

DEPARTMENT OF MASTER OF BUSINESS ADMINISTRATION

Introduction to Operations Research

1.1. OPERATIONS RESEARCH

1.1.1. Meaning and Definition

Operations Research (OR) is a discipline that deals with the application of advanced analytical methods to help in make better and improved decision. It is a systematic study of basic structure, characteristics, functions and relationships of an organisation, and provides a basis to managers for improved decision-making.

OR takes a scientific approach to best decide, how to design and operate man-machine systems, for industrial use. In other words, OR deals with optimal resource allocation. Most of the actual work is done using analytical and numerical techniques, that helps to develop and manipulate mathematical models of organisational systems.

Operations research is also known as **decision science** or **management science**. Unlike many other disciplines, that focus on technology, OR is an interdisciplinary mathematical study that focuses on the effective use of technology by organisations. Operations Research arrives at optimal or near-optimal solutions to complex decision-making problems, by employing techniques like mathematical modelling, statistical analysis, and mathematical optimisation.

According to Operations Research Society, America, "Operation research is concerned with scientifically deciding, how to best design and operate man machine systems; usually requiring the allocation of scarce resources".

According to T.L. Saaty, "Operation research is the art of giving bad answers to problems to which otherwise worse answers are given".

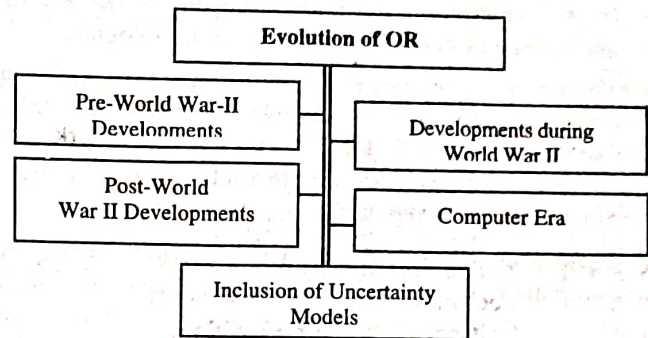
According to P.M. Morse and G.E. Kimball, "Operation research is a scientific method of providing executive departments with a quantitative basis for decision under their control".

According to H.M. Wagner, "Operation research is a scientific approach to problems solving for executive management".

According to Miller and Starr, "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".

1.1.2. Evolution of Operation Research

The operation research's beginning and development is explained through following hierarchy:



- 1) Pre-World War-II Developments:** Before introduction of the 'operations research', various other techniques such as inventory control, queuing theory and statistical quality control of the operations research were developed and were in use. A simple Economic Order Quantity (EOQ) model was developed which is used in optimising the total cost of the inventory system. EOQ was first developed by **Ford Harris** in 1915 and was finally evaluated in 1934 by **R.H. Wilson**. In same year, a Danish telephone engineer named **A.K. Erlang** developed new theoretical concepts of the queuing theory.

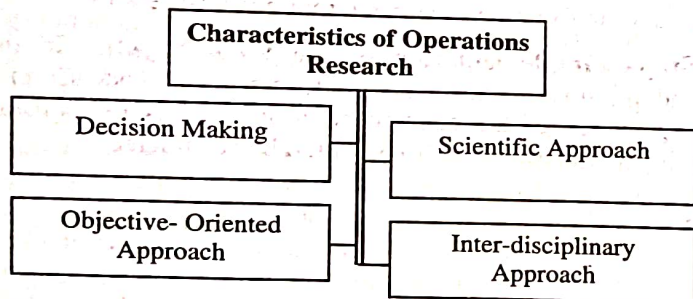
In early 1900s, Western Electric's Bell Laboratory's inspection engineering department analysed the problem occurred in the routine quality checks. This led to the development of the control charts in 1924 by **Shewhart** and was named as Shewhart control charts. Many terminologies related to the acceptance sampling of quality control were described by Western Electric Company in the time period of 1925-26. The attributes of raw materials/components/ finished products were controlled using these terminologies.

The developed terminologies were like consumer's risk, producer's risk, probability of acceptance, Operating Characteristics (OC) curve, Lot Tolerance Percent Defective (LTPD), double sampling plan, type-I error, type-II error and many more. The fundamental concept of sampling inspection was introduced in 1925 by **Dodge** and after a decade, the British Standard Institution Number 600 was developed by **Pearson** with title 'Application of statistical methods to international standardisation and quality control'.

- 2) **Developments during World War II:** At the time of World War II, the Britain military was mainly concerned for the effective exploitation of infrequent resources. Hence, a research was conducted by the native scientists. They discovered the various ways to make the fullest use of the resources to improve the efficiency of the military operations. This approach was incorporated in operations research methodologies for problem-solving aspects.
- 3) **Post-World War II Developments:** Post Second World War, the main emphasis of the American and British companies was to maximise the profit from limited resources, so, these companies focused on application of operation research methodologies.
The simplex method, for solving linear programming problem, was developed by Dantzing in 1947. Thereafter, in 1952, Operations Research Society of America and in 1953, the Institute of Management Sciences was established.
- 4) **Computer Era:** There were various complex computations in the operations research which consumed much time; hence, the computers were developed to solve such problems easily. The development of the recent interactive computers established a new milestone in the large size problems solving. The reason for this is that person involved towards sensitivity analysis of problems.
- 5) **Inclusion of Uncertainty Models:** The operations research techniques were more shaped with the use of the probability theory and statistics.

1.1.3. Characteristics of Operations Research

Operations research has the following characteristics:

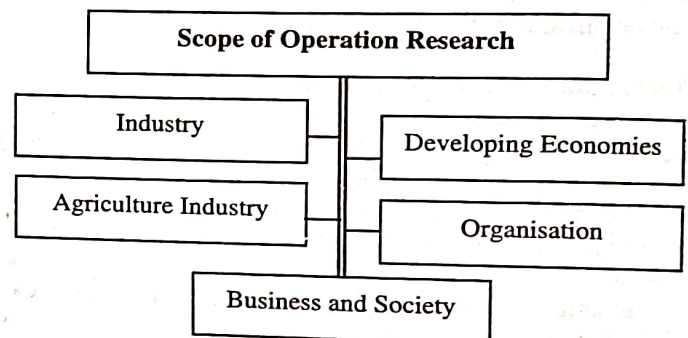


- 1) **Decision-Making:** Decision-making or problem solving constitutes the major working of operations research. Managerial decision-making is considered to be a general systematic process of operations research (OR).
- 2) **Scientific Approach:** Like any other research, operations research also emphasises on the overall approach and takes into account all the significant effects of the system. It understands and evaluates them as a whole. It takes a scientific approach towards reasoning. It involves the methods defining the problem, its formulation, testing and analysing of the results obtained.

- 3) **Objective-Oriented Approach:** Operations Research not only takes the overall view of the problem, but also endeavours to arrive at the best possible (say optimal) solution to the problem in hand. It takes an objective-oriented approach. To achieve this, it is necessary to have a defined measure of effectiveness which is based on the goals of the organisation. This measure is then used to make a comparison between alternative solutions to the problem and adopt the best one.
- 4) **Inter-Disciplinary Approach:** No approach can be effective, if taken singly. OR is also inter-disciplinary in nature. Problems are multi-dimensional and approach needs a team work. For example, managerial problems are affected by economic, sociological, biological, psychological, physical and engineering aspect. A team that plans to arrive at a solution, to such a problem, needs people who are specialists in areas such as mathematics, engineering, economics, statistics, management, etc.

1.1.4. Scope of Operations Research

Operation Research can be applied to different areas of business such as:



- 1) **Industry:** Industrial management deals with a series of problems, starting right from the purchase of raw materials till the dispatch of final products. The management is ultimately interested in overall understanding of the methods, of optimising profits. Therefore, to take decision on scientific basis, operations research team has to think about various alternative methods, to produce goods and obtaining returns in each case.

Not only this, the operations research study should also suggest possible changes in the overall structure like installation of a new machine or introduction to automation, etc., for optimising the results. Many industries have gained immensely by applying operations research in various tasks.

For example, operations research can be used in the fields of manufacturing and production, blending and product mix, inventory management, for forecasting demand, sale and purchase, for repair and maintenance jobs, for scheduling and sequencing planning, and also for scheduling and control of projects.

- 2) **Developing Economies:** OR is applicable to both developing and developed economies. But a lot of scope exists in developing economies, for building up an operations research approach towards planning. The basic idea is to orient the planning, to achieve maximum growth per capita income in minimum time; considering the goals and restrictions of the country.

Poverty and hunger are the core problems faced by many countries of Asia and Africa. Therefore, people like statisticians, economists, technicians, administrators, politicians and agriculture experts can work in conjunction, to solve this problem with an operations research approach.

- 3) **Agriculture Industry:** Operations research approach has a huge scope in agriculture sector. Population explosion has led to scarcity of food. Optimum allocation of land for various crops in accordance with climatic conditions is a challenge for many countries. Also, each developing country is facing the problem of optimal distribution of water from several water bodies. These areas of concern hold a great scope for scientific research.
- 4) **Organisation:** Organisation, big or small, can adopt operations research approach effectively. Operational productivity of organisations have improved by using quantitative techniques. Techniques of operations research, can be applied to minimise cost, and maximise benefit for decisions.

For example, a departmental store faces problem like, employing additional sales girls, or purchasing an additional van, etc.

- 5) **Business and Society:** Businesses and society can directly be benefited from operations research. **For example,** hospitals, clinics etc., Operations research methods can be applied directly to solve administrative problems such as minimising the waiting time of outdoor patients.

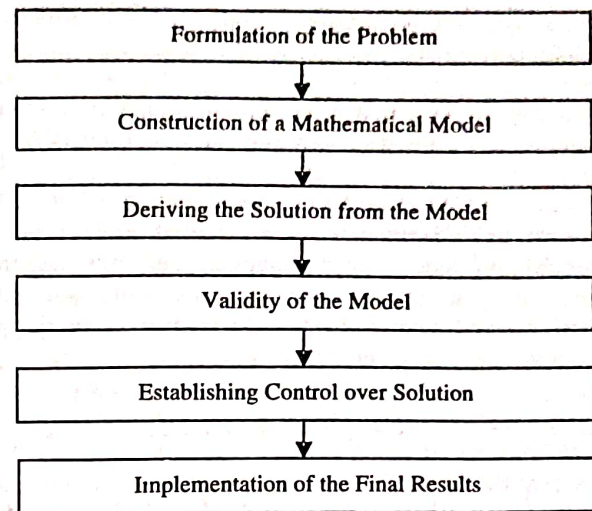
Similarly, the business of transport can also be benefited by applying simulation methods. Such methods can help to regulate train arrivals and their running timings. Queuing theory can be applied to minimise congestion and passengers waiting time.

These methods are increasingly being applied in L.I.C. workplaces. It helps in deciding the premium rates of various policies. Industries such as petroleum, paper, chemical, metal processing, aircraft, rubber, mining and textile have been extremely benefited by its use.

1.1.5. Phases in OR

Following are the six steps towards problem solving (figure below):

Step 1: Formulation of the Problem: First of all, a manager should be able to form an appropriate model of the problem, so as to arrive at a solution.



Step 2: Construction of a Mathematical Model: The second step is to build a mathematical model, which represents the system under study using variables.

Step 3: Deriving the Solution from the Model: An effective computation of all the decision variables that constitutes the problem is needed to maximise or minimise an objective function is required. Such solution is called an **optimal solution**.

Step 4: Validity of the Model: Every model needs a validation for accuracy. A model can be valid or accurate if:

- 1) All the objectives, constraints and decision variables included in the model and are relevant to the problem or are a part of it, and
- 2) It has valid functional relationships.

Step 5: Establishing Control over Solution: The immediate next step after arriving at a solution, is to exercise and establish control over it. It requires enforcing feedback on those variables, which actually have tendency to deviate from the acceptable regime considerably.

Step 6: Implementation of the Final Results: In the end, the final results of the model are put to work. Careful explanation of the adopted solution, and its relationship with the functional realities should be considered.

1.1.6. Quantitative Approach to Decision Making

The quantitative approach to decision making is assuming an increasing degree of importance in the theory and practice of management. The factors that are responsible for this development are:

- 1) Decision problems of management are so complex that only a conscious, systematic and scientifically based analysis can yield realistic solution,
- 2) Availability of well-structured quantitative models and methods that are available for solving these complex managerial problems,
- 3) Attitude of accumulating scientific knowledge in the management of organisations, and
- 4) Availability of computer software to apply quantitative models to real-life problems.

Hence, if decision-makers are totally or fully utilise the potentials of quantitative models, then the decision problem be defined, analysed and solved in a concise, rational, logical, systematic and scientific manner based on the data, facts, information and logic and not on guess.

The quantitative approach does not preclude the qualitative or judgemental elements that always put a substantial influence on managerial decision making. Rather, the quantitative approach must build upon, be modified by and continually benefit from the experiences and creative insights of business managers.

The quantitative approach attempts to cultivate a managerial style that demands a conscious, systematic, and scientific analysis – and resolution of decision problems. The symbolic relationship between qualitative and quantitative models is shown in figure 1.1:

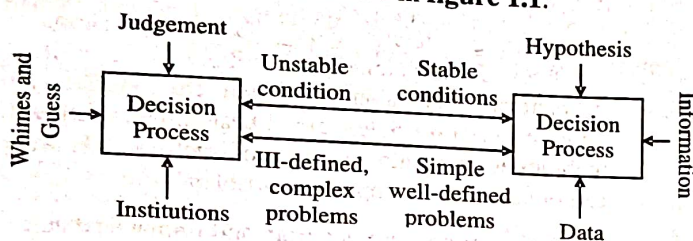


Figure 1.1: Symbiotic Relationship between Quantitative and Qualitative Models

In general, while solving a real life problem, the decision-maker must examine it both from quantitative as well as qualitative perspective. Information about the problem from both these perspectives needs to be brought together and assessed in the context of the problem. Based on some mix of the two sources of information, a decision should be taken by the decision-maker. Figure 1.2 illustrates this in a simplistic way:

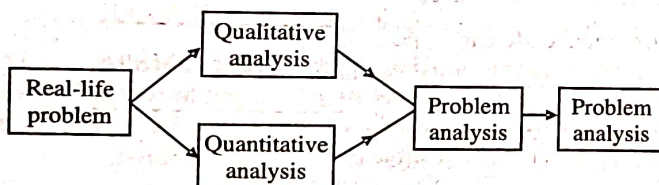


Figure 1.2: Decision Making Process

Figure 1.2 shows a flow chart of scientific procedure to arrive at a decision where it is possible to follow only the left-hand path (i.e., describe the data) in order to gather data in a qualitative manner.

For example, instead of claiming that most customers would buy the product if it is advertised on TV, it would be better to ask how many items customers would buy if the product price is also advertised on TV. Such questions implies that we intend to measure quantities (i.e., number of items bought at a certain price) and are using quantitative methods. Consequently, observations can be described in much detail. Also, we may follow, right-hand path (i.e., analyse the data) in order to gather data in quantitative manner to understand that a large number of people buy the product only if it is advertised on TV. As it

is known quantitative methods not only assist in decision-making but also help in arriving at a better decision. The quantitative approach to decision-making uses concepts and or tools (methods) of mathematics and statistics. The commonly used terms for quantitative approach to decision making are **Operations Research, Management Science, Decision Analysis and Decision science**.

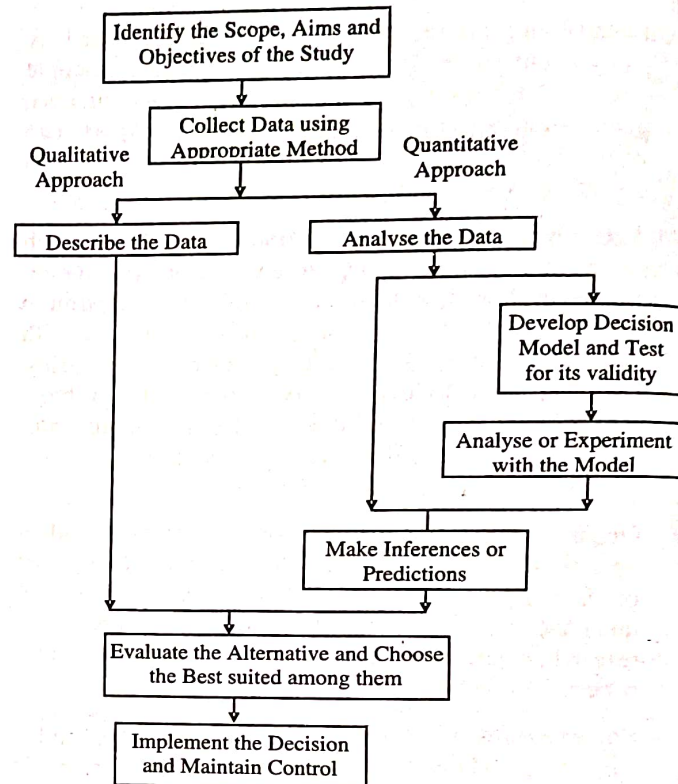


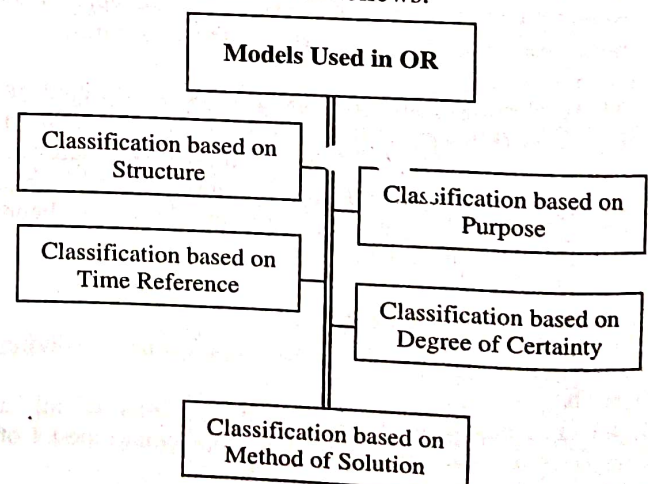
Figure 1.3: An Iconic Model of Data Analysis

1.1.7. Models Used in OR

Operation research has many models or techniques, by which any unique set of problems can be solved. There are various methods for classification of models. By the help of such models decision maker can easily recognise which type of model is best suitable for his problem.

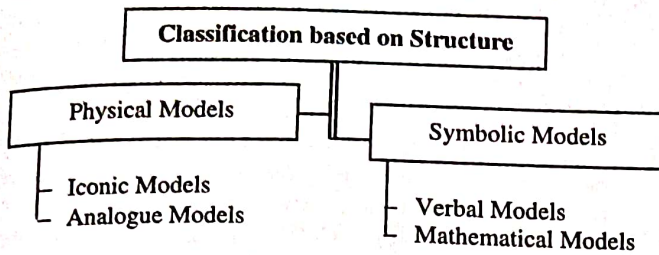
Different Types of Models

Several classifications are as follows:



1.1.7.1. Classification based on Structure

The model based on the structure includes:



- 1) **Physical Models:** The model which provides a physical presence, in a real form, for the problem is called physical model. Such models work either by reduction in size or by mounted up but apart from that these models are helpful only for designing the problems as they are easy to observe, build and describe.

For example, in the aircraft industry, scale models of the 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 not very useful for prediction, therefore, problems such as portfolio selection, media selection, production scheduling, etc., cannot be analysed with physical model.

Physical models are classified into the following two categories:

- i) **Iconic Models:** An iconic model is an unrealistic or topped variety of the system. This iconic model basically holds few physical properties and features of the system which they represent. Moreover this model signifies the system either by mounted it or by doing it down. For example, blue prints of a home, globes, photographs, drawings, atom, etc.

Generally iconic models are very easy to perceive, precise and tangible also. That's why they are useful in defining the system in place of explaining the system. Therefore we can say that iconic models are usually characterised of a static event and characteristics which are not useful in defining or forecasting effects due to certain changes in the original system. **For example,** for scientific study of the structure of an atom colour does not play any vital role.

- ii) **Analogue Models:** Analogue model signifies a system with the set of properties which is apart from the actual system and not similar substantially. But at the same time, when the problem is solved the solution is again interpreted with reference to original system.

For example, the organisational chart represents the state of formal relationships existing between members of the organisation. Maps in different colours may represent water, desert and other geographical features. Graphs of time series, stock-market changes, frequency curves, etc., may be used to represent quantitative relationship

between any two properties. These models are less specific and concrete but easier to manipulate and more general than iconic models.

- 2) **Symbolic Models:** The models which use symbols, letters and numbers for representing the properties of the system is called symbolic model. Such models are also useful in characterising relationship which can also be denoted in physical form.

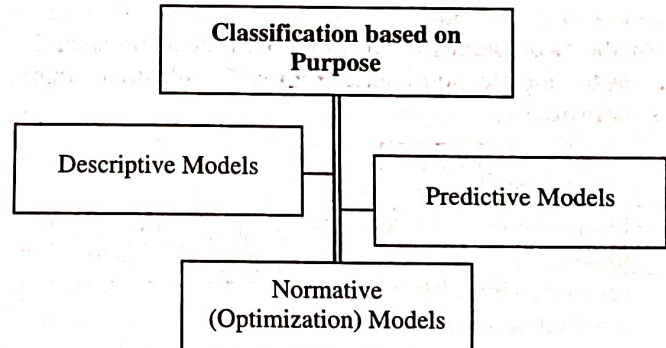
Symbolic models can be classified into two categories:

- i) **Verbal Models:** Verbal models are defined as the model which refers the condition in a written or spoken form. **For example,** written sentences, books etc.
- ii) **Mathematical Models:** The models, in which use of mathematical symbols, letters, numbers and mathematical operators (+, -, \square , \times) for representing relationships between various variables of the system for describing its properties or behaviour is called mathematical model. By applying appropriate and best mathematical techniques and with the help of such models we can obtain the solution of the problem.

Symbolic models are accurate and immaterial and can also be employed with the help of mathematical laws. Such symbolic mathematical models are clear in place of expressive.

1.1.7.2. Classification based on Purpose

The models based on the purpose of their utility include:



- 1) **Descriptive Models:** The model which describes the various facet of a situation, which is based on observation survey, questionnaire results or other offered data related with situation and do not forecasted or appraised.

For example,

- i) Organisation chart,
ii) Plant layout diagram,
iii) Block diagram representing an algorithm or method for solving a problem, etc.

- 2) **Predictive Models:** Predictive model works on mainly one strategy i.e. "if this occurs, then that will follow". Predictive model communicates dependent and independent variables and tries to find out, 'what if' questions. Basically predictive model can also be

defined as that model which is useful for forecasting the consequences because of an available set of alternatives for the situation. But on the contrary, predictive models do not have an objective function as a part of the model for evaluating decision alternatives.

For example, $S = a + bA + cI$ is a model that describes how the sale (S) 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 value of advertising expenditure (A) can be adjusted for a given value of I to study impact of advertising on sales.

For predictive models, no one can try to select the best available alternatives for decision, but they have only hint for each available alternative to him.

- 3) **Optimisation (Normative) Models:** Optimisation or we can say normative models provide the best or optimal solution for the problems within the given limits on the use of resources. Optimisation models provide acclaimed course of action. **For example,** for mathematical programming, generally models are framed for improving the given objective function, subject to restrictions on resources in the reference of the problem under consideration and non-negativity of variables. Such models are also known as prescriptive model. It is so because they proposed only what the decision-maker should do.

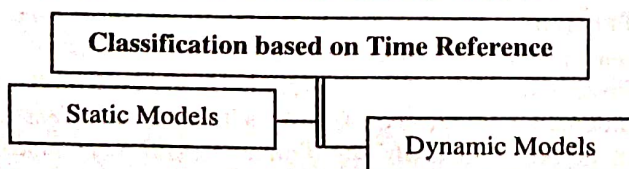
In optimisation model, when presentation of alternative occurs, an intensive effort is made for reaching an optimal solution. According to input criteria, when optimisation is solved, it produces the best alternatives. Therefore if we talk about optimisation model, it is basically concerned in arriving at an optimal solution, which is referred as the best solution.

Optimisation model works very simply by maximizing or minimizing a real function by choosing input values analytically from within an allowed set and figuring the value of the function. If we look a broad view of optimization theory and techniques to other originations, it encompasses a vast area of applied mathematics.

Commonly optimization theory comprises of finding best available values of few objective function within a given defined domain, comprises of different types of objective functions with different types of domain. These models are basically used in linear programming problem, transportation problems etc.

1.1.7.3. Classification based on Time Reference

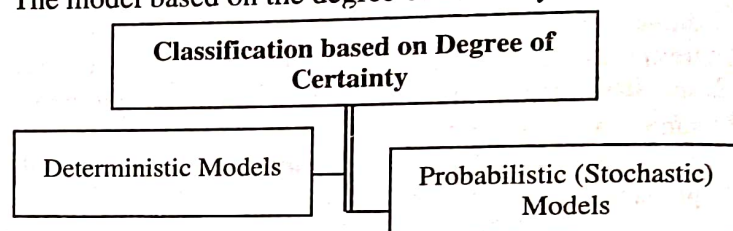
The models based on the time reference include:



- 1) **Static Models:** Static models present a system at some specified time and do not account for changes over time. **For example,** an inventory model can be developed and solved to determine economic order quantity for the next period assuming that the demand in planning period would remain the same as that for today.
- 2) **Dynamic Models:** The models, where time is measured as one of the variable and also acknowledges that the effect of changes are produced only by the time for selection of the optimal courses of the action. Therefore, we can say that the arrangements of inter-related decisions are created for realising the optimal course of action to optimise the given objective. Dynamic programming is an example of a dynamic model.

1.1.7.4. Classification based on Degree of Certainty

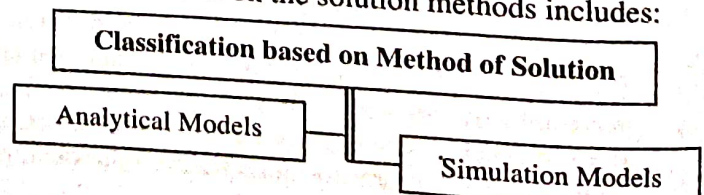
The model based on the degree of certainty includes:



- 1) **Deterministic Models:** A model is said to be deterministic if it is assumed that the all the parameters, constants and functional relationships are known with certainty when the decision is made. Thus in this case, the outcome associated with a particular course of action is known. There is a unique determined output for a specific set of input values. This output represents the solution of the model under the conditions of certainty. The results of the models assume single value. **For example,** linear programming and inventory problem model.
- 2) **Probabilistic (Stochastic) Models:** A model is called probabilistic (or stochastic) model if at least one parameter or decision variable is a random variable. An independent variable which is the function of dependent variable(s) will also be random because at least one decision variable is random. This means consequences or pay-off 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. **For example,** insurance against risk of fire, accidents, sickness, etc. where the pattern of events is studied in the form of a probability distribution.

1.1.7.5. Classification based on Method of Solution

The models based on the solution methods includes:



- 1) **Analytical Models:** The models, which are having a precise mathematical structure and that's why they can be known as analytical or mathematical technique, are known as analytical model. In other words, any type of optimisation model, in which maximisation or minimisation of an objective function is required, is known as analytical model.
- 2) **Simulation Models:** Simulation model also having a property of mathematical structure but such model cannot be solved by applying mathematical techniques for getting solution. As a substitute, simulation model is necessarily a computer assisted experimentation on any mathematical structure of a real life problem, for describing and evaluating its behaviour, under certain assumptions over a period of time.

Moreover we can say that simulation models are more flexible in comparison to any other mathematical model so, therefore, they are easy to represent a complex system, which otherwise cannot be represented mathematically. But at the same time simulation model cannot provide general solutions like other mathematical models.

1.1.8. Benefits of Operations Research

- 1) **Better Control:** For large organisations, it is practically impossible to continuously supervise every routine work. An OR approach comes handy and gives an analytical and quantitative basis to identify the problem area. OR approach is most frequently adopted with production scheduling and inventory replenishment.
- 2) **Better Systems:** For example, Problems identifying the best location for factories or decision on whether to open a new warehouse, etc., are often been studied and analysed by OR approach. This approach helps to improve the existing system such as, selecting economical means of transportation, production scheduling, job sequencing, or replacing old machinery.
- 3) **Better Decisions:** OR models help in improved decision-making and thereby reduce the risk of wrong decisions. OR approach gives the executive an improved insight into the problem and thereby improve decision-making.
- 4) **Better Coordination:** OR models help in coordination of different or various divisions of an organisation.

1.1.9. Limitations of Operations Research

- 1) **Dependence on an Electronic Computer:** OR approach is mathematical in nature. OR techniques try to find out an optimal solution to a problem, by taking all the factors into consideration. The need of computers become unavoidable because these factors are enormous (huge), it requires huge calculations to express them in quantity and to establish relationships among them.

- 2) **Non-Quantifiable Factors:** One of the drawbacks of OR techniques is that they provide a solution only when all the elements related to a problem are quantified. Since all relevant variables may not be quantified, they do not find a place in OR models.
- 3) **Wrong Estimation:** Certain assumptions and estimates are made for assigning quantitative values to factors involved in OR, so that a quantitative analysis can be done. If such estimates are wrong, the result can be misleading.
- 4) **Involves Time and Cost:** Operations research is a costly affair. An organisation needs to invest time, money and effort into OR to make it effective. Professionals need to be hired to conduct constant research. For better research outcomes, these professionals must constantly review the rapidly changing business scenarios.
- 5) **Implementation:** The complexities of human relations and behaviour must be taken into account while implementing OR decisions, as it is a very delicate task.

1.1.10. Applications of Operations Research

Uses, scope and applications of operations research in managerial decision-making are as follows:

- 1) **Finance, Budgeting and Investment**
 - i) Long range capital requirements, cash flow analysis, investment portfolios and dividend policies.
 - ii) Credit policies, credit risks and procedures for delinquent account.
 - iii) Procedures to deal with complaints and claim.
- 2) **Marketing**
 - i) Selection of product, its timing and competitive actions.
 - ii) Cost and time-based decision for advertising media.
 - iii) Rate of calling an account and requirement of number of salesmen, etc., and
 - iv) Market research effectiveness.
- 3) **Physical Distribution**
 - i) Size of warehouses, distribution centre, retail outlets, etc., and their location, and
 - ii) Policy for distribution.
- 4) **Purchasing, Procurement and Exploration**
 - i) Buying rules.
 - ii) Determining purchase timing and its quantity.
 - iii) Policies for bidding and analysis of vendor, and
 - iv) Replacement policies of equipment.
- 5) **Personnel**
 - i) Manpower requirement forecasting, recruitment policies and assignment of job.
 - ii) Suitable personnel selection considering age and skills, etc., and
 - iii) For each service centre determining the optimum number of persons.