Whether it is factory, farm, or a domestic kitchen, resources of men, material, machine and money have to be coordinated against time and space constraints to achieve given objectives in a most efficient manner. The manager has to constantly analyse the existing situations, determine the objectives, seek alternatives, implement, coordinate, control and evaluate. The common thread of these activities is the capability to evaluate information and make decisions. Managerial activities become complex as the organizational settings in which they have to be performed. As the complexity increases, management becomes more of a science than an art and a manager by birth yields place to a manager by profession.

Management, as an art, has been practised from time immemorial when man learnt to live in groups. Management of a tribe, a city or a nation has been a subject of intense study. Philosophers like Plato, Aristotle, Machiavelli, and Kautilya had chosen the art of managing a state as a subject for exploration and exposition. But till the modern times the focus of study in management of “administrations” has been on the leader, and immediately after industrialization, on the entrepreneur. However, with the change in the activities of a modern society brought about by industrialization, there is a need not only for examining the role of leaders and entrepreneurs in activities other than statecraft but also for training people down the hierarchy who can manage a system both efficiently and creatively. Management of organizations—initially involved in economic activity and later extended to organizations with social objectives or a mixture of economic and social objectives—has now come to be studied and taught as a subject by itself.

1.1 STATISTICS AND MANAGERIAL DECISION-MAKING

Since, the complexity of business environment makes the process of decision-making difficult, the decision-maker cannot rely entirely upon his observation, experience or evaluation to make
a decision. Decisions have to be based upon data which show relationship, indicate trends, and show rates of change in various relevant variables. The field of statistics provides methods for collecting, presenting, analysing and meaningfully interpreting data. Thus, the statistical methodology in collection, analysis and interpretation of data for better decision-making is a sine qua non for managerial decision-making and research in both physical and social sciences, particularly in business and economics. Figure 1.1 shows the classification of subject matter in the field of statistics.

![Fig. 1.1: Classification of Subject Matter in Statistics.](image)

Statistical data constitute the basic raw material of the statistical method. These data are either readily available or collected by the analyst. The manager may face four types of situations:

(i) when data need to be presented in a form which helps in easy grasping (for example, presentation of performance data in graphs, charts, and tables, in the annual report of a company);

(ii) where no specific action is contemplated but it is intended to test some hypotheses and draw inferences;

(iii) when some unknown quantities have to be estimated or relationships established through observed data; and

(iv) when a decision has to be made under uncertainty regarding a course of action to be followed.

As indicated in the figure, while situation (i) falls in the realm of descriptive statistics, situations (ii) and (iii) fall in the area of inductive statistics, and situation (iv) is dealt by the statistical decision theory. Thus, the descriptive statistics refers to the analysis and synthesis of data so that better description of the situation can be made and thereby promote better understanding of facts. Classification of production and sales in different locations and their presentation in tabular form is the task of descriptive statistics. Computation of changes in the values of relevant variables, or the average value of data are also a part of descriptive statistics.

Inductive statistics is concerned with the development of scientific criteria so that values of a group may be meaningfully estimated by examining only a small portion of that group. The group is known as 'population' or 'universe' and the portion is known as 'sample'. Further,
values in the sample are known as statistics and values in the population are known as parameters. Thus, inductive statistics is concerned with estimating universe parameters from the sample statistics. The term inductive statistics is derived from the inductive process which tries to arrive at information about the general (universe) from the knowledge of the particular (sample).

Samples are drawn instead of a complete enumeration for the following reasons: (i) at the time of completion of a full enumeration so much time is lost that often by that time the data become obsolete, (ii) sampling cuts down cost substantially, and (iii) sometimes securing information is a destructive process, for example, in case of quality control situation, pieces have to be broken down for testing.

Another component of statistics is statistical decision theory which concerns itself with establishment of rules and procedures for choosing one course from alternative courses of actions under situations of uncertainty. Since, the statistical decision theory also uses the subjective or prior probabilities in analysis, it is also known as subjectivist approach. Further, as the Bayes’ theorem makes it possible to revise prior probabilities in the light of additional information, this approach is also referred to as Bayesian approach.

### 1.2 STATISTICAL DATA

Application of statistical techniques to managerial decision problems depends on the availability and reliability of statistical data. Statistical data can be broadly grouped into two categories: (i) published data (that have already been collected and are readily available in the published form), and (ii) unpublished data (that have not yet been collected and the analyst himself will have to collect them).

Published data are available from numerous sources. For example, monthly data on monetary and banking activities and selected indicators of the economy (index of industrial production, prices, etc.) are presented in Reserve Bank Bulletins, and Currency and Finance reports published by the Reserve Bank of India. Economic Survey brought out by the Ministry of Economic Affairs also presents relevant data about the important indicators of the economy. Annual survey of industries and survey of small scale units present large mass of data relating to all the industrial units in the country. Census of India Statistics provides data on population characteristics. Monthly Statistics of Foreign Trade is brought out by Commerce Ministry. Industry Studies brought out by Industry Association and specialized bodies give the data on various aspects of these industries. In addition, a large number of research organizations and private sources provide useful statistical data. The Secretariat of the United Nations, through its appropriate Economic Commission for Europe, Latin America, Asia and Far East, annually publish International Statistics on population, national product prices, incomes, financing, investments, economic conditions, and agriculture and mining for these regions. World Bank and Asian Development Bank Annual Reports and Statistical Publications also provide the international statistics.

Published data sources, however, do not always suffice to provide required aid in decision-making. For example, there is hardly any published data available on the pesticide consumption
by crops in each district or even for each state in India. Even the total sales of pesticides by each company and pesticide industry as a whole, are not available. This data is very crucial for decision-making with respect to formulation of strategy for marketing and promotion of pesticides in India. Therefore, support has to be given for the collection of original data. Several methods could be employed to secure information from a sample survey or a census. Some of these are: observation method, personal interviews and questionnaires, etc.

Data are also classified as primary or secondary. All the original data collected by the analysts themselves fall in the category of primary data. Secondary data are those which are available for use from other sources.

Data are also generated by internal operations of the economic unit. For instance, sales, labour data, financial statements, production schedules, cash flow data, budget data, etc., pertaining to an industrial unit constitute internal data and are found in the internal records of the company. Data are also classified as micro and macro. Micro data relate to one unit or one region and macro data relate to the entire economy or entire industry.

**Types of Statistical Data**

Whenever observations are made on some characteristics of an elementary unit of a population or a sample, the outcome need not necessarily be a number. If the characteristics observed are not numerical, they are called qualitative characteristics or attributes. An attribute cannot be measured but only its presence or absence can be observed. For example, the attributes of a customer who visits a departmental store can be classified as male or female, rich or poor, young or old, etc. When dealing with qualitative or attributes data, numerical values result from counting the number of elementary units that fall into each category. The sales manager who gets a list of daily sales will categorize the sales into cash and credit and then find the total in each category. Thus, we have the classification by attributes and then the numerical values by the totals.

On the other hand, when a numerical value can be associated with some characteristics of an elementary unit by a process of counting or measuring, that characteristic is said to be a quantitative characteristic. Height, weight, marks obtained in a subject, age, income, yield, number of members in a family, etc. are all quantitative characteristics are generally called as variables, and the data resulting from such observations are referred to as variable data.

At this stage, it is also necessary to know that there are two types of variables: a variable that is restricted to certain values, usually whole numerical numbers, is said to be a discrete variable and a variable that can assume any value within some range of values is said to be continuous variable. Family size, marks, income, etc. are the examples of discrete variables while height, weight, yieild, etc. are the examples of continuous variables. Income can be in rupees and paise, but it is a discrete variable because the value can always be restricted to some whole number of paises. Even though the measurements such as height, weight or yield and recorded in terms of units such as centimeters, kilograms or tenths of a centimeter, the value of the characteristic measured is not restricted to any arbitrary unit of measurement. Whatever the refinements in gradations are made on a measuring scale, the actual value of the characteristic being measured can always fall between any two of them and hence these variables are considered as continuous.
1.3 OPERATIONS RESEARCH TECHNIQUES

Wagner\(^1\) has defined operations research as a scientific approach to solve problems for executive management. An application of operations research involves:

\(a\) Constructing mathematical, economic and statistical descriptions or models of decision and control problems to treat situations of complexity and uncertainty.

\(b\) Analysing the relationships that determine the probable future consequences of decision choices, and devising appropriate measures of effectiveness in order to evaluate the relative merit of alternative actions.

The essential characteristics of Operations Research (OR) are:

\(i\) Examination of functional relationship from a system overview;

\(ii\) Utilization of the interdisciplinary approach;

\(iii\) Adoption of the planned approach;

\(iv\) Uncovering of new problems or study.

In order to evaluate any decision or action in an organization, it is necessary to identify all the important interactions and to determine their impact on the organization. The functional relationships in a project are expanded so that all the significantly interacting functions and their related components are contained in a statement of the problem. Thus, a system overview consists of surveying the entire area under the manager’s control instead of one specialized area. For example, production department of a manufacturing company is looking for a long, uninterrupted production runs to reduce set-up and clean-up costs, which may result in large inventory of raw materials, work-in-process, and finished goods. The other departments involved in this system are marketing, finance, and personnel. Marketing department, wanting to give immediate delivery for a wide variety of goods, desires a diverse and large inventory of finished goods. Also, it would like a flexible production department that can fill special orders on short notice. Finance department wants to keep inventory at a low value in order to optimize investments that tie up assets for intermediate periods. Finally, the personnel department wants to reduce labour turnover by smoothing out production runs so as to keep all temporary layoffs to a minimum level. The optimum production-scheduling policy, then affects the operations of various functional departments. In such a situation, the OR group should analyse all the elements in each department, like material procurement cost, production set-up and clean-up cost, competitive forces and prices, and the cost of holding inventories and stock-out (shortage) costs. When all factors affecting the system are known, a mathematical model can be developed. The best solution for this problem is one that leads to optimization for the whole firm (a profit function), but not necessarily to optimization for the various functions (departments) of the firm.

In the early years of operations research, OR group consisted of specialists in mathematics, physics, chemistry, engineering, statistics, and economics and this helped very

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much to develop OR models with an interdisciplinary approach. The production scheduling problem, for example, is quite complex when it cuts across the entire firm. Thus, it is necessary to look at the problem in many different ways in order to determine which one (or which combination) of the various disciplinary approaches is the best. The interdisciplinary approach recognizes that most business problems have accounting, biological, economic, engineering, mathematical, physical, psychological, sociological and statistical aspects.

The solution to a mathematical model or equation can be thought of as a function of controlled and uncontrolled variables, related in some precise mathematical manner. The objective function developed (utilizing controlled and uncontrolled variables) may have to be supplemented by a set of restrictive statements on the possible values of the controlled variables. For example, in theoretical mathematics one deals with negative values also, while in business problems it is not possible since one either produces an item or does not. Another example could be that the available resources cannot be exceeded in any production process. These constraints are expressed as a set of supplementary equations or inequalities, where ‘greater than’ or ‘less than’ conditions are used. The objectives of OR models are of two types: minimizing costs in terms of inputs, and maximizing outputs or sales of the firm. Minimization of costs and maximization of sales income lead to optimization of profits for the firm. The basic approach of operations research to such problems is the scientific method. The steps are: observation, definition of the real problem, development of alternative solutions, selection of optimum solution using experimentation, and verification of optimum solution through implementation.

The fourth characteristic of operations research is that in the solution of an OR problem new problems are uncovered. All interrelated problems uncovered by the OR approach need not be solved at the same time. However, each must be solved with consideration for other problems if maximum benefits are to be obtained.

Operations Research Models
A model is defined as a representation or abstraction of an actual object or situation. It shows the relationships (direct or indirect) and interrelationships of action and reaction in terms of cause and effect. Quantitative techniques are utilized to investigate the relationship that exist among the variables in a model.

Classification of models provides an added insight into their essentials since, they can be described in many ways. Models can be categorized by their types, dimensionality, function, purpose, subject or degree of abstraction. The basic types of models are physical (iconic), diagrammatic (analog), and mathematical (symbolic).

An iconic (physical) model is a physical representation of some item either in an idealized form or on a different scale, i.e., a representation is an iconic model to the extent that its properties are the same as possessed by what it represents. Example of these models are: photograph, blue print, map or a prototype of an item.

Analog models can represent dynamic situations and are used more than iconic models, since they can depict the characteristics of the event under study. Examples are demand curves, frequency distribution and flow charts.

Symbolic (mathematical) models take the form of figures, symbols or mathematical equations. They start as abstract models and then are set forth as symbolic models. One most commonly used symbolic models in operations research is an equation.
INTRODUCTION: WHY QUANTITATIVE TECHNIQUES?

Types of Mathematical Models
As we are interested in studying the mathematical models in operations research, many categories of models which help us in classifying them are briefly discussed below:

(a) Quantitative versus qualitative: Most business problems start with qualitative type models and then develop to a point where quantitative models can be used. The qualitative model treats only qualities of problem components while quantitative model requires numerical definition of the problem. Operations research deals with systematizing qualitative models and developing them to the point where they can be quantified.

(b) Standard versus custom made: Standard models are used to describe those techniques that have become associated with operations research. To use these techniques, insert the proper numbers from a specific business problem into the standard model for an answer. A custom made model results from using the basics of various disciplines, like mathematics, statistics and economics to build a model that fits the particular situation.

(c) Probabilistic versus deterministic: Models based on probability and concerned with future uncertainties are called probabilistic models. Those quantitative models that do not contain probabilistic considerations are termed deterministic models. Linear programming models are said to be deterministic models, while waiting lines are an example of probabilistic model.

(d) Descriptive versus optimizing: In some situations, a model is developed simply to be a mathematical description of a real situation. These are called descriptive models and help us to understand more about the problem. In a descriptive model, if there are choices, it will display these choices and can help us to evaluate the results of one choice over another. In an optimizing model, a concerted attempt is made to reach an optimum solution when presented with alternatives. An optimization, when solved, yields the best alternative according to the input criteria. An optimization model, thus, is concerned at arriving an optimum solution, whereas the descriptive model does not attempt to select the best alternative, but only to describe the choices that are open to the decision maker.

(e) Static versus dynamic: Static models are concerned with determining an answer for a particular set of fixed conditions that will probably not change significantly in the short run. Linear programming models are static models. A dynamic model is subject to the time factor which plays an essential role in the sequence of decisions. Regardless of what the prior decisions have been, the dynamic model helps one to find the optimal decisions for the future time periods. Dynamic programming is an example of dynamic model.

(f) Simulation versus non-simulation: The development of computers has helped to the development of simulation models in operations research. Simulation is a method involving step-by-step calculations where the workings of large-scale problems or systems can be reproduced. In many situations, where complex relationships of both predictable and random nature occur, it is easier to set up and run through a simulated situation on a computer than to develop and use a mathematical model representing the entire process under study. However, there are situations where the problem is less complicated which lend themselves to non-simulation models. Linear programming and transportation problems can be considered as non-simulation models.
Essential Aspects of an OR Model

An OR model is of the form

\[ Z = f(X_1, X_2, \ldots, X_n, Y_1, Y_2, \ldots, Y_n) \]

where \( Z \) = objective function

\( X_1, X_2, \ldots, X_n \) = system variables that are subject to control (controllable variables) and

\( Y_1, Y_2, \ldots, Y_n \) = system variables that are not subject to control (uncontrollable variables).

The conditions on values of variables may be expressed in a supplementary set of equations and inequalities. The solution of such a model consists of determining the values of control variables \( X \) for which the measure of effectiveness is maximum. In some problems, the measure of effectiveness might consist of minimization. As an illustration, let us consider the arrival of customers at a bank branch for availing various banking services. Here, \( Z \) stands for the average waiting time of the customers. The controllable variables \( X \)'s refer to the number of counters, for example, \( X_1 \) represents the savings bank counters, \( X_2 \) represents current account counters, and so on. The \( Y \)'s are those variables that are not subject to managerial control, \( Y_1 \) is the number of customers arriving in the system, \( Y_2 \) is the type of service required i.e., savings bank account, current account etc., and so on. The management’s problem here is to minimize the average waiting time by the customers subject to the availability of service personnel, etc.

The best way to start constructing a model is to identify all the components that contribute to the effectiveness of the system. The next step is to determine whether or not each of these components be used. To understand the significance of each component in the system, it is advisable to test all the available data experimentally or by some statistical method. From amongst the selected variables (components), it is necessary to identify the controllable and uncontrollable variables and to assign a symbol to each element where at least one symbol represents the measure of effectiveness or ineffectiveness.

### 1.4 ORGANIZATION OF THIS TEXTBOOK*

This textbook has been divided into two parts: (i) Statistics and (ii) Operations Research Techniques. The book also contains supplementary readings in mathematics for the benefit of those who are not familiar with the various elementary concepts in mathematics. Therefore, the student is advised to go to supplementary readings and then take up Part I or Part II.

Part I covers three areas of statistics: descriptive, inductive, and decision theory. Descriptive statistics, includes presentation and data analysis (Chapter 2), measures of central tendency and location (Chapter 3), measures of dispersion (Chapter 4), and index numbers (Chapter 13). Inductive statistics includes the meaning of probability (Chapter 5), random variables and probability distributions (Chapter 6), theoretical probability distributions (Chapter 7), sampling and sampling distributions (Chapter 8), testing of hypotheses (Chapter 9), correlation, regression and multivariate analysis (Chapter 11), and time series analysis

*This textbook is not original research. It only presents state of the art material for the formal study of the subject by the students and teachers.
(Chapter 12). Chapter 3 and 4 are essential prerequisites for Chapter 6 to 11. Statistical decision theory is dealt in Chapter 10—Decision-making under uncertainty. It may be noted that Chapters 5, 6 and 7 are essential prerequisites for understanding Chapter 10.

It should also be noted that a portion of Chapter 5 (dealing with Bayes’ theorem and subjective approach to probability) and Chapter 10 can be classified as Bayesian approach to dealing with the problems of uncertainty. Other chapters in inductive statistics can be classified as classical approach to dealing with problems of uncertainly. In the classical approach, a decision-maker would be unwilling to assign prior probabilities to the states of the universe and would reserve his judgement until objective evidence on the basis of sample has been collected. The Bayesian (or subjectivist) would, however, draw upon the attitude, experience, and convictions of the decision-maker’s opinion on uncertain situations. For example, suppose a new mechanic has to be hired to make machine set-ups and no objective evidence exists as to the quality of his performance. In the classical approach, one would assign probability to the process being correctly set-up solely on the basis of observed sample evidence. In the Bayesian approach, on the other hand, prior probabilities would be assigned by the decision-maker based on his experience and convictions. However, these probabilities would be revised in the light of additional information in the form of actual data relating to the mechanic’s performance in terms of correct machine set-ups out of the total adjustments of machine set-ups.

Part II deals with various Operations Research techniques for managerial decision-making. These include linear programming (Chapter 14), transportation and assignment problems (Chapter 15), integer, dynamic and goal programming (Chapter 21), theory of games (Chapter 16), network analysis—PERT/CPM (Chapter 17), waiting lines (Chapter 18), inventory control models (Chapter 19), simulation of management systems (Chapter 22), and replacement decisions (Chapter 20). It may be noted that Chapter 14 is a prerequisite for Chapters 15, 16 and 21. Various concepts of probability discussed in Chapter 5 (Part I) are required to understand Chapters 17, 18, 19, 20 and 22. Concepts discussed in Chapters 18 and 19 are basic necessities for Chapter 22.

Supplementary readings in mathematics include topics such as elementary concepts in mathematics, variables and functions, elements of calculus, classical optimization techniques, vectors, matrices and determinants, mathematics of finance. All these topics have been dealt at the elementary level. Furthermore, an effort has been made to illustrate each concept with the help of one or more illustrations drawn from various functional areas of management (i.e., finance, production, marketing and personnel). Thus, even those who have sufficient background in mathematics may find these supplementary readings useful in understanding various managerial applications. Both parts draw upon the various mathematical concepts discussed in these supplementary readings.

Every effort has been made to demonstrate the relevance and use of statistics and operations research models to managerial decision-making situations in developing countries with particular reference of India. In order to make the textbook useful for various courses in functional areas of management and chartered and cost accounting, each major concept has been illustrated by problems drawn from these functional areas. In addition, a set of practice problems has been included at the end of each chapter. The student is advised to solve these problems for gaining further insight and clarity of concepts discussed in the chapter. While solving the problems, the students would find the brief summary and formulae given at a glance at the end of each chapter are very useful. Those who would like to acquire more advanced knowledge in statistics and operations, research, may refer to suggested readings given at the end of each part. The organization of chapters are presented in the block diagram given in Fig. 1.2.
Fig. 1.2: Organization of the book.
Progress in computer technology and an increased access to computer facilities now have greatly facilitated the use of quantitative techniques in managerial decision-making. It is now possible to perform difficult mathematical computations involved in the application of various quantitative techniques much more easily. Care, however, has to be taken in appropriate specifications of models and interpretation of computer results. For these purposes also, a clarity of various concepts discussed in this textbook is essentially required. As a textbook is a derived knowledge, a detailed bibliography and further recommended readings are presented at the end of the book.

**AT A GLANCE**

Statistics. A branch of applied mathematics which deals with the collection and analysis of numerical data.

Raw Data. The statistical data in the original form before any statistical techniques are used to refine, process or summarize.

Descriptive Statistics. A branch of statistics which is concerned only with collecting, describing and summarizing a set of data so as to derive meaningful information.

Inductive Statistics. Deals with methods and techniques used for the analysis of a set or sub-set of data leading to predictions or inferences about the entire population.

Population. The entire set of possible observations that may be made on the universe. Although the term universe refers to the observations made on the units, the two terms are frequently used interchangeably.

Universe. The entire body of elementary units that are of interest and are subject to statistical investigations.

Sample. Any portion drawn from a population. Generally, a sample consists of a fewer elementary units or observations that contained in a population. Thus, a sample is a sub-set of a population.

Elementary Unit. A physical entity on which an observation is made.

Survey. A planned and systematic process of collecting statistical data.

Census. A survey in which observations are made on every elementary units of the whole population.

Sample Survey. A survey in which observations are made on a sample of elementary units drawn from the population.

Attribute. A characteristics of an elementary unit that can only be observed as to its presence or absence.

Variable. An observable quantitative characteristics of an elementary unit that may vary from unit to unit.

Discrete Variable. A variable whose values are restricted to integer values only. Observations of a discrete variable are counts.

Continuous Variable. A variable that can assume any value within some interval, observations on a continuous variable are the result of measurements.

Operations Research. Scientific approach to solve problems of executive management. It involves (a). Constructing mathematical, economical and statistical descriptions or models of decision and control problems to treat situations of complexity and uncertainty and (b). Analysing the relationships that determine the probable future consequence of decision choices, and devising appropriate measures of effectiveness in order to evaluate the relative merits of alternative actions.