine space exploration, research and development projects.
6. **Network techniques of PERT and CPM** have been used in planning, scheduling and controlling construction of dams, bridges, roads, highways and development and production of aircrafts, ships, computers, etc.
7. **Simulation** has been helpful in a wide variety of probabilistic marketing situations. It has been, for example, used to find NPV (Net Present Value) distribution for the venture of market introduction of a new product.
8. **Replacement theory** has been extensively employed to determine the optimum replacement interval for three types of replacement problems:

(*a*) replacement of items that deteriorate with time.
(*b*) replacement of items that do not deteriorate with time but fail suddenly.
(*c*) staff replacement and recruitment.

Other techniques extensively employed are game theory, statistical quality control, investment analysis, goal programming, etc.

1.11 OBJECTIVES OF OPERATIONS RESEARCH

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The industrial growth has brought with it the need for *division of management function* within an organisation. Thus every organisation has in it a number of functional units or departments, each performing a part of the whole job and for its successful working, developing its own policies and objectives. These objectives, though in the best interest of the individual department, may not be in the best interest of the organisation as a whole. In fact, these objectives of the individual departments may be inconsistent and even clashing with each other. In this context reference was made in section 1.1 with regard to the attitudes of the various departments of a business organisation towards its inventory policy. Numerous examples of similar conflicts can be cited. Consider, for instance, the case of economic order quantity where there is a conflict between the acquisition cost and the inventory carrying cost with regard to the batch size with the former decreasing and the latter increasing with the batch size (Fig. 1.1). The total cost curve is cup-shaped. This cup shape as

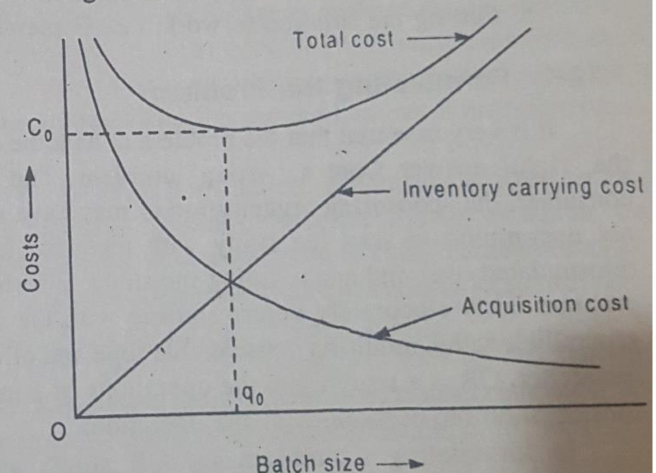

Fig. 1.1

such or reversed is bound to occur whenever there are conflicting costs or conflicting gains. Th objective of OR is to minimize the total cost *i.e.*, find the minimum of the cup-shaped cost cur of the reversed cup-shaped gain curve.

1.12 PHASES OF OR or METHODOLOGY OF OR or OR APPROACH or HOW OR WORKS

Operations research, like all scientific research, is based on scientific methodology, which proceeds along the following lines:

1. Formulating the problem.
2. Constructing a model to represent the system under study.
3. Deriving a solution from the model.
4. Testing the model and the solution derived from it.
5. Establishing controls over the solution.
6. Putting the solution to work, *i.e.*, implementation.

solution). On the other hand, ...

1.20 TYPES OF MATHEMATICAL MODELS

Many OR models have been developed and applied to problems in business and industry. Some of these models are:

1. Mathematical techniques
2. Statistical techniques
3. Inventory models
4. Allocation models
5. Sequencing models
6. Project scheduling by PERT and CPM
7. Routing models
8. Competitive models
9. Queuing models
10. Simulation techniques
11. Decision theory
12. Replacement models
13. Reliability theory
14. Markov analysis
15. Advanced OR models
16. Combined methods.

new processes ...

1.21 ROLE OF COMPUTERS IN OPERATIONS RESERACH

It was said in section 1.1 that the computer played a vital role in the development of OR. But for the computer, OR would not have achieved its present position. It is because in most OR techniques, computations are so complex and involved that these techniques would be of no real use in the absence of the computer. Most large-scale applications of OR techniques which require only a few minutes on the computer, may take weeks, months and even years to yield the same results manually.

Most of linear programming models for even small scale industries usually involve hundreds of decision variables and constraints. Likewise, most of the business problems, such as blending problems of oil refineries, may involve thousands of variables and constraints. It is simply impossible to solve such large problems manually; they are solved using sophisticated software packages. Many computer manufacturing companies have developed software packages for problems to be solved by the application of OR techniques. Companies such as IBM, ICL, UNIVAC, CDC have done so for solving scheduling, inventory, simulation, queuing, networking (PERT/CPM) and many other OR problems.

No doubt, the computer is an essential and integral part of OR. Today, OR methodology and computer methodology are growing in parallel. It appears that in the coming years the line dividing the two methodologies will disappear and the two sciences will combine to form a more general and comprehensive science.

1.23 LIMITATIONS OF OPERATIONS RESEARCH

1. Mathematical models, which are essence of OR, do not take into account qualitative factors or emotional factors which are quite real. All influencing factors which cannot be quantified find no place in mathematical models.
2. Mathematical models are applicable to only specific categories of problems.
3. OR tries to find optimal solution taking all the factors of the problem into account. Present day problems involve numerous such factors; expressing them in quantity and establishing relations among them requires huge calculations.

4. Being a new field, generally there is a resistance from the employees to the new proposals.
5. Management, who has to implement the advised proposals, may itself offer a lot of resistance due to conventional thinking.
6. Young enthusiasts, overtaken by its advantages and exactness, generally forget that OR is meant for men and not that men are meant for it.

Thus at the implementation stage, the decision cannot be governed by quantitative considerations alone. It must take into account the delicacies of human relationships. That is, in addition to being a pure scientist, one has to be tactful and learn the art of getting the decisions implemented. This art can be achieved by experience as well as by getting training in social sciences, particularly psychology.

In fact, many managers may make a joke of OR as they think that the decisions made otherwise may be better. But being aware of its limitations, they need to be convinced of its utility, which doubtlessly forms the essential guideline for making better decisions.

EXERCISES