SRI KRISHNA ARTS AND SCIENCE COLLEGE

Course : Operation Research

Unit – 1 : Operation Research – Introduction

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INTRODUCTION

- The activity “Operations Research “(abbreviated as O.R.) has become increasingly important in the face to fast moving technology and increasing complexities in business and industry.
- The new approach to systematic and scientific study of the operations of the system was called the ***Operations Research*** or ***Operational Research***(abbreviated as O.R).

- Literally, the word ‘**operation’** may be defined as **some action** that we apply to some problems or hypothesis and the word **’research’** is an organized **process of seeking out facts** about the same.

ORIGIN AND DEVELOPMENT OF OR

- The term, Operational Research, was first coined in 1940 by McClosky and Trefthen in a small town, Bowdsey, of the United Kingdom.
- This new science came into existence as a result of research on military operations during World War II. During the war there were strategic and tactical problems which were greatly complicated, expect adequate solutions from individuals or specialists was unrealistic.

- Therefore, the military management called on scientists from various disciplines and organized them in to teams to assist in solving strategic and tactical problems i.e ., to discuss, evolve and suggest ways and means to improve the execution of various military projects.
- By their joint efforts, experience and deliberations, they suggested certain approaches that showed remarkable progress. This new approach to systematic and scientific study of the operations of the system was called Operations Research or Operational Research.

NATURE AND FEATURES OF OR

O.R has been variously described as the “science of use”, ”quantitative common sense”, ***“scientific approach to decision making problems” .***

Some significant features of O.R are highlighted below

- Decision Making.
- Scientific Approach.
- Objective.
- Inter-disciplinary Team Approach.
- Digital Computer.

Operational research(OR) encompasses a wide range of problem-solving techniques and methods applied in the pursuit of improved decision-making and efficiency, such as simulation, mathematical optimization, queuing theory and other stochastic-process models, Markov decision processes, econometric methods, data envelopment analysis, neural networks, expert systems, decision analysis, and the analytic hierarchy process. Nearly all of these techniques involve the construction of mathematical models that attempt to describe the system.

Thus O.R. specialists are involved in three classical aspect of science, they are as follows:

i) Determining the systems behavior

ii) Analyzing the systems behavior by developing appropriate models

iii) Predict the future behavior using these models

METHODOLOGY OF OPERATIONS RESEARCH

The O.R approach to problem solving consists of the following seven steps

1. Formulate the problem.
2. Construct a mathematical model.
3. Acquire the input data.
4. Derive the solution from the model.
5. Validate the model.
6. Establish control over the solution.
7. Implement the final result.

APPLICATIONS OF OPERATIONAL RESEARCH

- Operational Research is mainly concerned with the techniques of applying scientific knowledge, besides the development of science. It provides an understanding which gives the expert/manager new insights and capabilities to determine better solutions in his decision-making problems, with great speed, competence and confidence. In recent years ,Operational Research has successfully entered many different areas of research in defence, government, service organizations and industry.

SCOPE OF OPERATION RESEARCH

The Multidisciplinary and Interdisciplinary Nature of Operations Research

I. IN DEFENCE OPERATIONS

- Administration.
- Intelligence.
- Operations.
- Training and supply.

II.IN INDUSTRY

Applications of operations research in the area of management

Production Management : The production manager can apply OR methods for

- The remunerative policy with regard to time and piece rate.
- Determination of optimum product mix.
- Production, scheduling and sequencing the production run by allocation of machines.
- Work study operation including time study.

- Selecting plant location and design of the sites.
- Distribution policy.
- Loading and unloading facility for road transportation.
- Maintenance crew sizes.

III. MARKETING MANAGEMENT

The marketing manager can apply OR method for

- Product selection, timing and formulation of competitive strategies.
- Marketing research.
- Distribution strategies.
- Sales forecasting.
- Selection of advertising media and terms of cost and time factor
- To find optimum number of Salesmen.

IV. FINANCIAL MANAGEMENT

The financial manager can apply OR method for

- Apply cash flow analysis for capital budgeting
- Formulate credit policies, evaluate credit risks
- Determine optimum replacement strategies.
- Frame claim and complaint procedures.
- Frame policies regarding capital structure.
- Long range capital requirement.
- Investments portfolio.
- Dividend policies.

V. PERSONAL MANAGEMENT

The personal manager can apply OR method for

- Forecasting the manpower requirement, framing of recruitment policies, assignment of jobs to machines or workers etc.
- Selection of suitable personnel with due consideration for age, education skills training etc.
- Determination of optimum number of persons for each service centre.
- The promotional policies.
- Mixes of age and skills.

VI. PURCHASE DEPARTMENT

The purchased department can apply OR method for

- Determining the quantity and timing of purchase of raw materials, machinery etc.
- Bidding policies.
- Rules for buying and supplies under varying pries.
- Equipment replacement policies.
- Determination of quantities and timing of purchases.

VII. RESEARCH AND DEVELOPMENT DEPARTMENT

The research and development department can apply OR method for

- Determining the areas for research and development.
- Scheduling and control of R and D projects.
- Resource allocation and crashing in projects.
- Project selection.
- Reliability and alternative design.

VIII. MANUFACTURING DEPARTMENT

- The manufacturing department can apply OR method for :
- Inventory control
- Projection marketing balance.
- Production scheduling
- Production smoothing.

IX. ORGANIZATION BEHAVIOUR DEPARTMENT

The OB department can apply OR method for

- Personnel selection and planning.
- Scheduling of training programs.
- Skills balancing.
- Recruitment of Employees.

X. **ACCOUNTING DEPARTMENT**

The accounting department can apply OR method for

- Cash flow and fund flow planning.
- Credit policy analysis.
- Planning of delinquent account strategy.

XI. TECHNIQUES AND GENERAL MANAGEMENT

The Techniques & General Management can apply OR method for

- Decision support systems and MIS;
- forecasting.
- Organizational design and control
- Projection management,
- strategic planning.

SRI KRISHNA ARTS AND SCIENCE COLLEGE COIMBATORE

Course : **Operations Research**

Unit – I : **Mathematical Formulation of L.P.P**

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LINEAR PROGRAMMING PROBLEM

INTRODUCTION:

Linear Programming is a technique for determining an optimum schedule of interdependent activities in view of the available resources. Programming is just another word of **“planning”** and refers to the process of determining a particular plan of action from amongst several alternativies. The word linear stands for indicating that all relationships involved in a particular problem are linear.

Definition :

LP is a mathematical technique for choosing the best alternatives from a set of feasible alternatives, in situations where the objective function as well as the restrictions or constraints can be expressed as a linear mathematical functions.

Linear programming problem

Many business and economic situations are concerned with a problem of planning activity.

In each of case, there are limited resources at your disposal and your problem is to make such a use of these resources so as to yield the maximum production (or) to minimize the cost production.

Linear programming is a technique for determining an optimum schedule of independent activities in the view of available resource.

Linear – the relationship of the interrelated variable which of the form $y = ax + b$ where x & y are variables when the degree one.

Programming – Planning a way of systematic action to achieving the optimal (or) required result

LINEAR PROGRAMMING PROBLEM

Linear Programming Problem(LPP) consists of three components, namely the

(i) Decision variables(activities)

(ii) The objectives(goal)

(iii) The constraints(restrictions)

(i) The **decision variables** refer to the activities that are competing one another for sharing the resources available. These variables are usually inter-related in terms of utilization of resources and need simultaneous solutions.

All the decision variables are considered as continuous, controllable and non-negative.

(ii)A linear programming problem must have **an objective** which should be clearly identifiable and measurable in quantitative terms.

It could be of profit(sales) maximization, cost(time) minimization, and so on. The relationship among the variables representing objective must be linear.

(iii) There are always **certain limitations(or constraints)** on the use of resources, such as labour, space, raw material, money, etc. that limit the degree to which an objective can be achieved.

Such constraints must be expressed as linear inequalities or equalities in terms of decision variables.

BASIC ASSUMPTIONS OF LPP

The linear programming problems are formulated on the basis of the following assumptions.

- **Proportionality:** The contribution of each variable in the objective function or its usage of the resources is directly proportional to the value of the variable. i.e., if resource availability increases by some percentage, then the output shall also increase by the same percentage.

Additivity: Sum of the resources used by different activites must be equal to the total quantity of resouces used by each activity for all the resources individually or collectively.

Divisibilty: The variables are not restricted to integer value.

Certainty or Deterministic: Co-efficients in the objective function and constraints are completely known and do not change during the period under study in all problems considered.

Finiteness: Variables and constraints are finite in number

Optimality: **I**n a linear programming problem we determine the decision variables so as to extremise (optimize)the objective function of the LPP

The problem involves only one objective namely profit maximization and cost minimization.

LPP can be divided into two types:

- **Maximization problem which has the maximize the profit ≤.**
- **Minimization problem which has the minimize the cost ≥**

LINEAR PROGRAMMING PROBLEM

LINEAR – All variables occurring in objective functions.

PROGRAMMING –process of determining particular course of action.

OBJECTIVE FUNCTION: LPP deals with optimization (maximization or minimize)of function of decision variables known as objective function.

Subject to a set of simultaneous linear equation is known as **constraints.**

Determining optimal allocation of limited resources to meet given objectives.

Resources may be men, raw materials ,machine ,money etc.

LPP deals with optimizing (Max or Min) of function of decision variables (variables determining solution of problem)is objective function, subject to simultaneous linear equation known as constraints.

MATHEMATICAL FORMULATION OF THE PROBLEM

The procedure for the mathematical formulation of a linear programming problem consists of the following major steps:

STEP 1:Study the given situation to find the key decision to be made.

STEP 2:Identify the variables involved and designate them by symbols x_j (j=1,2,…..)

STEP 3:State the feasible alternatives which generally are:

$x_j \geq 0$, for all j.

STEP 4: Identify the constraints in the problem and express them as linear inequalities or equations, LHS of which are linear functions of the decision variables.

STEP 5: Identify the objective function and express it as linear function of the decision variables.

General Linear Programming Problem

The linear programming problem involving more than two variables may be expressed as follows:

Maximize or Minimize

$$Z = c_1 x_1 + c_2 x_2 + c_3 x_3 \ldots + c_n x_n$$

Subject to the constraints

$$a_{11}x_1 + a_{12}x_2 + \cdots . + a_{1n}x_n \geq \text{(or)} \leq \text{(or)} = b_1$$

$$a_{21}x_1 + a_{22}x_2 + \cdots . + a_{2n}x_n \geq \text{(or)} \leq \text{(or)} = b_2$$

$$a_{31}x_1 + a_{32}x_2 + \cdots . + a_{3n}x_n \geq \text{(or)} \leq \text{(or)} = b_3$$

$$\vdots \qquad\qquad\qquad\qquad \vdots$$

$$a_{m1}x_1 + a_{m2}x_2 + \cdots . + a_{mn}x_n \geq \text{(or)} \leq \text{(or)} = b_m$$

And non negative restrictions

$$x_1, x_2, x_3 \ldots\ldots\ldots\ldots\ldots, \geq 0,$$

Problem

1.(Product Allocation Problem)

A company has three operational departments(weaving, processing and packing) with capacity to produce three different types of clothes namely suitings, shirtings and wollens yielding a profit of Rs.2,Rs.4 and Rs.3per meter respectively. one meter of suiting requires 3 minutes in weaving 2 minutes in processing and 1 minute in packing.

Similarly one meter of shirting require 4 minutes in weaving 1 minutes in processing and 3 minutes in packing.

One meter of wollen requires 3 minutes in each department .In a week, total run time of each department is 60,40 and 80 hours for weaving, processing and packing respectively.

Solution:

We have ->

	Weaving (in mins)	Processing (in mins)	Packing (in mins)	Profit(Rs)
Suiting	3	2	1	2
Shirting	4	1	3	4
Woollens	3	3	3	3
Availability (mins)	60*60	40*60	80*60	

Step 1: The ***key decision*** is to determine the weekly rate of production for the three types of clothes.

Step 2: Let us denote the weekly production of Suiting, Shirting and Woolens by x_1 meters, x_2 meters and x_3 meters respectively

Step 3: Since it is not possible to produce negative quantities $x_1 \geq 0$, $x_2 \geq 0$, $x_3 \geq 0$

Step 4:

The constraints are given by

$3\ x_1 + 4x_2 + 3\ x_3 \leq 3600$

$2\ x_1 + x_2 + 3\ x_3 \leq 2400$

$x_1 + 3x_2 + 3\ x_3 \leq 4800$

Step 5:

The objective is to maximize the total profit from sales. $Z = 2x_1 + 4x_2 + 3\ x_3$

The linear programming problem can thus be put in the following mathematical format: Find x_1 ,x_2 and x_3 so as to

Maximize **$Z= 2x_1 + 4x_2 + 3 x_3$**

Subject to the constraints:

$3 x_1 + 4x_2 + 3 x_3 \leq 3600$

$2 x_1 + x_2 + 3 x_3 \leq 2400$

$x_1 + 3x_2 + 3 x_3 \leq 4800$; $x_1 \geq 0$, $x_2 \geq 0$, $x_3 \geq 0$

2.(Blending Problem)

The manager of an oil refinery must decide on the optimum mix of the two possible blending process of which the input and output production runs are as follows:

Process	Crude A (Input)	Crude B (Input)	Gasoline x (Output)	Gasoline Y (Output)
1	6	4	6	9
2	5	6	5	5

The maximum amounts available of crudes A and B are 250 units and 200 units respectively. Market demand shows that at least 150 units of gasoline X and 130 units of gasoline Y Must be produced. The profits per production run from process 1 and process 2 are Rs.4 and Rs.5 respectively. Formulate the problem for maximizing the profit.

Solution:

We have

Process	Crude A (Input)	Crude B (Input)	Gasoline x (Output)	Gasoline Y (Output)	
1	6	4	6	9	Rs.4
2	5	6	5	5	Rs.5
	250units	200units	Atleast150	Atleast130	

Step 1: The key decision is to determine the number of units of gasoline produced from process1 and process 2.

Step 2: let x_1 , x_2 =number of units of gasoline produced from process 1 and process 2 respectively.

Step 3: Feasible alternatives: $x_1 \geq 0$, $x_2 \geq 0$

Step 4: The constraints are on the availability of crude oil and demand of the oil

$6\ x_1 + 5x_2 \ \leq 250$ (Availability of crude A)

$4x_1 + 6\ x_2 + \ \leq 200$ (Availability of crude B)

$6x_1 + 5x_2 \ \geq 150$ (Demand of gasoline X)

$9x_1 + 5x_2 \ \geq 130$ (Demand of gasoline Y)

Step 5: The objective is to maximize the total profit from the production of gasoline($4\ x_1 + 5x_2$).

The required LPP is

Maximize $z = 4\ x_1 + 5x_2$

Subject to the constraints

$6\ x_1 + 5x_2 \leq 250;\ 4x_1 + 6\ x_2 + \ \leq 200$

$6x_1 + 5x_2 \geq 150\ ;\ 9x_1 + 5x_2 \geq 130$

$x_1 \geq 0\ ,\ x_2 \geq 0$

3.Agriculturist Problem

An agriculturist has a farm with 125 acres .He produces Radish. Muttar and potato. Whatever he raises is fully sold in the market.

He gets Rs.5 for radish per Kg. Rs.4 for Muttar per acre and Rs.5 for potato per kg1200kg of potato per acre. To produce each 100 kg of Radish and Muttar and to produce each 80 kg. of Potato a sum of Rs.12.50 has to be used for manure

Labour required for each acre to raise the crop is 6 man-days for Muttar. A total of 500 man-days of Labour at a rate of Rs.40 per man-day are available.

Formulate this as a Linear Programming model to maximize the agriculturist's total profit.

4.Trim Loss Problem

Rolls of paper having a fixed length and width of 180cm being manufactured by a paper mill. These rolls have to be cut to satisfy the following demand:

Width	: 80cm	45cm	27cm
No. of rolls	: 200	120	130

Obtain the linear programming formulation of the problem to determine the cutting pattern. So that the demand is satisfied and wastage of paper is a minimum.

5.BLENDING PROBLEM

Three grades of coal A, B and C contain ash and phosphorus of impurities. In a particular industrial process a fuel obtained by blending the above grades containing not more than 25% ash and 0.03% phosphorus is required. The maximum demand of the fuel is 10 tons. percentage impurities and costs of the various grades of coal are shown below. Assuming that there is an unlimited supply of each grade of coal and there is no loss in blending, formulate the blending problem

Coal(grade)	% ash	%phosphorus	Costs per ton (in RS.)
A	30	0.02	240
B	20	0.04	300
C	25	0.03	280

SRI KRISHNA ARTS AND SCIENCE COLLEGE

Course : Operation Research

Unit – 1 :Graphical Method

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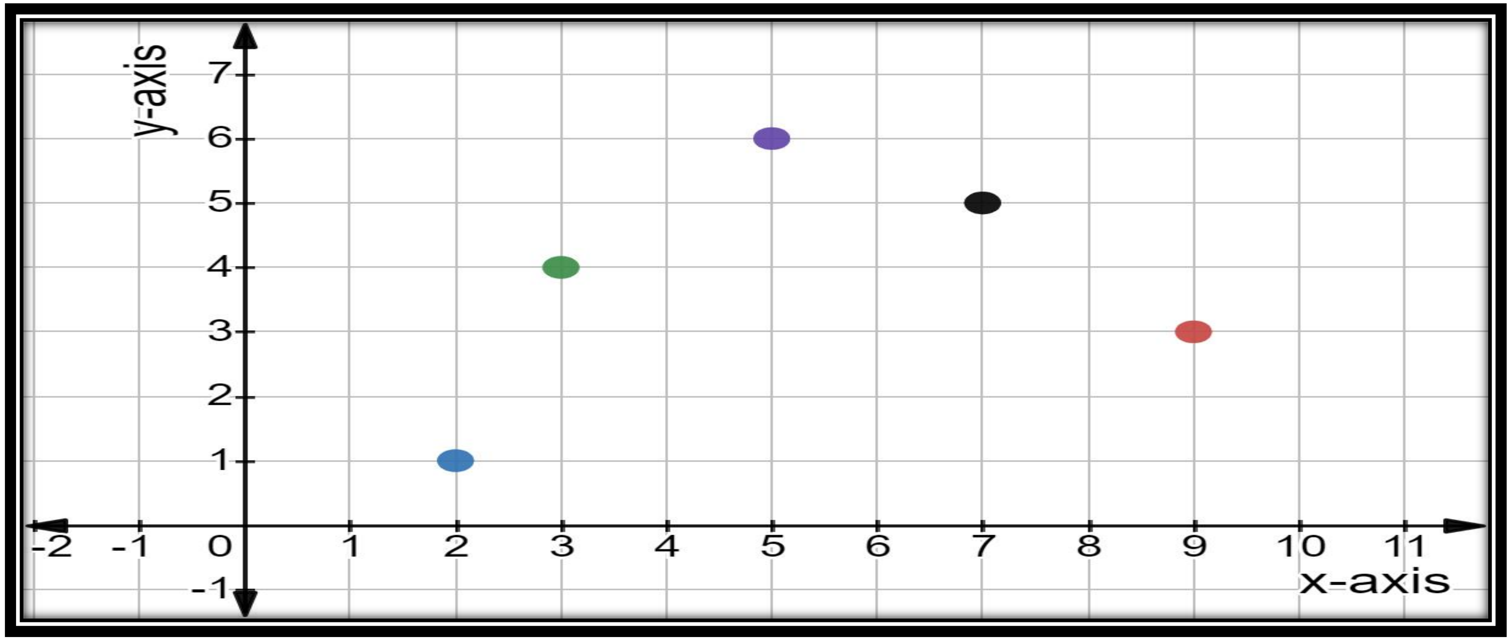
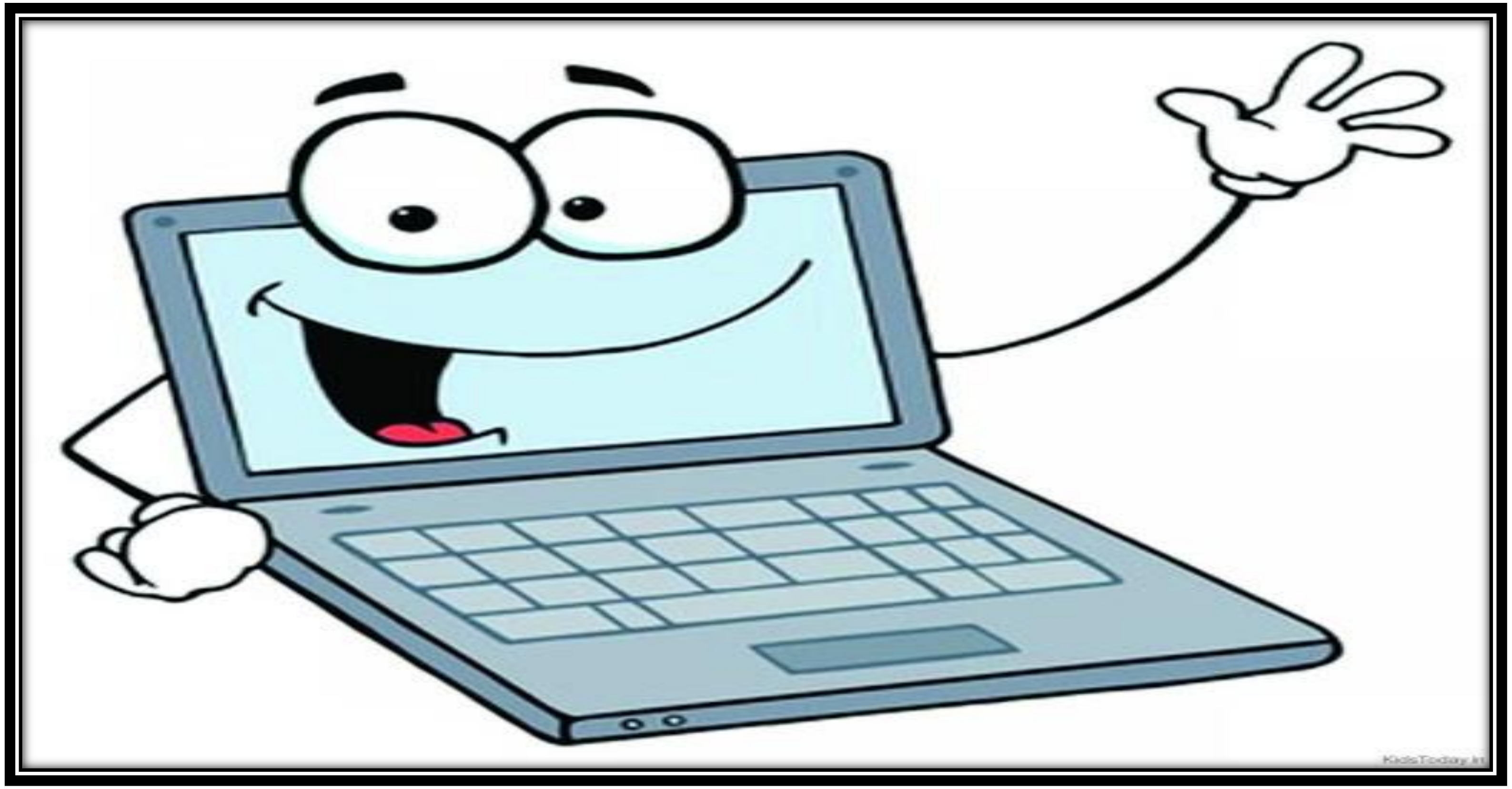
Topic - 4 : Graphical Method



Reference : Joshua Emmanuel (Youtube Channel**)**

Animated video



Reference : Muhammad Fiqiri(Youtube Channel)

GRAPHICAL METHOD

- Linear programming problems involving only two variables can be effectively solved by a graphical method which provides a pictorial representation of the problems and its solutions and which gives the basic concepts used in solving general L.P.P.
- This method is simple to understand and easy to use.
- Graphical method is not a powerful tool of linear programming as most of the practical situations do involve more than two variables.
- But the method really useful to explain the basic concepts of L.P.P to the person who are not familiar with this.

GRAPHICAL SOLUTION METHOD

Step1: Identify the problem-the decision variables, the objective and the restrictions.

Step 2: Set up the mathematical formulation of the problem.

Step 3: Plot a graph representing all the constraints of the problem and indentify the feasible region.

Step 4: The feasible region obtained in step 3 may be bounded or unbounded.

Compute the co-ordinates of all the corner points of the feasible region.

Step 5: Find out the value of the objective function at each corner (solution)point determined in step 4.

Step 6: Select the corner point that optimizes(maximizes or minimizes)the value of the objective function. It gives the **optimum feasible solution.**

The above method is known as ***Search Approach Method.***

Problem

1. Solve the following L.P.P by graphical method

Max Z= $3x_1 + 2x_2$

Subject to $-2x_1 + x_2 \leq 1$

$x_1 \leq 2$

$x_1 + x_2 \leq 3$ and $x_1, x_2 \geq 0$.

Solution :

First consider the inequality constraints as equalities

$-2x_1 + x_2 = 1$-----(1)

$x_1 = 2$ -------------(2)

$x_1 + x_2 = 3$---------(3)

And $x_1 = 0$-----(4) $x_2 = 0$-------(5)

For the line, -2$x_1 + x_2 = 1$,

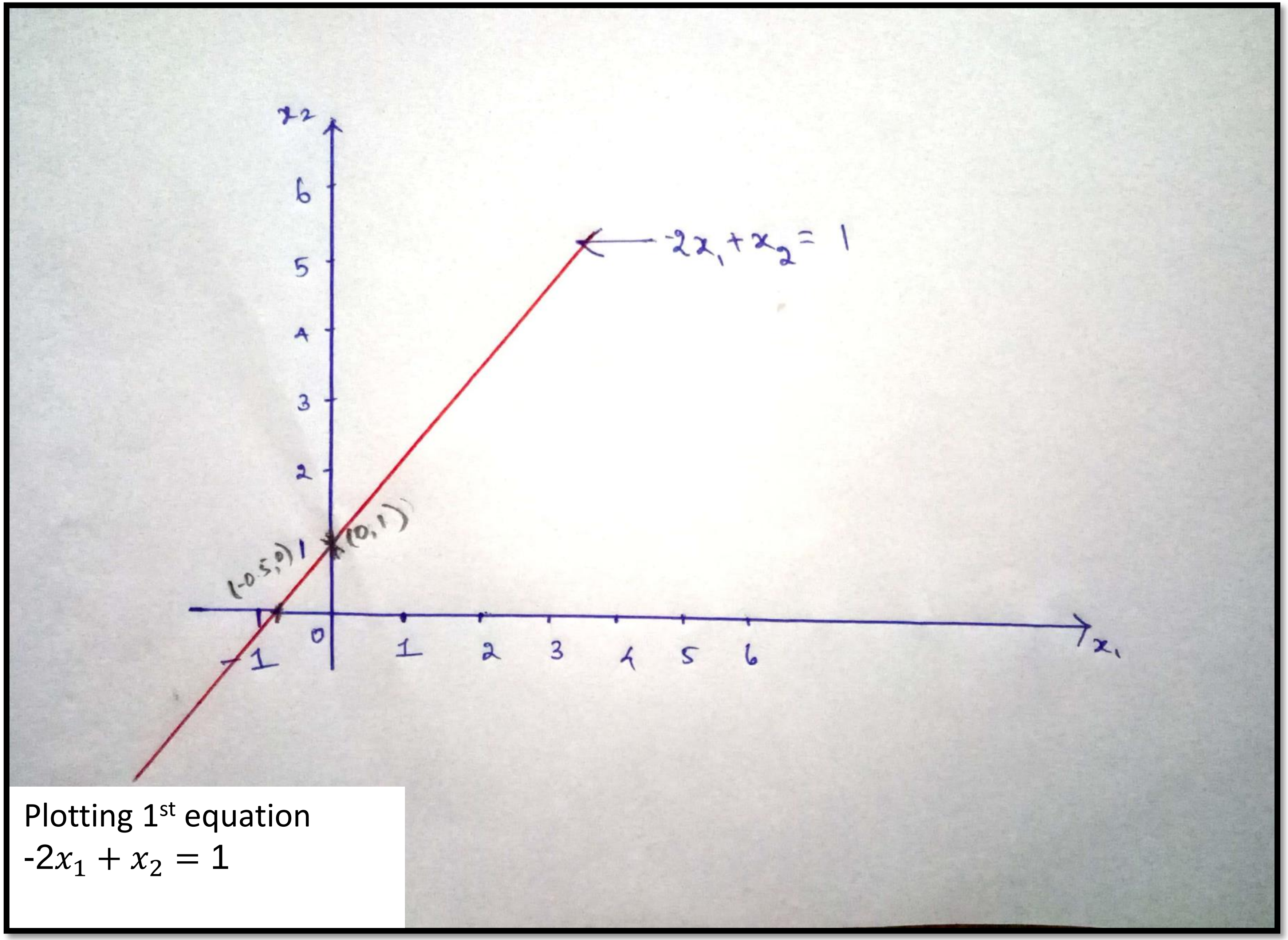
Put x_1=0 => $x_2 = 1$ =>(0,1)

Put x_2=0 => -2$x_1 = 1$ => x_1=-0.5 =>(-0.5,0).

So the line (1) passes through the points (0,1) and (-0.5,0).

All the points on the origin side and on this line satisfy the inequality

-2$x_1 + x_2$≤ 1

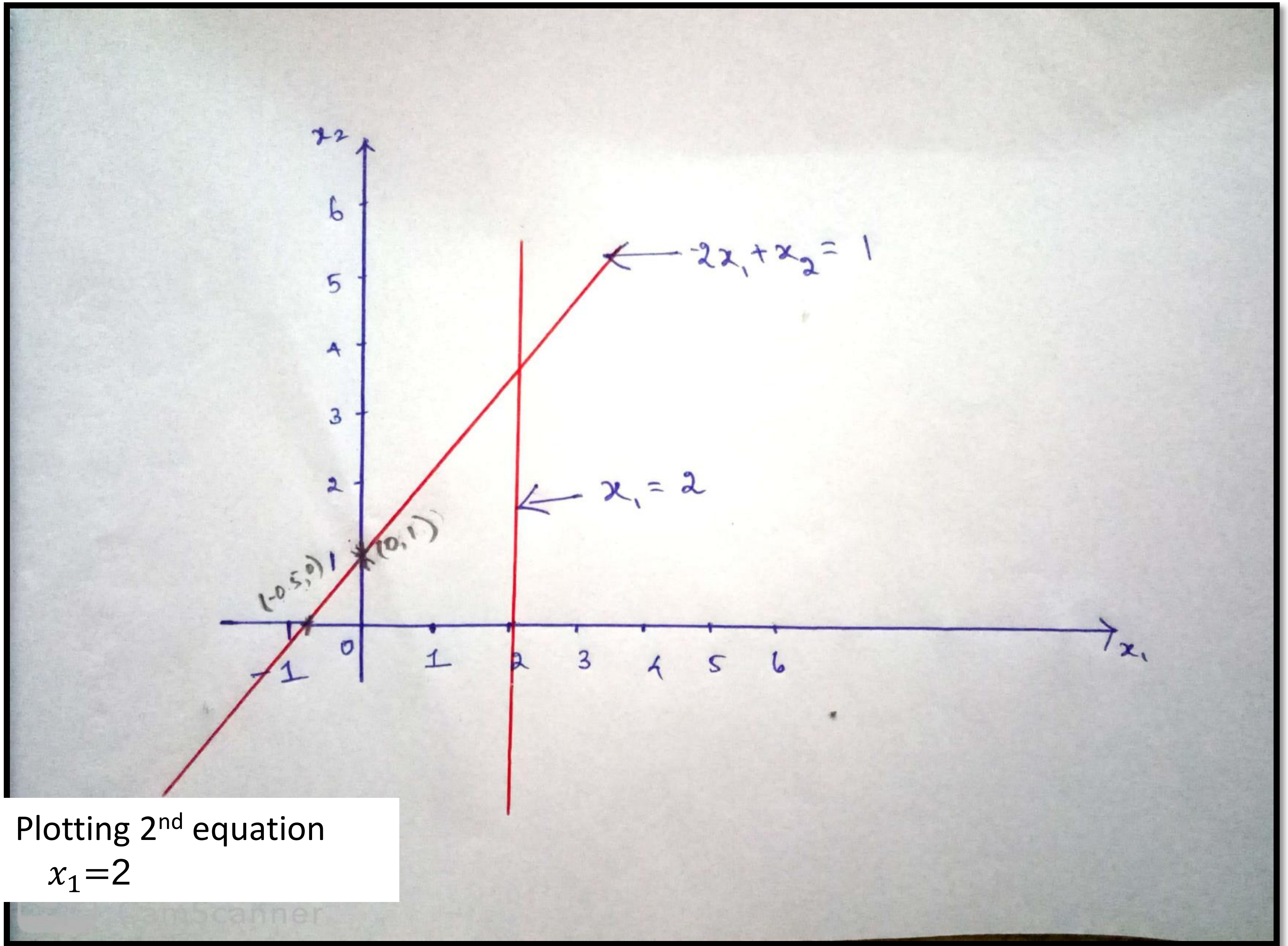


Plotting 1st equation
-2$x_1 + x_2 = 1$

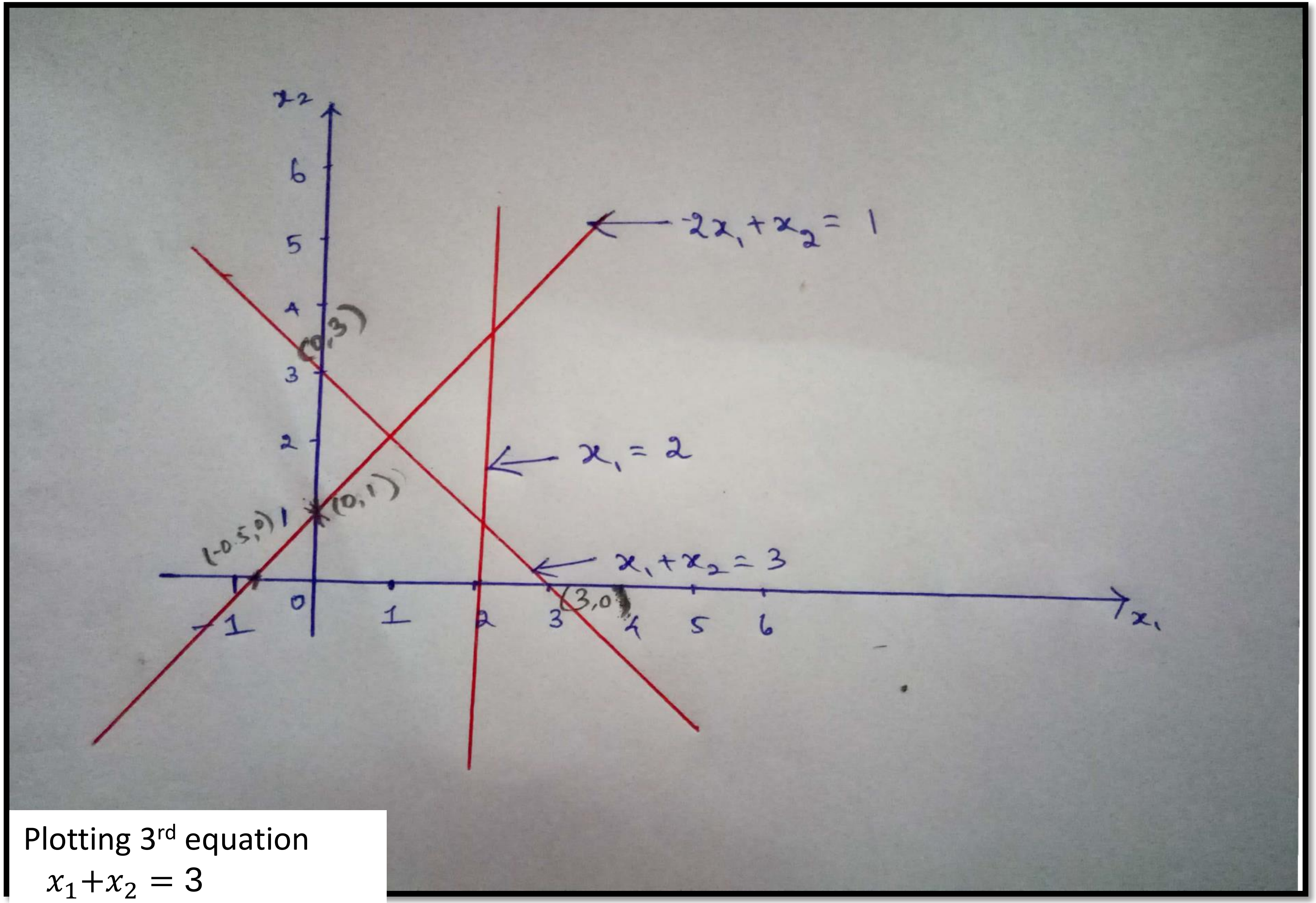
Similarly interpreting the other constraints we get the feasible region

OABCD. The feasible region is also known as solution space of the L.P.P.

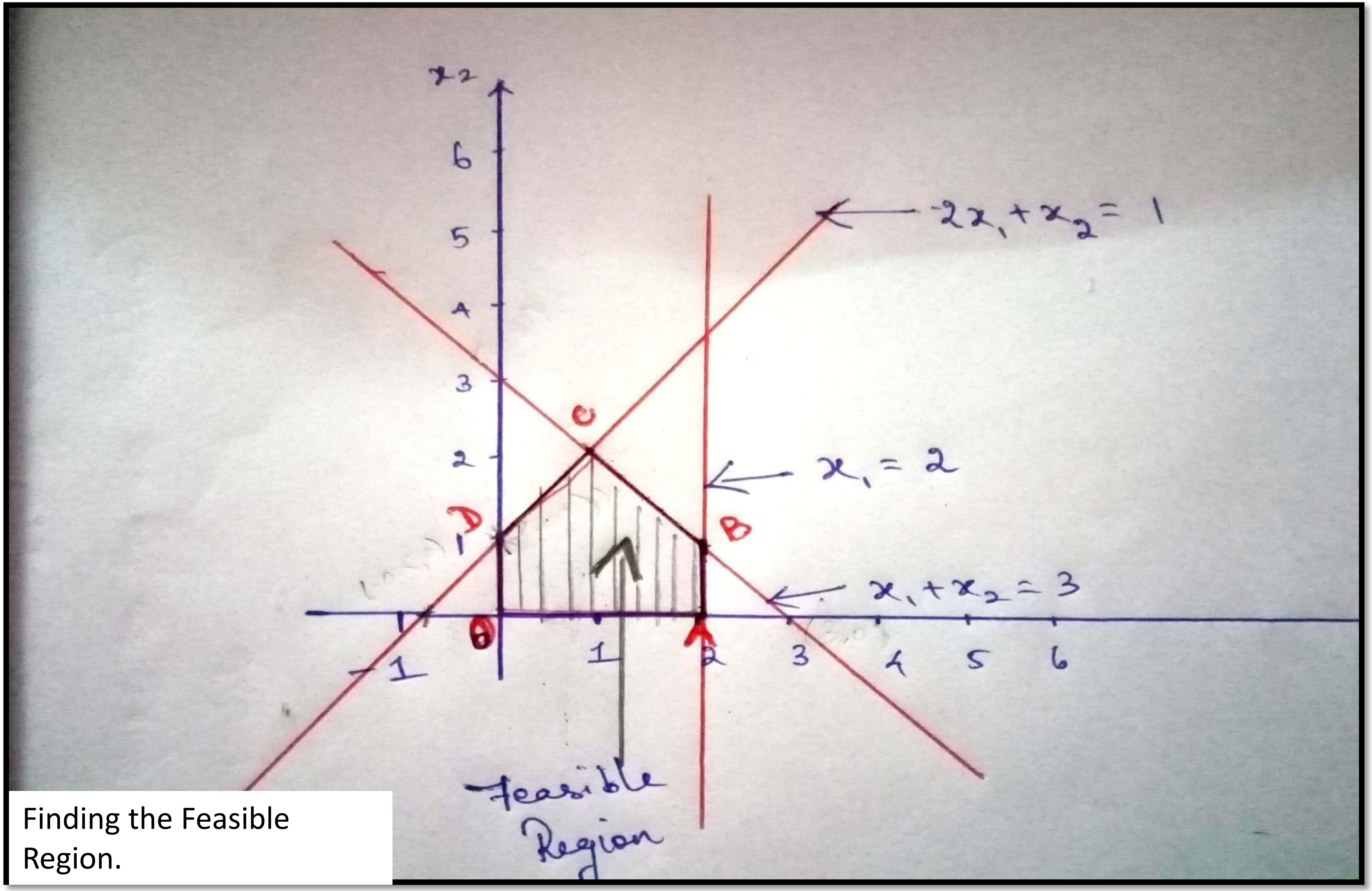
Every point within this area satisfies all constraints.



Plotting 2nd equation
x_1=2



Plotting 3rd equation
$x_1+x_2=3$



Finding the Feasible Region.

Now, our aim is to find the vertices of the solution space. B is the point of intersection of x_1=2 and $x_1+x_2 = 3$. Solving these two equations. We have x_1=2 and x_2=1. We have the vertex B(2,1). Similarly, C is the intersection of $-2x_1 + x_2$=1 and $x_1 + x_2$=3. Solving these we have C($\frac{2}{3}, \frac{7}{3}$).

Therefore the vertices of the solution space are O (0,0), A(2,0), B(2,1), C($\frac{2}{3}, \frac{7}{3}$) and D(0,1)

Therefore the vertices of the solution space are O (0,0), A(2,0), B(2,1), C($\frac{2}{3}$, $\frac{7}{3}$) and D(0,1)

The values of Z at these vertices are given by

Vertex	Value of Z (=$3x_1 + 2x_2$)
O(0,0)	0
A(2,0)	6
B(2,1)	8
C($\frac{2}{3}$, $\frac{7}{3}$)	$\frac{20}{3}$
D(0,1)	2

Since the problem is of maximization type, the optimum solution to L.P.P is **Maximize Z=8, x_1=2 and x_2=1.**

Problem

2. A farm is engaged in breeding pigs. The pigs are fed on various products grown on the farm. In view

of the need to ensure certain nutrient constituents(call them X,Y, and Z), it is necessary to buy two additional products. say A and B. One unit of product A contains 36 units of X, 3 units of Y and 20 units of Z.

One unit of product B contains 6 units of X,12 units of Y and 10 units of Z. The minimum requirement of X ,Y and Z is 108 units,36 units and 100 units respectively. Product A costs Rs.20 per unit and product B Rs.40 per unit.

Formulate the above as a linear programming problem to minimize the total cost, and solve the problem by using graphic method.

SOLUTION: FORMULATION OF LPP

Nutrient Constituents	Nutrient content in product		Minimum amount of nutrient
	A	B	
X	36	6	108
Y	3	12	36
Z	20	10	100
Cost of Product	Rs.20	Rs.40	

The linear programming problem, therefore can be put in the following mathematical format:

Minimize $Z = 20x_1 + 40x_2$

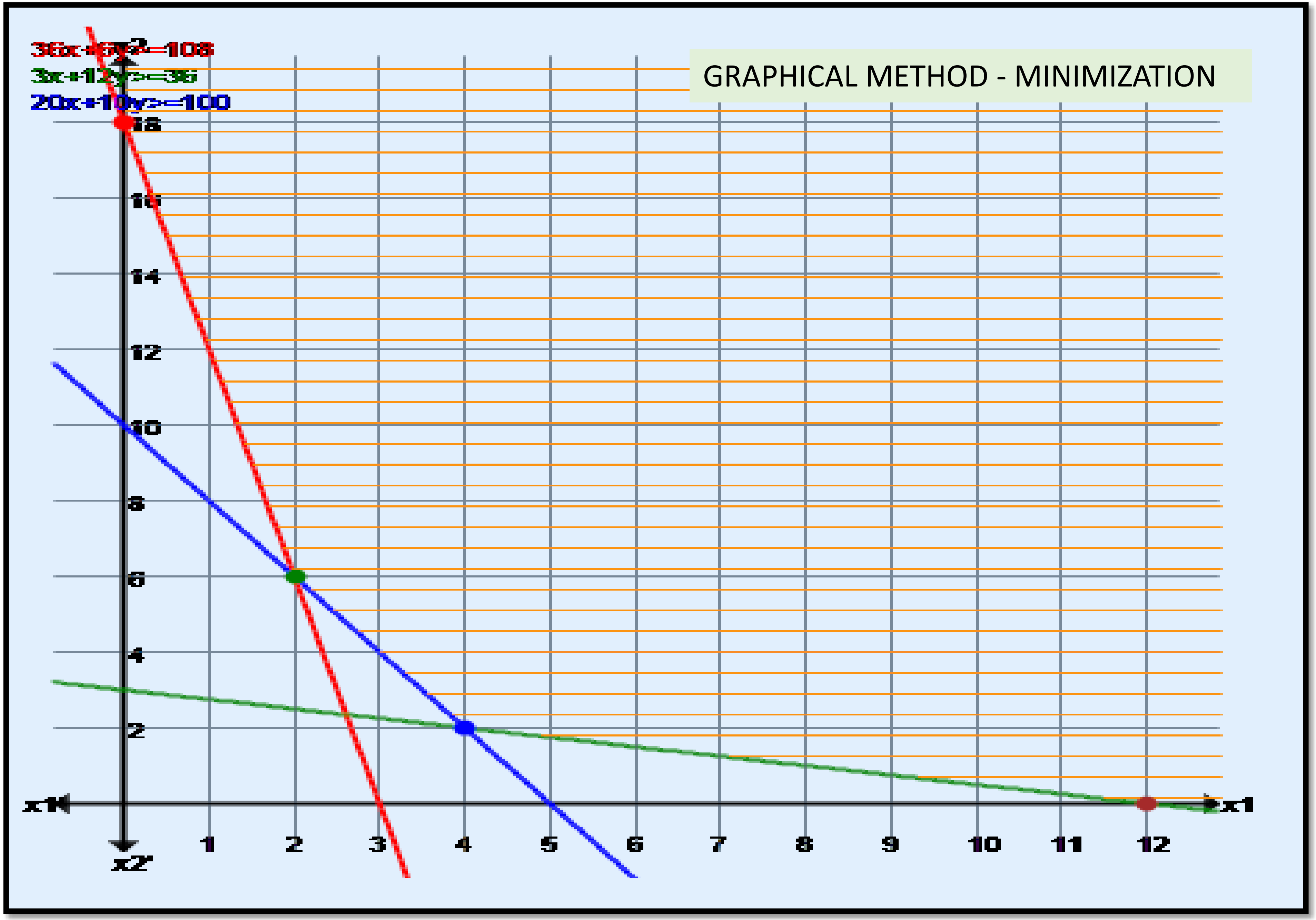
Subject to the constraints:

$36 x_1 + 6 x_2 \geq 108$

$3 x_1 + 12 x_2 \geq 36$

$20 x_1 + 10x_2 \geq 100$

$x_1 \geq 0 , x_2 \geq 0 .$


36x+6y>=108
3x+12y>=36
20x+10y>=100
GRAPHICAL METHOD - MINIMIZATION
x2
18
16
14
12
10
8
6
4
2
x1'
x1
1
2
3
4
5
6
7
8
9
10
11
12
x2'

Extreme points	(x_1, x_2)	$Z=20x_1 + 40x_2$
A	(0,18)	720
B	(2,6)	280
C	**(4,2)**	**160**
D	(12,0)	240

Hence, the optimum solution is to purchase 4 units of product A and 2 units of product B in order to maintain the minimum cost of Rs.160.

SOME EXCEPTIONAL CASES:

1.Alternative optima

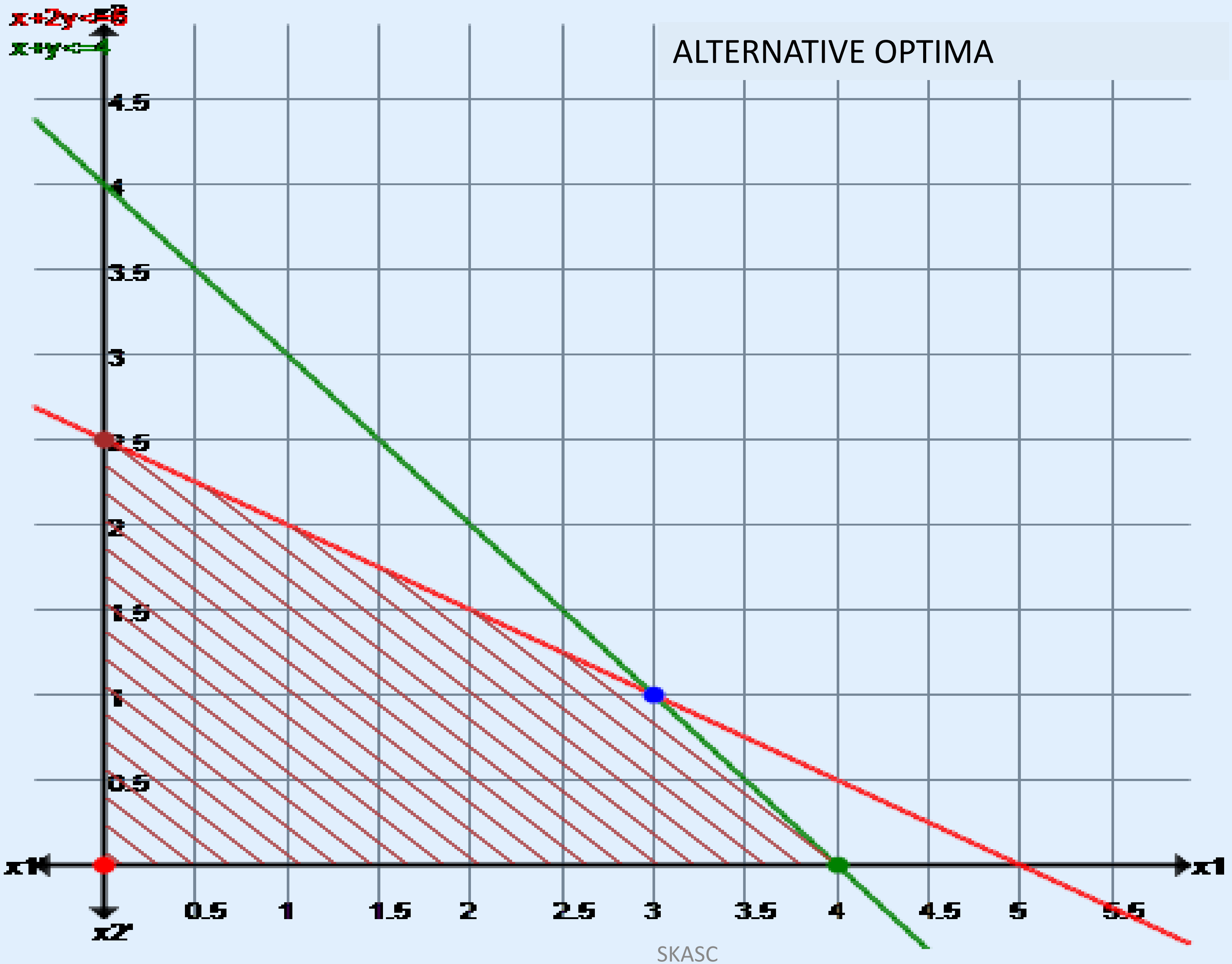
Use graphical method to solve the L.P.P

$$\text{Maximize } Z=2x_1 +4 x_2$$

$$\text{subject to } x_1 + 2x_2 \leq 5$$

$$x_1 + x_2 \leq 4 \text{ , } x_1 \geq 0 \text{ , } x_2 \geq 0 \text{ .}$$

ALTERNATIVE OPTIMA



Extreme points	(x_1, x_2)	$Z=20x_1 + 40x_2$
O	(0,0)	0
A	(4,0)	8
B	**(3,1)**	**10**
C	**(0,0,25)**	**10**

Since, any point on the line segment BC gives the maximum value(z=10) of the objective function, there exist an alternative optima.

2.UNBOUNDED SOLUTION

Maximize $Z = 6x_1 + x_2$

Subject to the constraints:

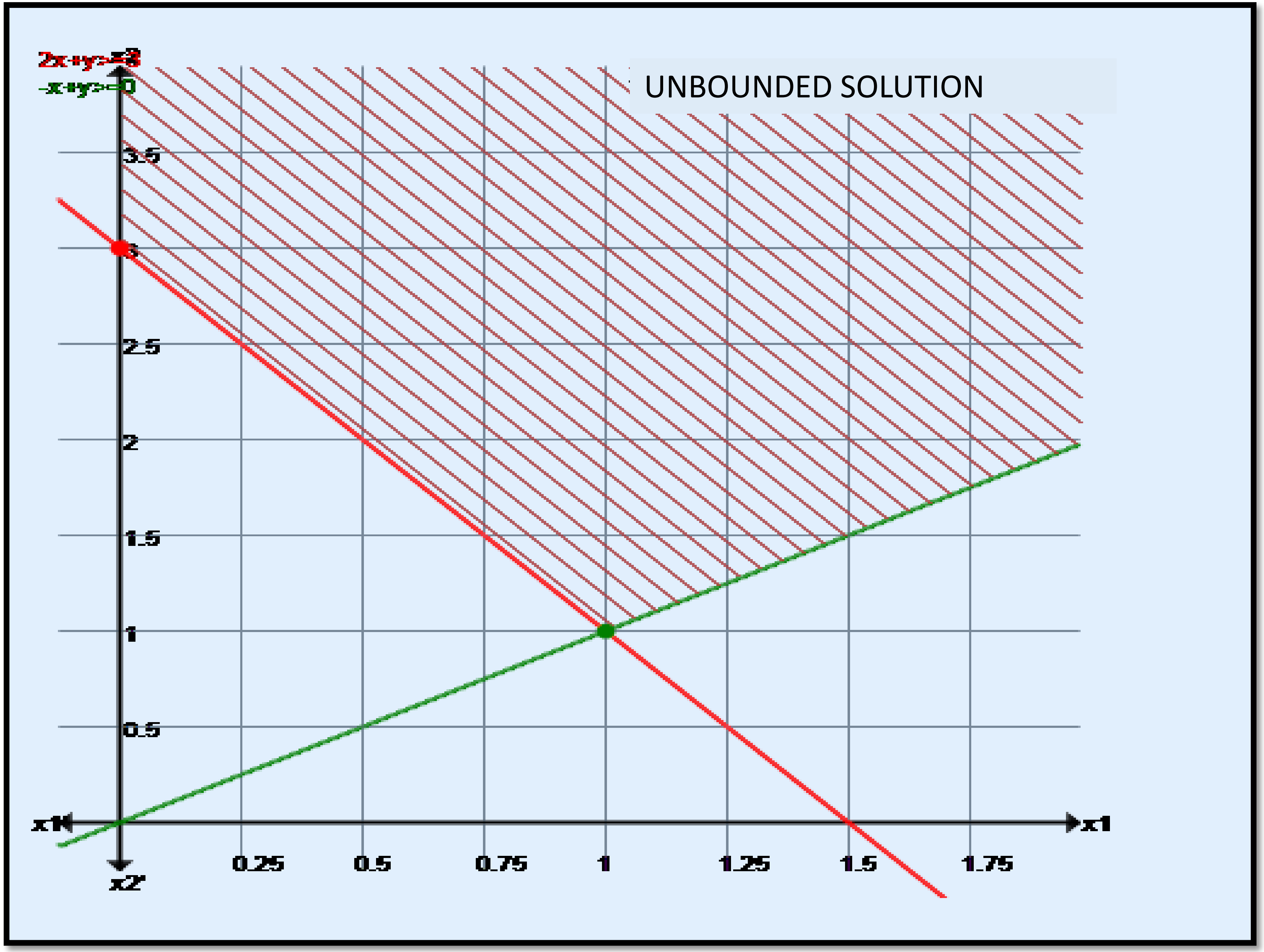
$2x_1 + x_2 \geq 3$

$x_2 - x_1 \geq 0$

$x_1 \geq 0 , x_2 \geq 0$

Solution:

The given Problem has unbounded Solution



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3.INFEASIBLE SOLUTION

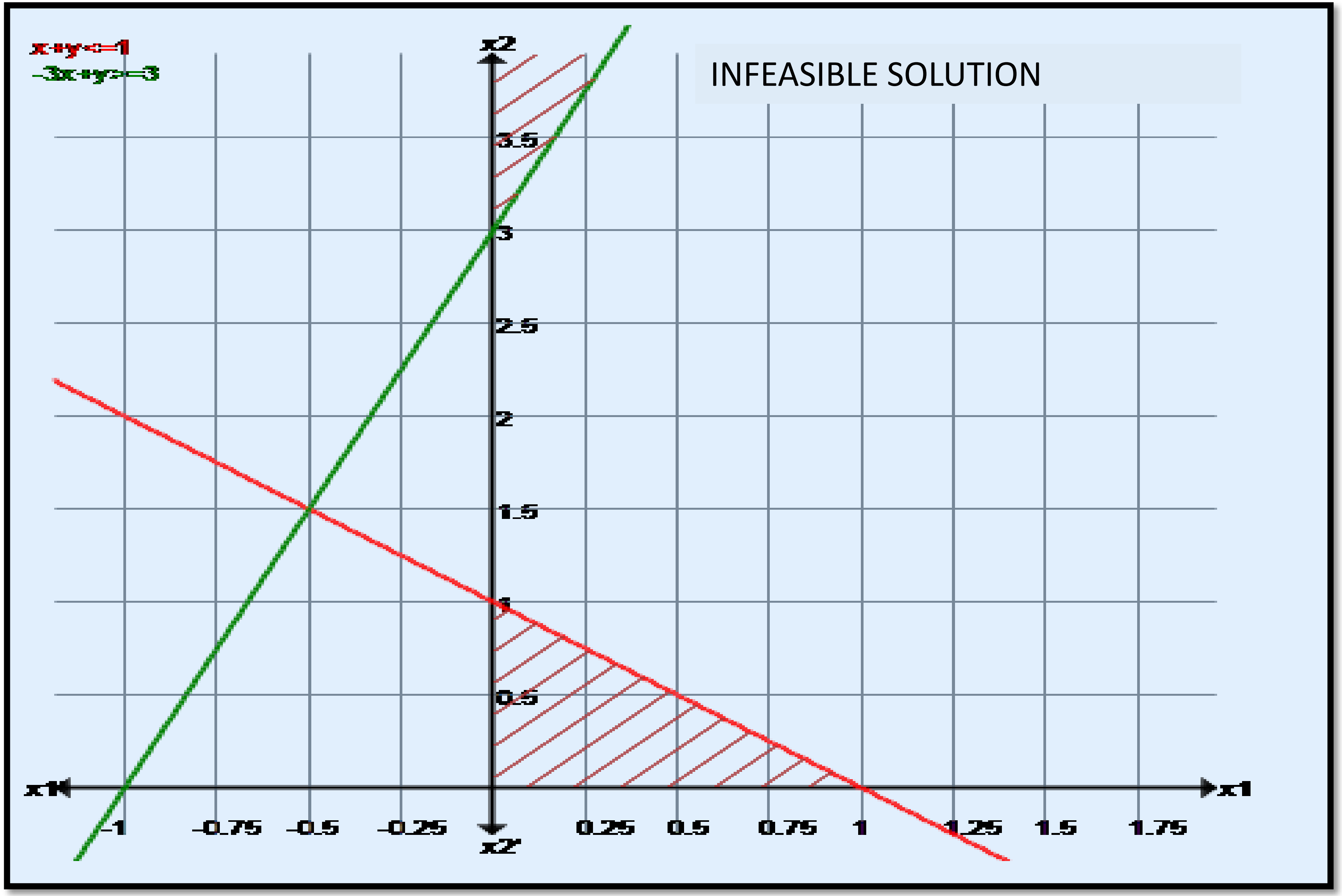
Maximize $Z = x_1 + x_2$

Subject to the constraints:

$x_1 + x_2 \leq 1$

$-3x_2 + x_1 \geq 3$

$x_1 \geq 0 , x_2 \geq 0$



x+y<=1
-3x+y>=3
x2
INFEASIBLE SOLUTION
3.5
3
2.5
2
1.5
1
0.5
x1'
x1
-1
-0.75
-0.5
-0.25
0.25
0.5
0.75
1
1.25
1.5
1.75
x2'

SOLUTION:

The problem is depicted graphically. There is no point(x1,x2) which lies in both regions, there exists no solution to the given problem. Thus there is infeasible solution.

Problems

1.A computer makes two kinds of leather belts. Belt A is a high quality belt,and belt B is of lower quality. The respective profits are Rs.400 and Rs.300 per belt. Each belt of type A requires twice as much time as a belt of type B, and if all belts were of type B, the company could make 1000 belts per day.

The supply of leather is sufficient for only 800 belts per day(Both A and B combined). Belt A requires a fancy buckle and only 400 buckles per day are available. There are only 700 buckles a day available for belt B. determine the optimal product mix.

Problems

2.Solve using graphical method : Maximize z=$x_1 - 2x_2$ subject to

-$x_1 + x_2 \leq 1,\ 6x_1 + 4x_2 \geq 24,\ 0 \leq x_1$ $\leq$5 and 2 $\leq x_2$ $\leq$4

3. Solve graphically the following L.P.P : Max Z= 3x+2y subject to

-2x+3y $\leq$ 9 ; x-5y $\geq$ -20 and x,y $\geq$0.

4. Solve using graphical method : Max Z= 3x-2y subject to x+y $\leq$1; 2x+2y $\geq$4 and x,y $\geq$0.

Answers :

2. Max Z=1, x_1=5 and $x_2 = 2$.

3. Unbounded

4. No feasible

TEST YOUR KNOWLEDGE

SRI KRISHNA ARTS AND SCIENCE COLLEGE COIMBATORE

Course : Quantitative Techniques

Topic : Simplex Method

Ms. B.Sruthi

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SIMPLEX METHOD

While Solving a LPP graphically, the region of feasible solutions was found to be convex. The optimal solution if it exists, occurred at some vertex. If the optimal solution was not unique, the optimal points were on an edge. These observations also hold for the general LPP. Essentially the problem is that of finding the particular vertex of the convex region which corresponds to the optimal solution. The most commonly used method for locating the optimal vertex is the **simplex method or simplex technique or simplex algorithm.**

Simplex method was developed by G. Dantzig in 1947.

The simplex method provides an algorithm which consists in moving from one vertex of the region of feasible solutions to another vertex in such a way that the value of the objective function at the succeeding vertex is more(or less in some case may be) that at the preceding vertex. This procedure of jumping from one vertex to another is then repeated. Since the number of vertices is finite, the method leads to an optimal vertex in a finite number of steps or indicates the existence of an unbounded solution.

SIMPLEX METHOD

Definition:(Basic solution)

Given a system of m simultaneous linear equations in n unknowns(m<n)

$$Ax=b, X^T= R^n$$

where A is an m x n matrix of rank m. Let B be any mxn submatrix, formed by m linearly independent columns of A.

Then, a solution obtained by setting n-m variables not associated with the columns of B, equal to zero, and solving the resulting system, is called a **basic solution to the given system of equations**.

Remark:

The m variables, which may be all different from zero, are called **basis variables.** The m x m (Singular matrix)

Is called **basis matrix** with columns as **basis vectors.**

Definition:(Degenerate solution)

A basic solution to the system is called **degenerate** if one or more of the basic variables vanish.

Definition: (Basic feasible solution)

A feasible solution to an L.P.P., which is also a basic solution to the problem is called **a basic feasible solution to the L.P.P.**

Definition:(Associated cost vector)

Let X_B be a basic feasible solution to the L.P.P:

Maximize z= cx subject to: Ax=b and x≥0

Then, the vector $C_B = (C_{B1}, C_{B2}, \ldots\ldots\ldots, C_{Bm})$,

Where C_{Bi} are components of C associated with the basic variables, is called the cost vector associated

With the basic feasible solution X_{B}.

Definition(Optimum basic feasible solution)

A basic feasible solution X_B to the L.P.P

Maximize $z= cx$ subject to:

$Ax=b$ and $x \geq 0$

if $Z_0 = C_B X_B \geq Z^*$,

where Z^* is the value of the objective function for any feasible solution.

SIMPLEX METHOD

SIMPLEX ALGORITHM

For the solution of any L.P.P by simplex algorithm ,the existence of an initial basic feasible solution is always assumed. The steps for the computation of an optimum solution are as follows:

Step 1:

Check whether the objective function of the given L.P.P is to be maximized or minimized. If it is to be minimized then we convert it into a problem of maximizing it by using the result Minimum $z = -$ Maximum(z)

Step 2:

Check whether all b_i (i=1,2,……m) are non-negative.If any one of b_i is negative then multiply the corresponding inequation of the constraints by -1,so as to get all b_i (i=1,2,……m) non-negative.

Step 3:

Convert all the in equations of the constraints into equations by introducing slack and/or surplus variables in the constraints. Put the costs of these variables equal to zero.

Step 4:

Obtain an initial basic feasible solution to the problem in the form

$x_B = B^{-1} b$ and put it in the first column of the simple table.

Step 5:

Compute the net evalutions $\boldsymbol{z_j - c_j}$ ***(j=1,2,….n)*** by using the relation $\boldsymbol{z_j - c_j = c_B\, y_j - c_j}$, where $\boldsymbol{y_j} = B^{-1}$ aj. Examine the sign $z_j - c_j$. *(i) If all(*$\boldsymbol{z_j - c_j} \geq 0$*) then the initial basic feasible solution* $\boldsymbol{x_B}$ *is an optimum basic feasible solution* *(ii) If at least one* $(\boldsymbol{z_j - c_j}) < \boldsymbol{0}$,proceed on to the next step.

Step 6:

If there are more than one negative $z_j - c_j$, then choose the most negative of them. Let it be $z_r - c_r$ for some j=r.

(i) If all $y_{ir} \le 0 (i=1,2,\ldots.m)$*,then there is an unbounded solution to the given problem.*

(ii) If atleast one $y_{ir} \ge 0 (i=1,2,\ldots..m)$ *then the corresponding vector* $\boldsymbol{y}_r$ *enters the basis* $\boldsymbol{y}_B$

Step 7:

Compute the ratios $\left\{\frac{x_{Bi}}{y_{ir}}, y_i > 0, i = 1,2, \dots . m\right\}$ and choose the minimum of them. let the minimum of these ratios be X_{Bk} / y_{ir} . Then the vector y_k will level the basis $y_{\mathbf{B}}$ .The common element y_{kr} , which is in the Kth row and the rth column is known as the leading element (or pivotal element)

Step 8:

Convert the leading element to unity by dividing its row by the leading element itself and all other elements in its column to zeros

Step 9:

Go to step 5 and repeat the computational procedure until either an optimum solution is obtained or there is an indication of an unbounded solution.

Problem

1. Use simplex method to solve the LPP

Maximize $Z=4x_1 + 10x_2$

subject to $2x_1 + x_2 \leq 50$

$2x_1 + 5x_2 \leq 100$

$2x_1 + 3x_2 \leq 90$ and $x_1, x_2 \geq 0$

Solution

By introducing the slack variable $s_{1,}s_{2,}s_{3,}$the problem in standard form becomes

Maximize Z = $4x_1$+ $10x_2$+$0s_1 + 0s_2 + 0s_3$

Subject to

$2x_1$+ x_2+$1.s_1 + 0s_2 + 0s_3$=50

$2x_1$+ $5x_2$+$0s_1 + 1.s_2 + 0s_3$=100

$2x_1$+ $3x_2$+$0s_1 + 0s_2 + 1s_3$ =90 and $x_{1,}x_2, s_1, s_2, s_3$≥0

Since there are 3 equations with 5 slack variables, the initial basic feasible solution is obtained by equating (5-3) = 2 variables to zeros.

Therefore the initial basic feasible solution is s_1=50, $s_2 = 100, s_3 = 90$

$(x_1 = 0, x_2 = 0, non - basic)$

The initial simplex table is given by

C_j	4	10	0	0	0

C_B	Y_B	X_B	x_1	x_2	s_1	s_2	s_3	$\theta = min\frac{X_{Bi}}{a_{ir}}$
0	s_1	50	2	1	1	0	0	50
0	s_2	100	2	(5)	0	1	0	20*
0	s_3	90	2	3	0	0	1	30
$Z_j - C_j$		0	-4	-10	0	0	0	

Here the net evaluation are calculated as $Z_j - C_j = C_B a_j - C_j$ .Thus $Z_1 - C_1 = -4, Z_2 - C_2 = -10, Z_3 - C_3 = Z_4 - C_4 = Z_5 - C_5 =$0. Since there are some $Z_j - C_j$ <0, the current basic feasible solution is not optimal.

To find the entering variable :

Since $Z_2 - C_2 = -10$ is the most negative, the corresponding non-basic variable x_2 enters the basis. The column corresponding to this x_2 is called the key column or pivot column.

To find the leaving variable :

Find the ratio $\theta = min\left\{\frac{X_{Bi}}{a_{ir}}, a_{ir} > 0\right\}$

$$= min\left\{\frac{X_{Bi}}{a_{i2}}, a_{i2} > 0\right\}$$

$$\theta = min\left\{\frac{50}{1}, \frac{100}{5}, \frac{90}{3}\right\}$$

= min {50,20,30} =20.Which corresponds to s_2.

Therefore the leaving variable is the basic variable s_2 which corresponds to the minimum ratio θ=20. The leaving variable row is called the pivot row or key row or pivot equation and 5 is the pivot element.

Now, New pivot equation = old pivot equation / pivot element.

=(100 2 5 0 1 0)/ 5

New s_1 equation = old $s_1$equation –(corresponding column co-efficient)x(New pivot equation)

	= 50	2	1	1	0	0
	(-) 20	2/5	1	0	1/5	0
=	30	8/5	0	1	-1/5	0

Similarly we calculate new s_3 equation and New $Z_j - C_j$ equation

The improved basic feasible solution is given in the following simplex table

			C_j	4	10	0	0	0
C_B	Y_B	X_B		x_1	x_2	s_1	s_2	s_3
0	s_1	30		8/5	0	1	-1/5	0
10	x_2	20		2/5	1	0	1/5	0
0	s_3	30		4/5	0	0	-3/5	1
$Z_j - C_j$		200		0	0	0	2	0

Since all $Z_j - C_j$ ≥0 the current basic feasible solution is optimal.

The optimal solution is Max Z= 200, $x_1 = 0$, x_2=20.

Problem

2. Use simplex method to solve the LPP

Maximize $Z=3x_1 -2 x_2 +5 x_3$

subject to $x_1 +4 x_2 \leq 420$

$3x_1 + 2x_3 \leq 460$

$x_1 + 2x_2 + x_3 \leq 430$

and $x_1 , x_2, x_3 \geq 0$

Problem

3. Use simplex method to solve the LPP

Minimize $Z = x_2 - 3x_3 + 2x_5$

subject to $3x_2 - x_3 + 2x_5 \le 7$

$-2x_2 + 4x_3 \le 12$

$-4x_2 + 3x_3 + 8x_5 \le 10$

and $x_2, x_3, x_5 \ge 0$

Problem

4. Use simplex method to solve the LPP

Maximize $Z = 300x_1 + 200x_2$

subject to $5x_1 + 2x_2 \leq 180$

$3x_1 + 3x_2 \leq 135$

and $x_1, x_2 \geq 0$

SRI KRISHNA ARTS AND SCIENCE COLLEGE
COIMBATORE

Course : Operations Research

Topic : Transportation Problem

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INTRODUCTION

INTRODUCTION:

The Transportation Problem is one of the subclasses of L.P.Ps. in which the objective is to **transport various quantities** of a single homogeneous commodity, that are initially stored at various origins ,**to different destinations** in such a way that the total transportation cost is **minimum**. To achieve this objective we must know the amount and location of available supplies and the quantities demanded.

- Level of supply at each source and the amount of demand at each destination and
- The unit transportation are known[given].

It is also assumed that the cost of transportation is **linear** .

Example:

Origins represent factories where we produce items & supply a required quantity of the products to a certain no.of destinations. To achieve this objective we must know the amount and location of available supplies and the quantities demanded. In addition we must know the costs that result from transporting one unit of commodity from various origins to various destinations.

General transportation problem

Let a_i = quantity of commodity avaliable at origin i.

b_j = quantity of commodity needed at destination j.

c_{ij} = cost of transporting one unit of commodity from origin i to destination j.

x_{ij} = quantity transported from origin i to destination j.

Mathematical formulation of a transportation problem:

Let us assume that there are m sources and n destinations.

Let $\boldsymbol{a_j}$ be the supply(capacity) at source i, $\boldsymbol{b_j}$ be the demand at destination j, $\boldsymbol{c_{ij}}$ be the unit transportation cost from i source to destination j and , $\boldsymbol{x_{ij}}$ be the number of units shifted from source i to destination j.

Then the transportation problem can be expressed mathematically as

Minimize z = $\sum_{i=1}^{m} \sum_{j=1}^{n} c_{ij}\ x_{ij}$

Subject to the constraints: $\sum_{j=1}^{n} x_{ij} = a_i$, i= 1,2,…,m

$\sum_{i=1}^{m} x_{ij} = b_j$, j = 1,2,…,n and

$x_{ij} \geq 0$ for all i and j.

Note 1: The two sets of constraints will be consistent if

$\sum_{i=1}^{m} a_i = \sum_{j=1}^{n} b_j$

Total supply = total demand

Which is the necessary and sufficient condition for a transportation problem to have a feasible solution. Problem satisfying this condition are called **balanced transportation problem.**

Note 2:

If $\sum_{i=1}^{m} a_i \neq \sum_{j=1}^{n} b_j$, then the transportation problem is said to be **unbalanced.**

Note 3:

For any transportation problem, the coefficients of all x_{ij} in the constraints are **unity.**

Definition 1: A set of non-negative values x_{ij} i=1,2….m;j=1,2,…..n that satisfies the constraints (rim conditions and also the non-negativity restrictions) is called a **feasible solution to the transportation problem.**

Note: A balanced transportation problem will always have a feasible solution.

Definition 2: A feasible solution to a (mxn) transportation problem that constraints no more than m+n-1 non-negative allocations is called **a basic feasible solution to the transportation problem.**

Note: The allocations are said to be independent positions if it is impossible to increase or decrease any allocation without either changing the position of the allocation or violating the rim requirements.

Definition 3: A basic feasible solution to a (mxn)transportation problem is said to be **non-degenerate basic feasible solution** if it contains exactly m+n-1 non-negative allocations in independent positions.

Definition 4: A basic feasible solution that contains less than m+n-1 non-negative allocations is said to be a **degenerate basic** feasible solution.

Definition 5: A feasible solution(not necessarily basic) is said to be an **optimal solution** if it minimizes the total transportation cost.

Note: ***The** number of **basic variables** in an mxn balanced transportation problem is atmost m+n-1.

*The number of **non-basic variables** in an mxn balanced transportation problem is atmost

mn-(m+n-1).

Methods for finding Initial Basic Feasible Solution

The transportation problem has a solution if and only if the problem is balanced. Therefore before starting to find the initial basic feasible solution, check whether the given transportation problem is balanced.

North West Corner Rule

Step 1:The first assignment is made in the cell occupying the upper left-hand(north-west)corner of the transportation table. The maximum possible amount is allocated there.

That is $x_{ij} = \min\{a_{1\,,}\, b_1\}$

case(i) : If $\min\{a_{1\,,}\, b_1\} = a_{1,}$ then put $x_{11} = a_{1\,,}$

decrease b_1 by a_1 and move vertically to the 2nd row(i.e.,) to the cell(2,1) cross out the first row.

case(ii) : If $\min\{a_1, b_1\} = b_1$, then put $x_{11} = b_1$,

decrease a_1 by b_1 and move horizontally right to the 2^{nd} row(i.e.,) to the cell(1,2) cross out the first column.

case(iii) : If $\min\{a_1, b_1\} = a_1 = b_1$ then put

$x_{11} = a_1 = b_1$, and move diagonally to the 2^{nd} row(i.e.,) to the cell(2,1) cross out the first row.

Step 2:Repeat the procedure until all the rim requirements are satisfied.

Problem:

1. Obtain an initial basic feasible solution to the following transportation problem using North-west corner rule.

	$D_{1,}$	$D_{2,}$	$D_{3,}$	$D_{4,}$	Available
$O_{1,}$	5	3	6	2	19
$O_{2,}$	4	7	9	1	37
$O_{3,}$	3	4	7	5	34
Requirement	16	18	31	25	

SOLUTION:

	$D_{1,}$	$D_{2,}$	$D_{3,}$	$D_{4,}$	Available
$O_{1,}$	**(16)** 5	**(3)** 3	6	2	19
$O_{2,}$	4	**(15)** 7	**(22)** 9	1	37
$O_{3,}$	3	4	**(9)** 7	**(25)** 5	34
Requirement	16	18	31	25	

The minimum transportation cost according to the above route is given by

Z=(5*16)+(3*3)+(15*7)+(22*9) +(9*7)+(25*5)=580.RS

SRI KRISHNA ARTS AND SCIENCE COLLEGE

Course : Operation Research

Topic : North West Corner Rule

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North West Corner Rule (NWCR)

Definition:

The North-West Corner Rule is a method adopted to compute the initial feasible solution of the transportation problem. The name North-west corner is given to this method because the basic variables are selected from the extreme left corner.

Finding an Initial Feasible Solution

The transportation problem has a solution if and only if the problem is balanced. Therefore before starting to find the initial basic feasible solution, check whether the given transportation problem is balanced.

Algorithm

Step 1: Find the total supply and total demand both should be equal.($\sum a_i = \sum b_j$)

Step 2: Select the upper left corner cell of the transportation matrix

and allocate min(s1, d1).

Step 3: a. Subtract this value from supply and demand of respective row and

column.

b. If the supply is 0, then cross (strike) that row and move down to

the next cell.

c. If the demand is 0, then cross (strike) that column and move right

to the next cell.

d. If supply and demand both are 0, then cross (strike) both row &

column and move diagonally to the next cell

Step 4: Repeat this steps until all supply and demand values are 0 and find the total transportation cost.

Solve the give table by NWCR

Store → Factory ↓	I	II	III	IV	Supply↓
A	1	3	5	6	90
B	11	1	3	8	70
C	10	16	12	10	40
Demand →	50	50	25	75	

Step I

$\sum$Demand = $\sum$ Supply

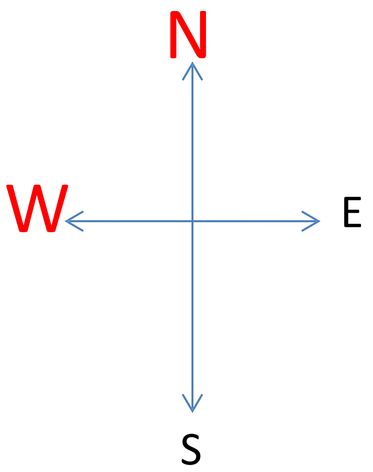
50+50+25+75 = 90+70+40

200 = 200 ……………………(satisfies)

Store → Factory ↓	I	II	III	IV	Supply ↓
A	1	3	5	6	90
B	11	1	3	8	70
C	10	16	12	10	40
Demand →	50	50	25	75	200 200

Step II

- Select the N-W corner cell of the matrix (marked in yellow colour)



1	3	5	6	90
11	1	3	8	70
10	16	12	10	40
50	50	25	75	

Step II

- For this selected cell, the corresponding demand and supply values are 50
  & 90 respectively.
- Select the least value among the above two values i.e **50.**
- Allocate this **50** value to the N-W corner cell.

					Supply↓
	1 (50)	3	5	6	90
	11	1	3	8	70
	10	16	12	10	40
Demand →	50	50	25	75	

Step II

- Subtract the allocated value (50) from corresponding demand and supply values.
- Now the new corresponding demand & supply values are 0 & 40 as shown below.

Supply↓

1 50	3	5	6	90 (90-50) **40**
11	1	3	8	70
10	16	12	10	40
50 (50-50) **0**	50	25	75	

Demand →

- As the demand value of first column is brought to zero, delete/scratch that column (First
column). After deleting the column, the new matrix will be of 3 factories & 3 Stores.

					Supply↓
	1 50	3	5	6	90 (90-50) **40**
	11	1	3	8	70
	10	16	12	10	40
Demand →	50 (50-50) **0**	50	25	75	

1 50	~~3~~	~~5~~	~~6~~	~~90~~	40
~~11~~	1	3	8	70	
~~10~~	16	12	10	40	
~~50~~	50	25	75		
0					

- Now select the N-W corner cell from this new matrix (marked in yellow color).
- Select the least value from the corresponding demand & supply value of this N-W corner cell viz 40. (among 50 & 40).
- Allocate this least value (**40)** into the allocation sign as shown and subtract it from both ends
- As the supply value for the first row is brought to zero, delete/scratch that row.
- The new matrix will be having 2 factories & 3 stores.

1 50	3 40	~~5~~	~~6~~	~~90~~	~~40~~	0
~~11~~	1	3	8	70		
~~10~~	16	12	10	40		
~~50~~	~~50~~	25	75			
0	10					

- Now select the N-W corner cell from this new matrix (marked in yellow color).
- Select the least value from the corresponding demand & supply value of this N-W corner cell viz 10. (among 10 & 70).
- Allocate this least value (**10)** into the allocation sign as shown and subtract it from both ends
- As the demand value for the first column is brought to zero, delete/scratch that column.
- The new matrix will be having 2 factories & 2 stores.

1 50	**3** 40	**5**	**6**	**90**	**40**	**0**
11	1 10	3	8	70	60	
10	16	12	10	40		
50	50	25	75			
0	10					

- Now select the N-W corner cell from this new matrix (marked in yellow color).
- Select the least value from the corresponding demand & supply value of this N-W corner cell viz 25. (among 25& 60).
- Allocate this least value (**25)** into the allocation sign as shown and subtract it from both ends
- As the demand value for the first column is brought to zero, delete/scratch that column.
- The new matrix will be having 2 factories & 1 store.

1 $\boxed{50}$	3 $\boxed{40}$	5	6	90	40	0
11	1 $\boxed{10}$	3 $\boxed{25}$	8	70	60	35
10	16	12	10	40		
50	50	25	75			
0	10	0				

- Now select the N-W corner cell from this new matrix (marked in yellow color).
- Select the least value from the corresponding demand & supply value of this N-W corner cell viz 35. (among 75 & 35).
- Allocate this least value (**35)** into the allocation sign as shown and subtract it from both ends
- As the demand value for the first row is brought to zero, delete/scratch that row.
- The new matrix will be having 1 factory & 1 store. i.e. only one value.

1 50	**3** 40	**5**	**6**	**90**	**40**	**0**
11	1 10	3 25	8 35	70	60	35 0
10	16	12	10	40		
50	50	25	75			
0	10	0	40			

- The new matrix is as below. The matrix is having only one cell value.
- Now select this only remaining cell (marked in yellow color).
- Select the least value from the corresponding demand & supply value of this N-W corner cell viz 40. (among 40 & 40). Both supply and demand values are same.
- Allocate this least value (**40)** into the allocation sign as shown and subtract it from both ends
- Hence the demand value as well as the supply value for this only remaining cell is brought to zero. This verifies that our calculations were right. At the end no demand and supply value should remain.

1 50	3 40	5	6	90	40	0
11	1 10	3 25	8 35	70	60	35 0
10	16	12	10 40	40		
50	50	25	75			
0	10	0	40			

Step III

The solution matrix is as follows

1 (50)	3 (40)	5	6
11	1 (10)	3 (25)	8 (35)
10	16	12	10 (40)

Corresponding Transportation cost

Allocation Value

Hence we have,

Transportation cost = 1 x 50 + 3 X 40 + 1 X 10 + 3 X 25 + 8 X 35 + 10 X 40

= 935 units

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Problem -2

Find the initial basic feasible solution of following transportation problem by applying NWC method:

	P	Q	R	Supply
A	4	9	6	7
B	5	5	3	10
C	7	6	9	9
D	3	8	4	16
Demand	9	13	20	42

Solution :

Total no of Supply = Total no of demand i.e 42 =42
Therefore, the given transportation problem is balanced

	P	Q	R	Supply
A	4 7	9	6	7
B	5 2	5 8	3	10
C	7	6 5	9 4	9
D	3	8	4 16	16
Demand	9	13	20	42

Total transportation cost $=4*7+5*2+5*8+6*5+9*4+4*16$

$=28+10+40+30+36+64$

$=208$

Problem - 3

Obtain an initial basic feasible solution to the following transportation problem using North-west corner rule.

	$D_{1,}$	$D_{2,}$	$D_{3,}$	$D_{4,}$	**Available**
$O_{1,}$	5	3	6	2	19
$O_{2,}$	4	7	9	1	37
$O_{3,}$	3	4	7	5	34
Requirement	16	18	31	25	

Solution:

Total supply=Total demand=90

Therefore ,The problem is Balanced.

	$D_{1,}$	$D_{2,}$	$D_{3,}$	$D_{4,}$	Available
$O_{1,}$	**(16)** 5	**(3)** 3	6	2	19
$O_{2,}$	4	**(15)** 7	**(22)** 9	1	37
$O_{3,}$	3	4	**(9)** 7	**(25)** 5	34
Requirement	16	18	31	25	**90**

The minimum transportation cost according to the above route is given by

Z =(5*16)+(3*3)+(15*7)+(22*9)+(9*7)+(25*5)

=Rs.580

Problem-4

Obtain an initial basic feasible solution to the following transportation problem using North-west corner rule.

	D	E	F	G	Available
A	11	13	17	14	250
B	16	18	14	10	300
C	21	24	13	10	400
Requirement	200	225	275	250	

Solution

Total supply=Total demand=950

Therefore ,The problem is Balanced.

	D	E	F	G	Available
A	**(200)** 11	**(50)** 13	17	14	**250**
B	16	**(175)** 18	**(125)** 14	10	**300**
C	21	24	**(150)** 13	**(250)** 10	**400**
Requirement	**200**	**225**	**275**	**250**	**950**

The minimum transportation cost according to the above route is given by

Z=(200*11)+(50*13)+(175*18)+(125*14) +(150*13)+(250*10)

=12,200

Advantage of North West Corner Method

a. This methods is very effective as it provide step by step solution.

b. It is very simple to obtain optimum solution through this method.

Disadvantage of North West Corner Method

a. This method does not take into consider the important factor viz, cost which is sought to be minimized.

b. NW corner rule take more time in obtaining optimal solution.

Practice Problems

1.Determine basic feasible solution to the following transportation problem using North West Corner Rule.

Sink							
Origin		A	B	C	D	E	Supply
	P	2	11	10	3	7	4
	Q	1	4	7	2	1	8
	R	3	9	4	8	12	9
	Demand	3	3	4	5	6	

2.Determine basic feasible solution to the following transportation problem using North West Corner Rule.

Destinations					
Source		A	B	C	Supply
	1	1	2	6	7
	2	0	4	2	12
	3	3	1	5	11
	Demand	10	10	10	