**Unit-I**

**Operations research (OR)**

Operations research (OR) is an analytical method of problemsolving and decision-making that is useful in the management of organizations. In operations research, problems are broken down into basic components and then solved in defined steps by mathematical analysis

**Application of operation research**

* Purchasing and procurement
* Production management 3.
* Research and development
* Personnel management
* Marketing
* finance, budgeting and investment.

**Main phases of OR**

* Definition and formulation of the problem
* Construction of the model
* Solution of the model
* Validation of the model
* Establish control over the solution
* Implementation of the solution

 **Advantages of OR**

* Optimum use of factors
* Improved quality of decision
* Preparation of future managers
* Modification of mathematical solution
* Alternative solution.

**Linear Programming Problem:**

LPP deals with optimization (maximization/minimization)of a linear function of variables called the objective function subjected to a set of linear equation and /or inequalities called the constraints or restriction.

 **Formulation of linear programming:**

 • Objective function • Constraints • Non negativity constraints

**Standard form of LPP**

Maximize z=c1x1+c2x2+…..+cnxn

Subject to constraints a11x1+a12x2+…..+a1nxn=b1

 a21x1+a22x2+……+a2nxn=b2

.

 am1x1+am2x2+….+amnxn=bn

x1≥0, x2 ≥0, ……..xn ≥0 b1 ≥0,b2 ≥0 ……..bn ≥0

**Applications of LPP**

Agriculture, Industry, Transporation, economics, health systems, behavioral and social sciences and the military. It can be computerized for 10000 of constraints and variables.

**Explain the types of solution of a LPP**

**Solution of LPP:** any set x={x1,x2,……xn+m} of variables is called a solution of LPP.if it satisfies only the set of given constraints equations.

 **Basic feasible solution of LPP:** A basic feasible solution is a basic solution which also satisfies all basic variables are non-negative.

**Optimal solution of LPP :**Any feasible solution which optimizes (Min or Max) the objective function of the LPP is called its optimum solution.

**Degenerate basic feasible solution:** A basic feasible solution is said to degenerate if one or more basic variable are zero.

 **Non-Degenerate basic feasible solution:** A basic feasible solution is said to be non degenerate if all the basic variables are greater than zero.

**Slack variable:** if a constraint is of <= type , we add a non negative variable called slack variables to the LHS of the constraint.

 **Surplus variable:** if the constraint is of >=type, we subtract a non-negative variable called the surplus variable from the LHS of the constraints.

**Unit-II**

**Simplex Method**

The simplex method is an iterative process, through which it reaches ultimately to the minimum or maximum value of the objective function. If the linear programming problem has larger number of variables, the suitable method for solving is Simplex Method

**The simplex method also helps the decision maker/manager to identify the following:**

* Redundant Constraint
* Multiple Solutions
* Unbounded Solution
* Infeasible Problem

**Basic Solution**

 First we introduce the variables s3, s4, s5 ≥ 0 So that the constraints becomes equations, thus 2x1 + x2 + s3 = 300 3x1 + 4x2 + s4 = 509 4x1 + 7x2 + s5 = 812 Corresponding to the three constraints, the variables s3, s4, s5 are called as slack variables. Now, the system of equation has three equations and five variables. We may equate any two variables to zero in the above system of equations, and then the system will have three variables. Thus, if this system of three equations with three variables is solvable such a solution is called as basic solution.

**For example**

 suppose we take x1=0 and x2=0, the solution of the system with remaining three variables is s3=300, s4=509 and s5=812, this is a basic solution and the variables s3, s4, and s5 are known as basic variables where as the variables x1, x2 are known as non-basic variables.

**Basic Feasible Solution**

 A basic solution of a linear programming problem is called as basic feasible solutions if it is feasible it means all the variables are non-negative. The solution s3=300, s4=509 and s5=812 is a basic feasible solution.

**Original Problem:** This is the original linear programming problem, also called as primal problem.

 **Dual Problem:** A dual problem is a linear programming problem is another linear programming problem formulated from the parameters of the primal problem.

**Dual Variables:** Dual programming problem variables.

**Optimum Solution:** The solution where the objective function is minimized or maximized.

**Shadow Price:** Price of a resource is the change in the optimum value of the objective function per unit increase of the resource.

**What is sensitivity analysis?**

The change in parameters of the problem may be discrete or continuous. The study of the effect of discrete changes in parameters on the optimal solution is called the sensitivity analysis.

**Unit-III**

**Transportation Algorithm**

The steps of the transportation algorithm are exact parallels of the simplex algorithm, they are:

Step 1: Determine a starting basic feasible solution, using any one of the following three methods

1. North West Corner Method 2. Least Cost Method 3. Vogel Approximation Method

Step 2: Determine the optimal solution using the following method 1. MODI (Modified Distribution Method) or UV Method.

**Definition of transportation problem**

It is a special type of linear programming model in which the goods are shipped from various origins to different destinations. The objective is to find the best possible allocation of goods from various origins to different destinations such that the total transportation cost is minimum.

**Definition of Feasible solution:**

A set of non-negative decision values xij (i = 1, 2, . . . m; j = 1, 2 . . . n) satisfies the constraint equations is called a feasible solution.

 **Basic feasible solution:**

A basic feasible solution is said to be basic if the number of positive allocations are m + n − 1 (m-origin and n-destination).If the number of allocations are less than (m + n − 1) it is called degenerate basic feasible solution.

**Optimal solution in transportation problem:**

A feasible solution is said to be optimal, if it minimizes the total transportation cost.

**What are the methods used in transportation problem to obtain the initial basic feasible solution?**

 • North-west corner rule • Lowest cost entry method or matrix minima method • Vogel’s approximation method

**Assignment problem**

Given n facilities, n jobs and the effectiveness of each facility to each job, here the problem is to assign each facility to one and only one job so that the measure of effectiveness if optimized. Here the optimization means Maximized or Minimized. There are many management problems has a assignment problem structure.

**Balanced & unbalanced assignment problem**

 The number of persons to be assigned and the number of jobs were same. Such kind of assignment problem is called as balanced assignment problem. Suppose if the number of person is different from the number of jobs then the assignment problem is called as unbalanced.

 **Write down the basic steps involved in solving a transportation problem.**

• To find the initial basic feasible solution

 • To find an optimal solution by making successive improvements from the initial basic feasible solution.

 **What do you understand by degeneracy in a transportation problem?**

If the number of occupied cells in a m x n transportation problem is less than (m+n-1) then the problem is said to be degenerate.

**What is balanced transportation problem & unbalanced transportation problem?**

 When the sum of supply is equal to demands, then the problem is said to be balanced transportation problem. A transportation problem is said to be unbalanced if the total supply is not equal to the total demand.

**How do you convert an unbalanced transportation problem into a balanced one?**

The unbalanced transportation problem is converted into a balanced one by adding a dummy row (source) or dummy column (destination) whichever is necessary. The unit transportation cost of the dummy row/ column elements are assigned to zero. Then the problem is solved by the usual procedure.

**Explain how the profit maximization transportation problem can be converted to an equivalent cost minimization transportation problem.**

If the objective is to maximize the profit or maximize the expected sales we have to convert these problems by multiplying all cell entries by -1. Now the maximization problem becomes a minimization and it can be solved by the usual algorithm

 **Define transshipment problems?**

A problem in which available commodity frequently moves from one source to another source or destination before reaching its actual destination is called transshipment problems.

 **What is the difference between Transportation problem & Transshipment Problem?**

 In a transportation problem there are no intermediate shipping points while in transshipment problem there are intermediate shipping points

**Unit-IV**

 **What is assignment problem?**

 An assignment problem is a particular case of a transportation problem in which a number of operations are assigned to an equal number of operators where each operator performs only one operation, the overall objective is to maximize the total profit or minimize the overall cost of the given assignment.

 **Explain the difference between transportation and assignment problems?**

|  |  |
| --- | --- |
| **Transportation problems** | **Assignment problems** |
| supply at any source may be a any positive quantity | Supply at any source will be 1 |
| Demand at any destination may be a positive quantity | Demand at any destination will be 1 |
| One or more source to any number of destination | One source one destination. |

**Define unbounded assignment problem and describe the steps involved in solving it?**

 If the no. of rows is not equal to the no. of column in the given cost matrix the problem is said to be unbalanced. It is converted to a balanced one by adding dummy row or dummy column with zero cost

 **Explain how a maximization problem is solved using assignment model?**

The maximization problems are converted to a minimization one of the following method.

• Since max z = min(−z)

 • Subtract all the cost elements all of the cost matrix from the Highest cost element in that cost matrix.

**What do you understand by restricted assignment? Explain how you should overcome it?**

 The assignment technique, it may not be possible to assign a particular task to a particular facility due to technical difficulties or other restrictions. This can be overcome by assigning a very high processing time or cost (it can be ∞) to the corresponding cell.

**How do you identify alternative solution in assignment problem?**

Sometimes a final cost matrix contains more than required number of zeroes at the independent position. This implies that there is more than one optimal solution with some optimum assignment cost.

**What is a travelling salesman problem?**

A salesman normally must visit a number of cities starting from his head quarters. The distance between every pair of cities are assumed to be known. The problem of finding the shortest distance if the salesman starts from his head quarters and passes through each city exactly once and returns to the headquarters is called Traveling Salesman problem.

 **Define route condition?**

The salesman starts from his headquarters and passes through each city exactly once.

**Give the areas of operations of assignment problems?**

 • Assigning jobs to machines.

• Allocating men to jobs/machines.

• Route scheduling for a traveling salesman.

**How do you convert the unbalanced assignment problem into a balanced one?**

Since the assignment is one to one basis, the problem have a square matrix. If the given problem is not square matrix add a dummy row or dummy column and then convert it into a balanced one (square matrix). Assign zero cost values for any dummy row/column and solve it by usual assignment method.

**How does a travelling salesman problem differ from a routine assignment model?**

 Travelling salesman problem is similar to the assignment problem with the difference that there is the additional constraint that no city is to be visited again before the tour of all the cities is completed.

**Unit-V**

**Network**

Network is a technique used for planning and scheduling of large projects in the fields of construction, maintenance, fabrication, purchasing, computer system instantiation, research and development planning etc. It is a graphical representation of logical and sequentially connected activities and events of a project. Network is also called arrow diagram. PERT (Programme Evolution Review Technique) and (Critical Path Method) are the two most widely applied techniques.

**Project**

 A project is defined as a combination of interrelated activities which must be executed in a certain order in for its completion.

 **Project Management Process**

Network analysis is the general name given to certain specific techniques which can be used for the planning, management and control of projects

**Activity**

Any individual operation, which utilizes resources and has an end and a beginning, is called activity.

* A task or a certain amount of work required in the project
* Requires time to complete
* Represented by an arrow

These are usually classified into four categories:

* Predecessor activity
* Successor activity
* Concurrent activity
* Dummy activity

**Dummy Activity**

 It Indicates only precedence relationships and does not require any time of effort

**PERT(Program Evaluation and Review Technique)** is a method to analyze the involved tasks in completing a given project, especially the time needed to complete each task, and identifying the minimum time needed to complete the total project.

PERT is based on the assumption that an activity’s duration follows a probability distribution instead of being a single value .

**Three time estimates are required to compute the parameters of an activity’s duration distribution:**

1. Pessimistic time (tp ) - the time the activity would take if things did not go well
2. Most likely time (tm ) - the consensus best estimate of the activity’s duration
3. Optimistic time (to ) - the time the activity would take if things did go well.

Mean (expected time) = 

Variance 

**Probability computation:**

 Determine probability that project is completed within specified time 

Where = project mean time,= project standard mean time, X= (proposed) specified time

**Float:**

 Float of an activity represents the excess of available time over its duration.

**Total Float (Ft)**

 The amount of time by which the completion of an activity could be delay beyond the earliest expected completion time without affecting the overall project duration.

i.e. Tf= (Latest start-Earliest start) for activity(i-j), or,(Tf)ij=(LS)jj-(ES)ij

**Free Float (Ff)**

The time by which the completion of an activity can be delayed beyond the earliest finish time without affecting the earliest start of a subsequent (succeeding) activities.

**Benefits of CPM/PERT**

* Useful at many stages of project management
* Mathematically simple
* Give critical path and slack time
* Provide project documentation
* seful in monitoring costs

**Inventory Theory**

**Reasons for Carrying Inventory**

 Inventories are carried by organisations because of the following major reasons :

 **Improve customer service**- An inventory policy is designed to respond to individual customer’s or organization’s request for products and services.

 **Reduce costs**- Inventory holding or carrying costs are the expenses that are incurred for storage of items. However, holding inventory items in the warehouse can indirectly reduce operating costs such as loss of goodwill and/or loss of potential sale due to shortage of items. It may also encourage economies of production by allowing larger, longer and more production runs.

 **Maintenance of operational capability**

 Inventories of raw materials and workin-progress items act as buffer between successive production stages so that downtime in one stage does not affect the entire production process.

**Irregular supply and demand**

 Inventories provide protection against irregular supply and demand; an unexpected change in production and delivery schedule of a product or a service can adversely affect operating costs and customer service level

**Quantity discount**

Large size orders help to take advantage of price-quantity discount. However, such an advantage must keep a balance between the storage cost and costs due to obsolescence, damage, theft, insurance, etc.

**Avoiding stockouts (shortages)**

 Under situations like, labor strikes, natural disasters, variations in demand and delays in supplies, etc., inventories act as buffer against stock out as well as loss of goodwill.

**Costs Associated with Inventories**

**Purchase (or production) cost:**

It is the cost at which an item is purchased, or if an item is produced.

**Carrying (or holding) cost:**

The cost associated with maintaining inventory is known as holding cost. It is directly proportional to the quantity kept in stock and the time for which an item is held in stock. It includes handling cost, maintenance cost, depreciation, insurance, warehouse rent, taxes, etc.

**Shortage (or stock out) cost:**

 It is the cost which arises due to running out of stock. It includes the cost of production stoppage, loss of goodwill, loss of profitability, special orders at higher price, overtime/idle time payments, loss of opportunity to sell, etc.

**Ordering (or set up) cost:**

The cost incurred in replenishing the inventory is known as ordering cost. It includes all the costs relating to administration (such as salaries of the persons working for purchasing, telephone calls, computer costs, postage, etc.).

**Demand**

It is an effective desire which is related to particular time, price, and quantity. The demand pattern of a commodity may be either deterministic or probabilistic. In case of deterministic demand, the quantities needed in future are known with certainty. This can be fixed (static) or can vary (dynamic) from time to time. On the contrary, probabilistic demand is uncertain over a certain period of time but its pattern can be described by a known probability distribution.

**Ordering cycle**

An ordering cycle is defined as the time period between two successive replenishments. The order may be placed on the basis of the following two types of inventory review systems:

• Continuous review: In this case, the inventory level is monitored continuously until a specified point (known as reorder point) is reached. At this point, a new order is placed.

• Periodic review: In this case, the orders are placed at equally spaced intervals of time. The quantity ordered each time depends on the available inventory level at the time of review.

 **Planning period**

This is also known as time horizon over which the inventory level is to be controlled. This can be finite or infinite depending on the nature of demand.

 **Lead time or delivery lag**

 The time gap between the moment of placing an order and actually receiving it is referred to as lead time. Lead time can be deterministic (constant or variable) or probabilistic.

 **Buffer (or safety) stock**

Normally, demand and lead time are uncertain and cannot be predetermined completely. So, to absorb the variation in demand and supply, some extra stock is kept. This extra stock is known as buffer stock.

**Re-order level**

The level between maximum and minimum stocks at which purchasing activity must start for replenishment is known as re-order level.

**EOL**

EOL means economic order level. There should be enough for each time so that customers orders can be reasonably met from this stock until replenishment. This Stock level, becomes economic order level.

**Unit-V**

**Queue (waiting line)**

 A flow of customers from finite or infinite population towards the service facility forms a queue (waiting line) an account of lack of capability to serve them all at a time. In the absence of a perfect balance between the service facilities and the customers, waiting time is required either for the service facilities or for the customers arrival.

 **Queueing system**

 The queueing system consists of one or more queues and one or more servers and operates under a set of procedures. Depending upon the server status, the incoming customer either waits at the queue or gets the turn to be served. If the server is free at the time of arrival of a customer, the customer can directly enter into the counter for getting service and then leave the system. In this process, over a period of time, the system may experience “ Customer waiting” and /or “Server idle time”

A queueing system can be completely described by

* the input (arrival pattern)
* the service mechanism (service pattern)
* The queue discipline and
* Customer’s behaviour

**Input (arrival pattern)**

The input described the way in which the customers arrive and join the system. Generally, customers arrive in a more or less random manner which is not possible for prediction. Thus the arrival pattern can be described in terms of probabilities and consequently the probability distribution for inter-arrival times (the time between two successive arrivals) must be defined. We deal with those Queueing system in which the customers arrive in poisson process. The mean arrival rate is denoted byλ

**Service Mechanism:**

This means the arrangement of service facility to serve customers. If there is infinite number of servers, then all the customers are served instantaneously or arrival and there will be no queue. If the number of servers is finite then the customers are served according to a specific order with service time a constant or a random variable. Distribution of service time follows ‘Exponential distribution’ defined by f(t) = λe -λt, t > 0

The mean Service rate is E(t) = 1/λ

**Queueing Discipline:**

 It is a rule according to which the customers are selected for service when a queue has been formed. The most common disciplines are

* First come first served – (FCFS)
* First in first out – (FIFO)
* Last in first out – (LIFO)
* Selection for service in random order (SIRO)

**Customer’s behaviour**

1. Generally, it is assumed that the customers arrive into the system one by one. But in some cases, customers may arrive in groups. Such arrival is called ***Bulk arrival.***
2. If there is more than one queue, the customers from one queue may be tempted to join another queue because of its smaller size. This behaviour of customers is known as ***jockeying***
3. If the queue length appears very large to a customer, he/she may not join the queue. This property is known as ***Balking***of customers.
4. Sometimes, a customer who is already in a queue will leave the queue in anticipation of longer waiting line. This kind of departare is known as ***reneging.***

**Traffic intensity (or utilization factor)**

 An important measure of a simple queue is its traffic intensity given by Traffic intensity φ = (Mean arrival timeδ/ Mean service timeμ ) < 1and the unit of traffic intensity is Erlang

**Simulation :**

 Simulation is an experiment conducted on a model of some system to collect necessary information on the behaviour of that system. The representation of reality in some physical form or in some form of Mathematical equations

**For example :**

1. Children cycling park with various signals and crossing is a simulation of a read model traffic system
2. Planetarium
3. Testing an air craft model in a wind tunnel.

**Some advantage of simulation :**

1. Simulation is Mathematically less complicated
2. Simulation is flexible
3. It can be modified to suit the changing environments.
4. It can be used for training purpose
5. It may be less expensive and less time consuming in a quite a few real world situations.

 **Some Limitations of Simulation :**

1. Quantification or Enlarging of the variables maybe difficult.
2. Large number of variables make simulations unwieldy and more difficult.
3. Simulation may not. Yield optimum or accurate results.
4. Simulation are most expensive and time consuming model.
5. We cannot relay too much on the results obtained from simulation models.

**Steps in simulation :**

1. Identify the measure of effectiveness.
2. Decide the variables which influence the measure of effectiveness and choose those variables, which affects the measure of effectiveness significantly.
3. Determine the probability distribution for each variable in step 2 and construct the cumulative probability distribution.
4. Choose an appropriate set of random numbers.
5. Consider each random number as decimal value of the cumulative probability distribution.
6. Use the simulated values so generated into the formula derived from the measure of effectiveness.
7. Repeat steps 5 and 6 until the sample is large enough to arrive at a satisfactory and reliable decision.

**Uses of Simulation**

Simulation is used for solving

* Inventory Problem
* Queueing Problem
* Training Programmes etc.