OPERATIONS RESEARCH

Course	Code	Credits	L-T-P	Assessment		Exam Duration
				SEE	CIA	
Operations Research	15ME81	4	3-2-0	80	20	3 Hrs

Course objectives:

1. To enable the students to understand the scientific methods of providing various departments of an organization with a quantitative basis of decision making.
2. To enable the studentsto understand the importance of various tools and techniques in finding optimal solutions to problems involving limited resources in the form of Men, Materials and machinery.

MODULE -1

Introduction: Evolution of OR, Definitions of OR, Scope of OR, Applications of OR, Phases in OR study. Characteristics and limitations of OR, models used in OR,

Linear Programming Problem (LPP), Generalized LPP- Formulation of problems as L.P.P. SolutionstoLPP by graphical method(Two Variables).

08 Hours

MODULE -2

LPP: Simplex method, Canonical and Standard form of LP problem, slack, surplus and artificial variables, Solutions to LPP by Simplex method, Big-M Method and Two Phase Simplex Method, Degeneracy in LPP. Concept of Duality, writing Dual of given LPP. Solutions to L.P.P by Dual Simplex Method.

12 Hours

MODULE -3

Transportation Problem: Formulation of transportation problem, types, initial basic feasible solution using North-West Corner rule, Vogel's Approximation method. Optimality in Transportation problem by Modified Distribution(MODI) method. Unbalanced T.P. Maximization T.P. Degeneracy in transportation problems, application of transportation problem.

Assignment Problem-Formulation, Solutions to assignment problems by Hungarian method, Special cases in assignment problems, unbalanced, Maximization assignment problems.

Travelling Salesman Problem (TSP). Difference between assignment and T.S.P, Finding best route by Little's method. Numerical Problems.

12 Hours

MODULE -4

Network analysis: Introduction, Construction of networks, Fulkerson's rule for numbering the nodes, AON and AOA diagrams; Critical path method to find the expected completion time of a project, determination of floats in networks, PERT networks, determining the probability of completing a project, predicting the completion time of project; Cost analysis in networks. Crashingofnetworks- Problems.

Queuing Theory: Queuing systems and their characteristics, Pure-birth and Pure-death models (only equations), Kendall & Lee's notation of Queuing, empirical queuing models – Numerical on M/M/1 and M/M/C Queuing models.

10 Hours

MODULE -5

Game Theory: Definition, Pure Strategy problems, Saddle point, Max-Min and Min-Max criteria, Principle of Dominance, Solution of games with Saddle point. Mixed Strategy problems. Solution of 2X2 games by Arithmetic method, Solution of 2Xn m and mX2 games by graphical method. Formulationof games.

Sequencing: Basic assumptions, Johnson's algorithm, sequencing 'n' jobs on single machine using priority rules, sequencing using Johnson's rule-'n' jobs on 2 machines, 'n' jobs on 3 machines, 'n' jobs on 'm' machines. Sequencing of2 jobs on 'm' machines using graphical method.

08 Hours

Course outcomes:

On completion of this subject, students will be able to:

1. Understand the meaning, definitions, scope, need, phases and techniques of operations research.
2. Formulate as L.P.P and derive optimal solutions to linear programming problems by graphical method, Simplex method, Big-M method and Dual Simplex method.
3. Formulate as Transportation and Assignment problems and derive optimum solutions for transportation, Assignment and travelling salesman problems.
4. Solve problems on game theory for pure and mixed strategy under competitive environment.
5. Solve waiting line problems for M/M/1 and M/M/K queuing models.
6. Construct networkdiagrams and determine critical path, floats for deterministic and PERT networks including crashing of Networks.
7. Determine minimum processing times for sequencing of n jobs-2 machines, n jobs-3machines,n jobs-m machinesand 2 jobs-n machines using Johnson's algorithm.

TEXT BOOKS:

1. Operations Research, P K Gupta and D S Hira,S. Chand and Company LTD. Publications, New Delhi – 2007
2. Operations Research, An Introduction, Seventh Edition, Hamdy A. Taha, PHI Private Limited, 2006.

REFERENCE BOOKS:

1. Operations Research, Theory and Applications, Sixth Edition, J K Sharma, Trinity Press, Laxmi Publications Pvt.Ltd. 2016.
2. Operations Research, Paneerselvan, PHI
3. Operations Research, A M Natarajan, P Balasubramani, PearsonEducation, 2005
4. Introduction to Operations Research, Hillier and Lieberman,8th Ed., McGraw Hill

Scheme of Examination:
Two questions to be set from each module. Students have to answer five full questions, choosing at least one full question from each module.

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CO-PO & CO-PSO Mapping (15 Scheme)

Programme	Course Code	Course Name	Credits	L-T-P	Assessment		Exam Duration
					SEE	CIE	
B.E	15ME81	Operations Research	4	3-2-0	80	20	3Hrs

CO's

15C409.1	Realize the importance of operations research and apply the acquired knowledge to solve real world problems.
15C409.2	Optimally allocate scare resources such as men, machines, materials, money and time.
15C409.3	Analyze and Execute optimization techniques for game theory and sequencing problems and for decision making and optimally managing projects.
15C409.4	Appraise the significance of Queuing theory and solve the waiting line problems.

PSO's

PSO-1: Ability to acquire competencies in designing, analyzing and evaluating the mechanical components.
PSO-2: Ability to work professionally by applying manufacturing and management practices.

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
15C409.1	2	3	2	1	2	2	-	-	-	-	-	1	1	1
15C409.2	2	3	2	1	2	2	-	-	-	-	-	1	1	1
15C409.3	2	3	2	1	2	2	-	-	1	1	2	1	1	1
15C409.4	2	2	1	1	1	1	-	-	-	-	-	1	1	1
AVG	**2**	**2.75**	**1.75**	**1**	**1.75**	**1.75**	**-**	**-**	**1**	**1**	**2**	**1**	**1**	**1**

Course Owner

HOD

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Department of Mechanical Engineering
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CO-PO/PSO Mapping Table														
PO/PSO	Total	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	2.28	2	3	2	1	2	2						1	1	1
CO2	2.48	2	3	2	1	2	2						1	1	1
CO3	2.58	2	3	2	1	2	2			1	1	2	1	1	1
CO4	2.52	2	2	1	1	1	1						1	1	1
Sum		8	11	7	4	7	7			1	1	2	4	4	4
Number		4	4	4	4	4	4			1	1	1	4	4	4
Average		**2**	**2.75**	**1.75**	**1**	**1.75**	**1.75**			**1**	**1**	**2**	**1**	**1**	**1**
Weighted Sum		19.72	27.05	17.20	9.86	17.20	17.20			2.58	2.58	5.16	9.86	9.86	9.86
PO Attainment		**1.64**	**2.25**	**1.43**	**0.82**	**1.43**	**1.43**			**0.86**	**0.86**	**1.72**	**0.82**	**0.82**	**0.82**

Operations Research			
VIII		2019-20	
Dr. Ranganatha Swamy L			

Head of the Department
Department of Mechanical Engineering
BGSIT B G Nagar-571448

6 . Course Information

6 . 2

Semester : 8 **Section :** A **Course :** OPERATIONS RESEARCH

Period	Planned			Execution		
	Date	Topic	Source material to be referred	Date	Topic	Source material to be referred
			1			
1	2020-02-11	Evolution of OR	-	2020-02-11	Evolution of OR	Ref 1
2	2020-02-12	Evolution of OR	-	2020-02-12	Evolution of OR	Ref 1
3	2020-02-17	Definitions of OR	-	2020-02-17	Definitions of OR	Ref 1
4	2020-02-17	Definitions of OR	-	2020-02-17	Definitions of OR	Ref 1
5	2020-02-18	Scope of OR	-	2020-02-18	Scope of OR	Ref 1
6	2020-02-19	Applications of OR	-	2020-02-19	Applications of OR	Ref 1
7	2020-02-24	Phases in OR study	-	2020-02-24	Phases in OR study	Ref 1
8	2020-02-24	Characteristics and limitations of OR	-	2020-02-24	Characteristics and limitations of OR	Ref 1
9	2020-02-24	models used in\nOR	-	2020-02-24	models used inOR	Ref 1
10	2020-02-24	\nLinear Programming Problem (LPP)	-	2020-02-25	Linear Programming Problem (LPP)	Ref 1
11	2020-02-24	Generalized LPP- Formulation of problems as L.P.P	-	2020-02-26	Generalized LPP- Formulation of problems as L.P.P	Ref 1
12	2020-02-24	Solutions to LPP by graphical method(Two Variables)	-	2020-03-02	Solutions to LPP by graphical method(Two Variables)	Ref 1
			2			
49	2020-05-13	Simplex method, Canonical and Standard form of LP problem	-	2020-06-01	Simplex method, Canonical and Standard form of LP problem	Ref 1
50	2020-05-18	slack	-	2020-06-01	slack	Ref 1
51	2020-05-18	surplus and artificial variables	-	2020-06-02	surplus and artificial variables	Ref 1
52	2020-05-19	Solutions to LPP by Simplex method	-	2020-06-03	Solutions to LPP by Simplex method	Ref 1
53	2020-05-20	Big-M Method\nand Two Phase Simplex Method	-	2020-06-04	Big-M Methodand Two Phase Simplex Method	Ref 1
54	2020-05-26	Degeneracy in LPP	-	2020-06-04	Degeneracy in LPP, Concept of Duality	Ref 1
55	2020-05-27	Concept of Duality	-	2020-06-05	writing Dual of given LPP, Solutions to L.P.P by Dual Simplex Method	Ref 1
56	2020-05-27	writing Dual of given LPP	-	2020-06-05	Solutions to L.P.P by Dual Simplex Method	Ref 1

57	2020-05-27	Solutions to L.P.P by Dual Simplex Method	-	-	-	
			3			
23	2020-03-23	Formulation of transportation problem, types	-	2020-04-13	Formulation of transportation problem, types	Ref 1
24	2020-03-23	initial basic feasible solution using North-West Corner rule, Vogel\u2019s Approximation method	-	2020-04-15	initial basic feasible solution using North-West Corner rule, Vogel\u2019s Approximation method	Ref 1
25	2020-03-24	Optimality in Transportation problem by Modified Distribution(MODI) method	-	2020-04-20	Optimality in Transportation problem by Modified Distribution(MODI) method	Ref 1
26	2020-03-30	Unbalanced T.P	-	2020-04-21	Unbalanced T.P	Ref 1
27	2020-03-30	Maximization T.P	-	2020-04-22	Maximization T.P	Ref 1
28	2020-03-31	Degeneracy in transportation problems	-	2020-04-27	Degeneracy in transportation problems	Ref 1
29	2020-04-01	application of transportation problem	-	2020-04-27	application of transportation problem	Ref 1
30	2020-04-07	Formulation, Solutions to assignment problems by Hungarian method	-	2020-04-28	Formulation, Solutions to assignment problems by Hungarian method	Ref 1
31	2020-04-08	Special cases in assignment problems, unbalanced	-	2020-04-29	Special cases in assignment problems, unbalanced	Ref 1
32	2020-04-13	Maximization assignment problems	-	2020-05-07	Maximization assignment problems	Ref 1
33	2020-04-13	Travelling Salesman Problem (TSP)	-	2020-05-08	Travelling Salesman Problem (TSP)	Ref 1
34	2020-04-15	Difference between assignment and T.S.P	-	2020-05-09	Difference between assignment and T.S.P	Ref 1
35	2020-04-27	Finding best route by Little \u2019s method	-	2020-05-11	Finding best route by Little \u2019s method	Ref 1
36	2020-04-27	Numerical Problems	-	2020-05-11	Numerical Problems	Ref 1
			4			
37	2020-04-29	Introduction, Construction of networks	-	2020-05-12	Introduction, Construction of networks	Ref 1
38	2020-05-04	Fulkerson\u2019s rule for numbering the nodes, AON and AOA diagrams; Critical path method to find the expected completion time of a project	-	2020-05-13	Fulkerson\u2019s rule for numbering the nodes, AON and AOA diagrams; Critical path method to find the expected completion time of a project	Ref 1
39	2020-05-04	determination of floats in networks, PERT networks	-	2020-05-18	determination of floats in networks, PERT networks	Ref 1
40	2020-05-05	determining the probability of completing a project	-	2020-05-18	determining the probability of completing a project	Ref 1

41	2020-05-06	predicting the completion time of project; Cost analysis in networks	-	2020-05-19	predicting the completion time of project; Cost analysis in networks	Ref 1
42	2020-05-11	Crashingofnetworks-Problems	-	2020-05-20	Crashingofnetworks-Problems	Ref 1
43	2020-05-11	Queuing systems and their characteristics	-	2020-05-26	Queuing systems and their characteristics	Ref 1
44	2020-05-12	Queuing systems and their characteristics	-	2020-05-27	Queuing systems and their characteristics	Ref 1
45	2020-05-12	Pure-birth and Pure-death models (only equations)	-	2020-05-28	Pure-birth and Pure-death models (only equations)	Ref 1
46	2020-05-12	Kendall & Lee\u2019s notation of Queuing	-	2020-05-28	Kendall & Lee\u2019s notation of Queuing	Ref 1
47	2020-05-12	empirical queuing models	-	2020-05-29	empirical queuing models	Ref 1
48	2020-05-12	Numerical on M\/M\/1 and M\/M\/C Queuing models	-	2020-05-30	Numerical on M\/M\/1 and M\/M\/C Queuing models	Ref 1
			5			
13	2020-03-03	Definition, Pure Strategy problems	-	2020-03-02	Definition, Pure Strategy problems	Ref 1
14	2020-03-04	Saddle point, Max-Min and Min-Max criteria	-	2020-03-03	Saddle point, Max-Min and Min-Max criteria	Ref 1
15	2020-03-09	Principle of Dominance, Solution of games with Saddle point	-	2020-03-04	Principle of Dominance, Solution of games with Saddle point	Ref 1
16	2020-03-09	Mixed Strategy problems, Solution of 2X2 games by Arithmetic method	-	2020-03-09	Mixed Strategy problems, Solution of 2X2 games by Arithmetic method	Ref 1
17	2020-03-10	Solution of 2Xn m and mX2 games by graphical method, Formulationof games	-	2020-03-09	Solution of 2Xn m and mX2 games by graphical method, Formulationof games	Ref 1
18	2020-03-11	Basic assumptions, Johnson \u2019s algorithm	-	2020-03-10	Basic assumptions, Johnson \u2019s algorithm	Ref 1
19	2020-03-16	sequencing \u2018n\u2019 jobs on single machine using priority rules, sequencing using Johnson \u2019s rule-\u2018n\u2019 jobs on 2 machines	-	2020-03-11	sequencing \u2018n\u2019 jobs on single machine using priority rules, sequencing using Johnson \u2019s rule-\u2018n\u2019 jobs on 2 machines	Ref 1
20	2020-03-16	\u2018n\u2019 jobs on 3 machines	-	2020-04-07	\u2018n\u2019 jobs on 3 machines	Ref 1
21	2020-03-17	\u2018n\u2019 jobs on \u2018m\u2019 machines	-	2020-04-08	\u2018n\u2019 jobs on \u2018m\u2019 machines	Ref 1
22	2020-03-18	Sequencing of2 jobs on \u2018m\u2019 machines using graphical method	-	2020-04-13	Sequencing of2 jobs on \u2018m\u2019 machines using graphical method	Ref 1

CHAPTER 1

Module-1

INTRODUCTION

1.1 DEVELOPMENT / ORIGIN OF OPERATIONS RESEARCH

The name *Operations Research* was coined by Mc Closky and Trefthen in 1940 in UK during Second World war, because the team of scientists was carrying out the research on (military) operations.

During Second World War, the military management in England called on a team of scientists. The objective was to find out the most effective allocation (deployment) of limited military resources such as newly invented radars, British Air Force planes etc., to the various military operations and to the activities within each operation. This group of scientists formed the first OR team.

Soon after the war, the success of military teams attracted the attention of industrial managers who were seeking solutions to their problems. Industrial Operations Research was developed in UK and USA. In USA, the National Research Council formed a committee on operations research in 1951. The growth of OR has reached to many countries of the world, as a result, International Federation of Operations Research Societies was founded in 1959 which comprises of member societies from different parts of the world.

In India, the first OR unit was established in the Regional Research laboratory at Hyderabad in 1949. In the meantime, Defense Science Laboratory was set up to clear up the problems of stores, purchase and planning.

1.2 DEFINITION OF OPERATIONS RESEARCH

An operation refers to a set of course of actions required for the accomplishment of desired objective. Some of the definitions suggested are shown below:

1. Operations research is an art of giving bad answers to the problems to which otherwise, worse answers are given.
-Thomas L Saaty
2. Operations research is an application of scientific method by interdisciplinary teams for the problems involving the control of organized systems (man-machine) so as to provide solutions which best serves the purpose of an organization as a whole. *– Ackoff and Sasieni*
3. Operations research is a scientific method of providing executive departments with a quantitative basis for decisions regarding the operations under their control. *– Morse and Kimball*

In scientific method (Approach), actual problem/situation is expressed in the form of number of mathematical equations.

1.3 NATURE / CHARACTERISTICS OF OPERATIONS RESEARCH

The essential characteristics of operations research are

a) System orientation
b) Use of interdisciplinary teams
c) Application of scientific method
d) Uncovering of new problems
e) Improvement in the quality of decisions (solutions)
f) Use of computer
g) Quantitative solutions and
h) Human factors.

1.3.1 System orientation: Every organization has several divisions. Any activity performed (decision taken) in the one division affects the activities of every other division. Therefore, in OR study, before taking any decision, one must identify all possible interactions and determine their impact on the organization as a whole.

1.3.2 Use of interdisciplinary teams: OR study is performed by a team of scientists whose individual members are drawn from different scientific and engineering disciplines. The people from different disciplines can produce more unique solutions providing better results than one could be expected from the same number of persons from a single discipline. No single person can collect all useful scientific information from all disciplines.

1.3.3 Application of scientific method: In OR, scientific method is used to solve the problem under study. The OR team do not conduct any experimentation on the system, instead the actual situation / problem is expressed in the form of mathematical model (set of mathematical equations) and conduct research on it.

1.3.4 Uncovering of new problems: The solution of an OR problem may uncover number of new problems. All uncovered problems need not be solved at the same time. In order to get full benefits, each of them must be solved individually by continuity of research.

1.3.5 Improvement in the quality of decisions/solutions: OR gives bad answers to the problems, otherwise worse answers are given to those. By applying its scientific-approach, it can only improve the quality of the solution, but it may not be able to give perfect solution.

1.3.6 Use of computer: OR requires a computer to solve complex mathematical models and to manipulate a large amount of data or to perform a large number of computations that are involved.

1.3.7 Quantitative solutions: OR provides the management, a quantitative basis for decision-making. It will give answer like for example: The profit to the company is 'X', if decision 'A' is taken and is 'Y', if decision 'B' is taken and so on.

1.3.8 Human factors: While obtaining the quantitative solutions, we do not consider the human factors, which play a great role in the problem faced. OR study is incomplete without a study of human factors.

1.4 SCOPE / AREAS OF APPLICATIONS OF OPERATIONS RESEARCH

Whenever there is a problem for optimization, there is scope for the application of OR in the following fields.

1.4.1 In Industry: In industries, there is series of problems, starting from purchase of raw materials to the dispatch of finished goods. In order to take decisions, OR team consider various alternative methods of producing the goods and return (profit) in each case. OR study also point out the possible changes in the entire system like installation of new machine, increased automation etc. OR has been successfully applied in industries, in the field of production, blending, sale and purchase, transportation and planning etc.

1.4.2 In defense operations:

Generally, defense operations are carried out by number of agencies like Air force, Navy and Army. Under each agency, there will be sub-activities like operations, intelligence, administration, training etc. There is a need to co-ordinate various activities in order to achieve desired results. Operations Research conducted by team of experts from each field plays a major role in accomplishing the desired goals.

1.4.3 In finance / developing economies: The basic problem of various countries is to remove poverty and hunger. There is a great scope for OR experts (economists, statisticians, technicians, politicians and agriculturists) working together to solve this problem with an OR approach

i) To maximize the per capita income with minimum resources.
ii) To find out the profit plan for the country etc.

1.4.1 In agriculture: With population explosion and consequent shortage of food, every country is facing the problem of optimum allocation of land to various crops in accordance with climatic conditions and available facilities as well as the problem of optimal distribution of water from various resources for irrigation purposes. These problems can be solved by OR approach.

1.4.5 In marketing: With the help of OR techniques, a marketing manager can decide

i). Where to distribute the products for sale so that the total cost of transportation is minimum.

ii). Size of the stock to meet the future demand.

iii). How to select best advertising media with respect to time and cost etc.

1.4.6 In personnel management: The personnel manager can use OR techniques

i). To appoint the most suitable persons on minimum salary.

ii). To determine the best age of retirement for employees.

iii). To find out the number of persons to be appointed on full time basis when work load is seasonal.

1.4.7 In production management: A production manager can use OR techniques

i). To find out the number and size of the items to be produced.

ii). In scheduling and sequencing the production run by proper allocation of machines.

iii). To select, locate and design the sites for the production plants.

1.4.8 In LIC: The LIC officer can use OR techniques to decide the premium rates of various policies.

1.4.9 OR approach is also applicable to big and small organizations while taking any decisions to minimize the cost and maximize the profit (benefit).

1.4.10 OR techniques can also be used in big hospitals to reduce waiting time of out-door patients and also to solve administrative problems.

1.4.11 OR techniques are also used in the area of transportation to regulate train arrivals and their running times.

1.5 PHASES OF OR / METHODOLOGY OF OR / OR APPROACH / HOW OR WORKS

OR study generally involves the following eight major phases

a) Formulating / defining the problem
b) Collection of data
c) Construction of mathematical model to represent the problem under study
d) Deriving solution from the model
e) Testing/Verifying the model and use the model for prediction
f) Selection of suitable alternative
g) Conclusion of study and presentation of results to the organization
h) Implementation and evaluation of recommendations

1.5.1 Formulating / defining the problem: In order to find the solution, the problem must be clearly defined by OR team. Defining the problem includes specifying

*i) **Environment:*** The frame work within which the system has to achieve its goal. It includes men, machines, materials etc.

*ii) **Decision maker:*** The person who is in actual control of the operations (system) under study.

*iii) **The objectives:*** The set of goals to be achieved.

*iv) **Constraints / restrictions:*** The limitations on fulfilment of the objectives.

1.5.2 Collection of Data: It involves the collection of data of the various parameters which affect the organization problem and those data to be used in the next phase.

1.5.3 Construction of mathematical model: This involves the mathematical representation of the actual problem / situation in the form of equations. The equations include objective function, decision variables and constraints / restrictions.

1.5.4 Deriving solution from the model: The solution can be obtained from a model/set of equations either by conducting experiments on it i.e. by simulation or by mathematical analysis.

Mathematical analysis has two procedures

i) Analytical method: It involves the use of calculus, algebra etc.
ii) Numerical method: It involves the use of simple trial and error to complex iteration.

1.5.5 Testing (i.e., verifying) the model and use the model for prediction: This involves to check whether the mathematical model developed accurately represents the reality (problem) and also to check the validity of the model for some other situation.

1.5.6 Selection of suitable alternative: With the given model and set of alternatives, OR scientists have to choose the alternative that best meets the organization objectives.
1.5.7 Conclusion of study and presentation of results to the organization: This involves the submission / presentation of the model and recommendations to the organization by OR team. Sometimes, OR people have to give several alternatives and let the organization to choose the one that best meets its needs.
1.5.8 Implementation and evaluation of recommendations: If the organization has accepted the study, then the recommendations must be implemented and constantly monitored to ensure that the recommendations enable the organization to meet its objectives.

1.6 OBJECTIVES OF OPERATIONS RESEARCH

i) To minimize the cost (total cost) and maximize the profit.

ii) To provide a scientific basis to the managers of an organization for solving the problems involving interactions of the components of the system, by employing team of scientists drawn from different disciplines, for finding a solution which is in the best interest of the organization as a whole.

1.7 ADVANTAGES OF OPERATIONS RESEARCH

1. Optimum use of production factors: Linear programming techniques indicate how a manager can most effectively utilize his production factors by efficiently selecting and distributing these elements.
2. Improved quality of decision: OR always improves the quality of solution by employing scientific approach. OR gives the clear picture of effect of different elements involved in the problem and it also indicate effect on the profit due to changes made in the production method (pattern).
3. Preparation of future managers: OR techniques very much helpful in improving the knowledge and skill of young managers.
4. Modification of mathematical solution: OR presents a possible solution that exists for a given problem, but it is the responsibility of the manager to accept or modify the solution before its use.
5. Alternative solutions: OR techniques give all alternative solutions available for the given problem so that management may decide based on their strategies.

1.8 DISADVANTAGES / LIMITATIONS OF OPERATIONS RESEARCH

i) Mathematical models of OR do not take in to account emotional factors (such as human relations) which are quite real.
ii) Mathematical models are applicable only for specific categories of the problem.
iii) A non-linear relationship changed to linear for fitting the problem to linear programming pattern. This may disturb the reliability of the solution.
iv) Generally, there will be resistance from the employees to the new proposals of OR
v) Management, who has to implement the advised proposals of OR, may itself offer a lot of resistance due to conventional thinking.
vi) OR process is a time consuming, costlier one.

1.9 MODELS IN OPERATIONS RESEARCH

A Model in OR is the idealized representation of real-life situation in the form of mathematical equations. The objective of the model is to provide an aid for analyzing the behavior of the system for the purpose of improving its performance.

1.9.1 Classification of Models

The models are broadly classified into following types.

a) Iconic or Physical Models
b) Analogous or Schematic Models
c) Symbolic or Mathematical Models
d) Static Models
e) Dynamic Models
f) Deterministic Models
g) Probabilistic Models
h) Descriptive Models
i) Predictive Models
j) Prescriptive Models
k) Analytic Models

1. Iconic Model: This is a physical or pictorial representation of various visible features of the real system. The iconic models resemble the system they represent but differ in size.

Example: Globes used to represent the various continents, oceans and other geographical features of the earth.

2. Schematic Model: These models are used more often and use one set of properties to represent some other set of properties the system under study possess.

Example: A flow process chart that represents order of occurrence of various events to make a product.

3. Symbolic Model: This uses mathematical symbols like letters and numbers, etc.to represent the decision variables of the system under study.

Example: An equation representing kinetic energy.

4. Static Model: It represent a system at a specified time and does not take into account the changes over a time.

Example: An assignment problem.

5. Dynamic Model: It represents the situation where the time often plays an important role.

Example: A dynamic programming problem.

6. Deterministic Model: It is one in which variables are completely defined and outcomes are certain.

Example: Transportation problem

7. Probabilistic Model: it is one in which the input and/or output variables take the form of probability distribution.

Example: Game theory is a probabilistic model.

8. Descriptive Model: it is one which describes some features of the system on the basis of observation, survey or questionnaire etc.

Example: Pie diagram and layout plan describes the salient features of their respective system.

9. Predictive Model: It predict or explain the behavior of the system based on some data.

Example: Predicting the election results based on the survey.

i) **Prescriptive Model:** It prescribes a course of action for a problem.

Example: A linear or dynamic problem.

ii) **Analytic Model:** It is one in which exact solution is obtained by mathematical methods.

Example: General linear programming model.

1.9.2 Characteristics of a Good Model

i) The number of assumptions made to simplify it should be as less as possible.
ii) The model should be simple and approaching the reality.
iii) It should be easy and economical to construct.
iv) Number of variables used should be as less as possible.
v) It should be adaptable to parametric type of treatment

USN :

BGS Institute of Technology, Mandya
DEPARTMENT OF MECHANICAL ENGINEERING

I - OTHER ASSESSMENT (ASSIGNMENT)

Semester: 8-CBCS
Subject: OPERATIONS RESEARCH (15ME81)
Faculty: Dr Ranganatha Swamy. L

Date: 2 May 2020

Max Marks: 5

Answer any 5 question(s)

Q.No		Marks	CO	BT/CL
1	A college athletic conference has 6 basketball officials. It must assign to 3 conference games. Two officials must be assigned to each game. The conference office desires to assign the officials such that the total distance travelled by all the six officials will be minimized. The distance each official would have to travel to each game are given below: The conference office has decided not to assign the official 4 to game A because of the previous conflicts with one of the coaches. Determine the optimal assignment.	1	CO2	L3

Officials

Games	1	2	3	4	5	6
A	20	40	60	∞	70	80
B	45	90	70	60	15	25
C	10	70	30	40	50	35

Q.No		Marks	CO	BT/CL
2	A solicitor's firm would like to employ typists on hourly piece-rate basis for their work. There are five typists and their charges and capability (typing speed) are different. There are five jobs available with the firm and one job is to be assigned to one typist. A typist is paid for full hours even if he/she works for a fraction of an hour. Find an optimum assignment of typists to jobs to minimize the total cost to the firm, given the following data:	1	CO2	L3

Typist	Rate/hr, Rs.	No. of pages typed/hr.
A	5	12
B	6	14
C	3	8
D	4	10
E	4	11

Job	Number of pages
P	199
Q	175
R	145
S	298
T	178

Q.No		Marks	CO	BT/CL
3	An airline company has drawn up a new flight schedule involving five flights. To assist in allocating five pilots to the flights, it has asked them to state their preference scores by giving each flight a number out of 10. The higher the number, the greater is the preference. Certain of these flights are unsuitable to some pilots owing to domestic reasons. These have been marked with a 'X'. What should be the allocation in order to meet as many preferences as possible?	1	CO2	L3

of the bus service
prepared by the transport authorities in both directions is given in the table below: The cost of
providing this service by the transport company depends upon the time spend by the bus crew (driver
and conductor) away from their places in addition to service time. There are five crew. There is,
however, a constraint that every crew should be provided with more than four hours of rest before
the return trip again and should not wait for more than 24 hours for the return trip. The company has
residential facilities for the crew at Chennai as well as at Bangalore. Suggest how crew should be
assigned with which line of service or which service line should be connected with which other line,
so as to reduce the waiting time to the minimum.

Departure from Chennai	Route Number	Arrival at Bangalore	Arrival at Chennai	Route Number	Departure from Bangalore
06.00	a	12.00	11.30	1	05.30
07.30	b	13.30	15.00	2	09.00
11.30	c	17.30	21.00	3	15.00
19.00	d	01.00	00.30	4	18.00
00.30	e	06.30	06.00	5	00.00

5 A company has four territories open, and four salesmen available for an assignment. The territories
are not equally rich in their sales potential. It is estimated that a typical salesman operating in each
territory would bring in the following annual sales:
Territory: I II III IV
Annual sales (Rs): 1,26,000 1,05,000 84,000 63,000
The four salesmen also differ in their ability. It is estimated that, working under the same conditions,
their yearly sales would be proportionately as follows:
Salesmen: A B C D
Annual sales (Rs): 7 5 5 4
If the criterion is maximum expected total sales, the intuitive answer is to assign the best salesman
to the richest territory, the next best salesman to the second richest, and so on; verify this answer by
the assignment technique. 1 CO2 L3

6 A salesman has to visit five cities A, B, C, D & E. The distance (in hundred km) between the five cities are as follows:If the salesman starts from city A and has to come back to city A, which route should he select so that the total distance travelled id minimum? 1 CO2 L3

To

From	A	B	C	D	E
A	–	7	6	8	4
B	7	–	8	5	6
C	6	8	–	9	7
D	8	5	9	–	8
E	4	6	7	8	–

Bratt

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Department of Mechanical Engineering

OPERATIONS RESEARCH 15ME81

ASSIGNMENT-2

Q.NO	Question	CO	Levels
1	An airline's organization has one reservation clerk on duty in its local branch at any given time. The clerk handles information regarding passenger reservation and flight timings. Assume that the number of customers arriving during any given period is Poisson distributed with an arrival rate of eight per hour and that reservation clerk can serve a customer in six minutes on an average, with an exponentially distributed service time. i) What is the probability that system is busy? ii) What is the average time a customer spends in the system? iii) What is the average length of the queue? iv) What is the average number of customers in the system?	4	3
2	At a petrol pump, customer's arrival is a Poisson process, with an average time of 5 minutes between arrivals. The time intervals between services at the petrol pump follows exponential distribution and as such the mean time taken to service a unit is two minutes. Find the following: i) Expected average queue length. ii) Average customers in the queue system. iii) Expected waiting time in the queue and the system.	4	3
3	In a railway marshalling yard, goods train arrive at a rate of 30 trains per day. Assuming arrival and service as per Poisson and exponential distributions and mean service time of 36 minutes, calculate i) The mean queue size (including train being served) ii) The probability that the queue size exceeds 10.	4	3
4	At the balcony ticket counter of a cinema hall, customers arrive at the rate of 12 per hour according to Poisson distribution. The single clerk at the counter serves the customers at the rate of 30 per hour. i) What is the probability that there is no customer in the counter? ii) What is the probability that there are more than 2 customers in the counter? iii) Average number of customers in the system (counter) and in the queue. iv) Average time a customer spends in the system and in the queue.	4	3
5	In a machine shop, the inter arrival times at the tool rib are exponential, with an average time of 10 minutes. The length of the	4	3

	service time is assumed to be exponential with a mean of 6 minutes. Find i) The probability that a person arriving at the booth will have to wait. ii) Average length of the queue. iii) The probability that an arrival will have to wait for more than 12 minutes for service and to obtain his tools.		
6	In a hair dress by saloon with one barber, the customer arrival follows Poisson distribution at an average rate of one every 45 minutes. The service time is exponentially distributed with a mean of 30 minutes. Find: i) Average number of customers in a saloon. ii) Average waiting time of a customer before service. iii) Average idle time of barber.	4	3
7	Arrivals at a telephone booth are considered to be Poisson distribution at an average time of 8 minutes between one arrival and the next. The length of the phone call is distributed exponentially with a mean of 4 minutes. Determine i) Expected fraction of the day that the phone will be in use. ii) Expected number of units in the queue. iii) What is the probability that an arrival will have to wait more than 6 minutes in queue for service? iv) What is the probability that more than 5 units are in the system?	4	3
8	The rate of arrival of customers at a public telephone booth follows Poisson distribution, with an average time of 10 minutes between one customer and the next. The duration of a phone call is assumed to follow exponential distribution, with mean time of 3 minutes. i) What is the probability that a person arriving at the booth will have to wait? ii) What is the average length of the non-empty queues that form from time to time? iii) The telephone department will install a second booth when it is convinced that the customers would expect waiting for at least 3 minutes for their turn to make a call. By how much time should the flow of customers increase in order to justify a second booth? iv) Estimate the fraction of a day that the phone will be in use.	4	3

Pmat

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DEPARTMENT OF MECHANICAL ENGINEERING

I - INTERNAL ASSESSMENT

Semester: 8-CBCS
Subject: OPERATIONS RESEARCH (15ME81)
Faculty: Dr Ranganatha Swamy. L

Date: 4 May 2020
Time: 02:00 PM - 03:30 PM
Max Marks: 30

PART A

Answer any1 question(s)

Q.No			Marks	CO	BT/CL
1	a	Define an assignment problem. List out the areas of applications of assignment technique.	3	CO2	L1
	b	Five men are available to do five different jobs. From past records, timing in hours, each man takes to do the job is known and is given in the following table.	12	CO2	L3

	I	II	III	IV	V
A	2	9	2	7	1
B	6	8	7	6	1
C	4	6	5	3	1
D	4	2	7	3	1
E	5	3	9	5	1

Find the assignment of men to jobs that will minimize the time taken.

Q.No			Marks	CO	BT/CL
2	a	Define the following operating characteristics of a queuing system. i) Queue length ii) System length iii) Waiting time in the queue iv) Total time in the system v) Utilization factor	5	CO4	L1
	b	A box office ticket window managed by manned by a single server, customers arrive to purchase tickets according to Poisson's distribution with a mean rate of 30/hr. The time required to serve a customer has an exponential distribution with a mean of 90 sec. Determine: i) Mean queue length. ii) Mean waiting time in the queue. iii) Probability that there are 3 or more customers in the system. iv) Percentage of time the server is busy.	10	CO4	L3

PART B

Answer any1 question(s)

Q.No			Marks	CO	BT/CL
3	a	Write a note on Travelling salesman problem.	3	CO2	L2
	b	A travelling salesman has to visit five cities. He wishes to start from a particular city, visit each city once and then return to his starting point. The travelling cost (in '000 Rs) of each city from a particular city is given below:	12	CO2	L3

	A	B	C	D	E
A	2	9	2	7	1
B	6	8	7	6	1
C	4	6	5	3	1
D	4	2	7	3	1
E	5	3	9	5	1

What should be the sequence of visit of the salesman so that the cost is minimum?

Q.No			Marks	CO	BT/CL
4	a	Explain briefly the elements of queuing system.	5	CO4	L2
	b	A public telephone booth is in a post office. The arrivals are considered to be Poisson's with an average inter arrival time of 12 minutes. The length of the phone call is assumed to be exponentially distributed with an average of 4 minutes, calculate the following: i) What is the probability that fresh arrival will not have to wait for the phone? ii) What is the probability that an arrival will have to wait more than 10 minutes before the phone is free? iii) What is the average length of the queue that forms time to time? iv) What is the probability of finding more than 5 customers in the system?	10	CO4	L3

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CBCS Scheme (ACU)

DEPARTMENT: MECHANICAL ENGINEERING

Scheme & Solution – ONLINE TEST-I **Date**: 04.05.2020

Semester: VIII **Subject Title**: Operations Research **Subject Code**: 15ME81

Question Number	Solution	Marks Allocated

1

a) Definition

1. Assignment of workers to machines. — 1
2. Assignment of salesmen to different sales areas.
3. Assignment of classes to rooms. — 2
4. Assignment of vehicles to routes etc.

b) Check for the balance — 1

	I	II	III	IV	V
A	1	8	1	6	0
B	5	7	6	5	0
C	3	5	4	2	0
D	3	1	6	2	0
E	4	2	8	4	0

— 2

(Reduced time matrix)

	I	II	III	IV	V
A	0	7	0	4	0
B	4	6	5	3	0
C	2	4	3	0	0
D	2	0	5	0	0
E	3	1	7	2	0

— 2

(Opportunity time matrix)

K=1

	I	II	III	IV	V
A	0	7	0	5	1
B	3	5	4	3	0
C	1	3	2	0	0
D	2	0	5	1	1
E	2	0	6	2	0

— 2

	I	II	III	IV	V
A	$\cancel{0}$	9	$\boxed{0}$	6	3
B	1	5	2	2	$\boxed{0}$
C	$\cancel{0}$	4	1	$\boxed{0}$	$\cancel{0}$
D	$\boxed{0}$	$\cancel{0}$	3	$\cancel{0}$	1
E	$\cancel{0}$	$\boxed{0}$	4	1	$\cancel{0}$

— 3

1

Men		Jobs		Time
A	→	III	→	2
B	→	V	→	1
C	→	I / IV	→	4 / 3
D	→	IV / I	→	3 / 4
E	→	II	→	3
		Total		**13 hours**

— 2

2

a) i) Queue length (L_q): The average number of customers in the queue waiting to get service. — 1

ii) System length (L_s): The average number of customers in the system — 1

A $\longrightarrow$ B $\longrightarrow$ C $\longrightarrow$ D $\longrightarrow$ E $\longrightarrow$ A

2 + 3 + 4 + 5 + 1 = Rs. 15 * 1000

Feasible solution.

	A	B	C	D	E
A	∞	$\boxed{1}$	3	6	$\cancel{0}$
B	4	∞	0	6	$\boxed{0}$
C	4	3	∞	$\boxed{0}$	3
~~D~~	~~8~~	~~0~~	$\boxed{1}$	~~∞~~	~~1~~
E	$\boxed{0}$	2	0	7	∞

2

A $\longrightarrow$ B $\longrightarrow$ E $\longrightarrow$ A $\longrightarrow$ and C $\longrightarrow$ D $\longrightarrow$ C

Infeasible solution i.e. non-optimal solution.

	A	B	C	D	E
A	∞	$\boxed{1}$	3	6	0
B	4	∞	$\boxed{0}$	6	0
C	4	3	∞	$\boxed{0}$	3
~~D~~	~~8~~	~~0~~	~~1~~	~~∞~~	$\boxed{1}$
E	$\boxed{0}$	2	$\cancel{0}$	7	∞

2

A $\longrightarrow$ B $\longrightarrow$ C $\longrightarrow$ D $\longrightarrow$ E $\longrightarrow$ A

2 + 3 + 4 + 5 + 1 = Rs. 15 * 1000

The least cost is Rs. 15000.

4

a)

1. The input (or arrival pattern)
2. The service mechanism (or service pattern)
3. The queuing process
4. The queue discipline
5. Service channels and
6. Customers behaviour

5

b)

λ = 1/12 Arrivals/Min 1

μ = 1/4 Phone calls/Min 1

i) P_o = 0.67 2

ii) P (wt $\geq$10) = 0.06 2

iii) L_n = 1.5 Arrivals 2

iv) P (>5) = 0.0014 2

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DEPARTMENT OF MECHANICAL ENGINEERING

II - INTERNAL ASSESSMENT

Semester: 8-CBCS
Subject: OPERATIONS RESEARCH (15ME81)
Faculty: Dr Ranganatha Swamy. L

Date: 8 Jun 2020
Time: 09:30 AM - 10:30 AM
Max Marks: 30

PART A

Answer any1 question(s)

Q.No			Marks	CO	BT/CL
1	a	Define the following related to game theory: i) Payoff ii) Two-person game iii) Strategy iv) Optimal strategy and v) Value of the game.	5	CO3	L1
	b	Deduce the following game by dominance principle and find the value of the game.	10	CO3	L3

Player A strategies	Player B strategies			
	B_1	B_2	B_3	B_4
A_1	3	2	4	0
A_2	3	4	2	4
A_3	4	2	4	0
A_4	0	4	0	8

Q.No			Marks	CO	BT/CL
2	a	Define the following related to sequencing: i) Total elapsed time ii) Processing time iii) Processing order iv) Number of machines and v) Idle time on a machine.	5	CO3	L1
	b	Use graphical method to minimize the time required to process the following jobs on the machines. Calculate the total elapsed time to complete the jobs. For each machine, specify the job that should be done first.	10	CO3	L3

Machines

Job 1	Sequence:	A	B	C	D	E
	Time (hr):	6	8	4	12	4
Job 2	Sequence:	B	C	A	D	E
	Time (hr):	10	8	6	4	12

PART B

Answer any1 question(s)

Q.No			Marks	CO	BT/CL
3	a	List out the characteristics of Two-person zero sum game.	5	CO3	L1
	b	Obtain the optimal strategies for both persons and the value of the game for two-person zero-sum game whose payoff matrix is as follows:	10	CO3	L3

Player A	Player B	
	B_1	B_2
A_1	1	-3
A_2	3	5
A_3	-1	6
A_4	4	1
A_5	2	2
A_6	-5	0

	b	There are seven jobs, each of which has to go through the machines A and B in the order AB. Processing time in hours are given as follows:	10	CO3	L3

Job	1	2	3	4	5	6	7
Machine A	3	12	15	6	10	11	9
Machine B	8	10	10	6	12	1	3

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CBCS Scheme (ACU)

DEPARTMENT: MECHANICAL ENGINEERING

Scheme & Solution – ONLINE TEST-II **Date:** 08.06.2020

Semester: VIII **Subject Title:** Operations Research **Subject Code:** 15ME81

Question Number	Solution	Marks Allocated
1 a)	**i) Payoff:** A quantitative measures of satisfaction a player gets at the end of the play. **ii) Two-person game:** The game in which the number players are two only. **iii) Strategy:** The strategy for a player is the list of all possible actions (moves or courses of action) that he will take for every payoff (outcome) that might arise. **iv) Optimal strategy:** The particular strategy by which a player optimizes his gains or losses without knowing the competitor strategies is called optimal strategy. **v) Value of the game:** The expected outcome per play when players follow their optimal strategy is called the value of the game.	1x5 = 5
b)	(see tables below)	

Player A strategies	Player B strategies B_1	B_2	B_3	B_4
A_2	3	4	2	4
A_3	4	2	4	0
A_4	0	4	0	8

Marks: 2

Player A strategies	Player B strategies B_2	B_3	B_4
A_2	4	2	4
A_3	2	4	0
A_4	4	0	8

Marks: 2

Player A strategies	Player B Strategies B_3	B_4	Probabilities	Oddments of A
A_3	4	0	p_1	8
A_4	0	8	p_2	4
Probabilities	q_1	q_2		
Oddments of B	8	4		

Marks: 2

$$p_1 = \frac{8}{8+4} = \frac{8}{12} = 0.67;$$

$$p_2 = \frac{4}{8+4} = \frac{4}{12} = 0.33;$$

Marks: 1

$$q_1 = \frac{4}{8+4} = 0.33;$$ 1

$$q_2 = \frac{8}{8+4} = 0.67;$$

$$\text{Value of the game } V = \frac{(8\times4)-(0)}{(8+4)-(0)} = \frac{32}{12}$$ 2

$$V = 2.67$$

2 a)

i) Total elapsed time: This is the time interval between starting the first job on the first machine to the completion of last job on the last machine, including the idle time of the machines, if any.
ii) Processing time: It defined as the time required by a job on each machine. 1x5 = 5
iii) Processing order: It refers to the order in which machines are required for completing the job.
iv) Number of machines: It refers to the number of service facilities through which a job must pass before it is assumed to be completed.
v) Idle time on a machine: This is the time during which a machine does not have a job to process.i.e. The time interval from the end of first job to start of the second job on the machine.

b)

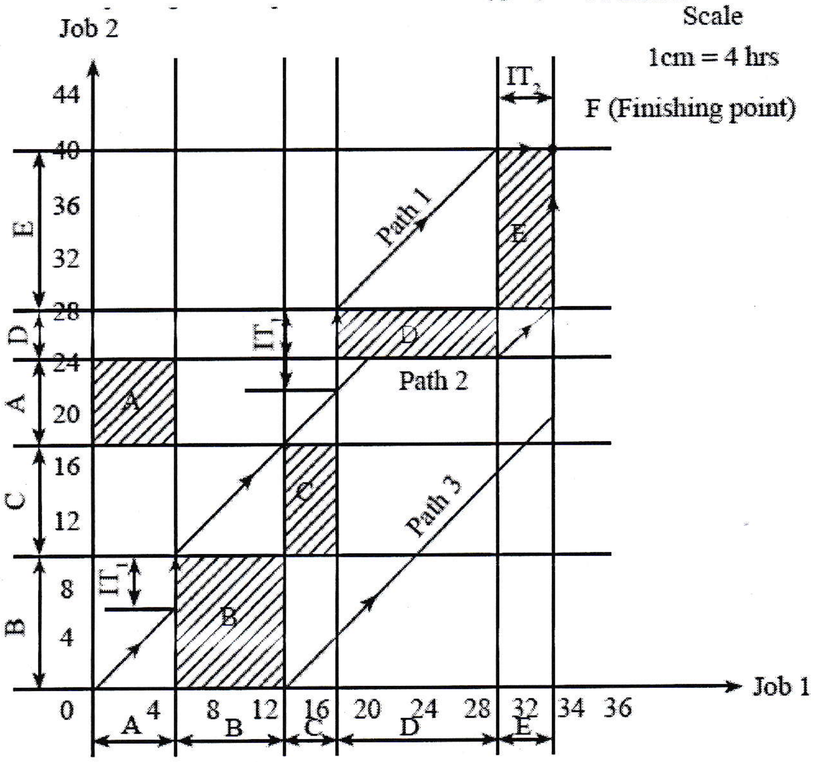
Path 1

Idle time for job 1 = 4+6 =10 hrs

Idle time for job 2 = 4 hours

Total minimum elapsed time for job 1 = Processing time + idle time
= 34+ 10 = 44 hours

Total minimum elapsed time for job 2 = Processing time + idle time
= 40+4 = 44 hours



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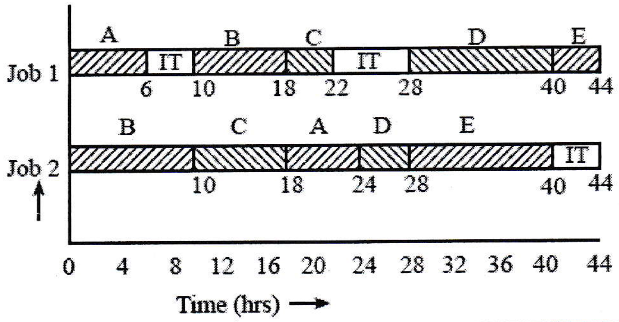


2

The optimal schedule or sequence on various machines for two jobs 1 and 2 is as follows:

Machine A $\rightarrow$ job 1 precedes job 2
Machine B $\rightarrow$ job 2 precedes job 1
Machine C $\rightarrow$ job 2 precedes job 1
Machine D $\rightarrow$ job 2 precedes job 1
Machine E $\rightarrow$ job 2 precedes job 1

2

3 a)

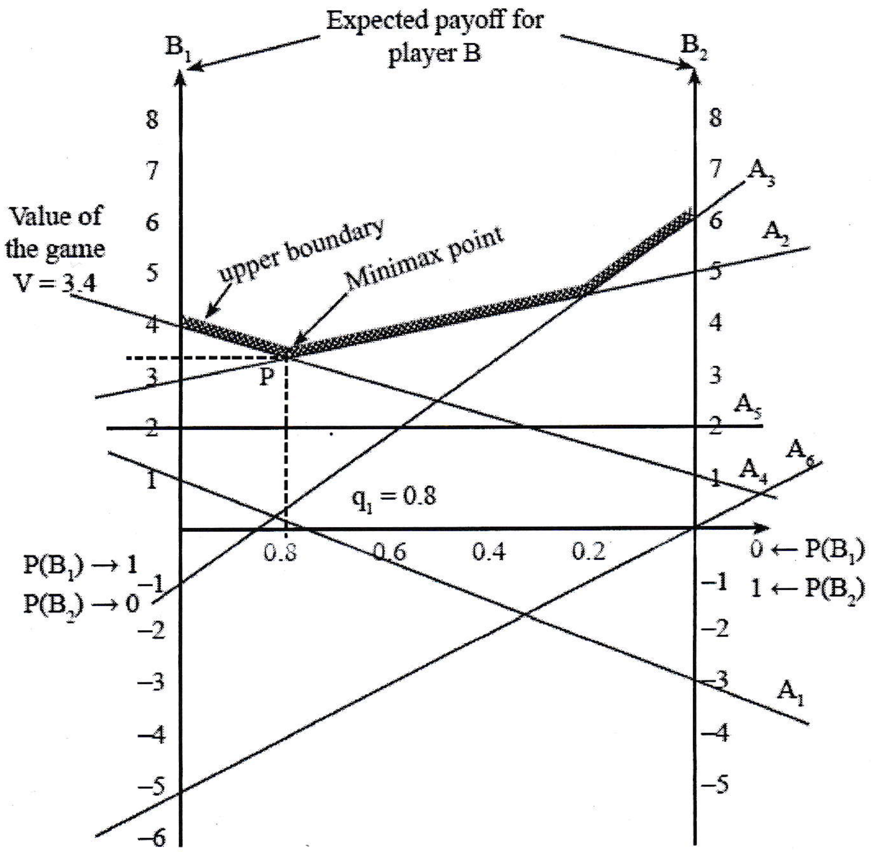
1. Only two players participate.
2. Each player has finite number of strategies (i.e. courses of action) to use.
3. Each specific strategy results in a payoff.
4. Total payoff to the two players at the end of each play is zero.
5. Players act rationally and intelligently.

1x5 = 5

b)

Player A's strategies	Player B's expected payoff
A_1	$q_1 - 3p_2$
A_2	$3q_1 + 5q_2$
A_3	$-q_1 + 6q_2$
A_4	$4q_1 + q_2$
A_5	$2q_1 + 2q_2$
A_6	$-5q_1$

2



4

From the graph, the lowest loss for player B is found at point 'P', where two lines A_2 and A_4 meets. Now, player A uses strategies A_2 and A_4 only, then the resultant (2x2) matrix is shown below.

Player A	Player B B_1	B_2	Probabilities	Oddments of A
A_2	3	5	p_1	3
A_4	4	1	p_2	2
Probabilities	q_1	q_2		
Oddments of B	4	1		

	To find p_1 and p_2 $$p_1 = \frac{3}{3+2} = \frac{3}{5} = 0.6;$$ $$p_2 = \frac{2}{3+2} = \frac{2}{5} = 0.4;$$ $$p_1 + p_2 = 0.6 + 0.4 = 1.$$ $$\text{Value of the game } V = \frac{(3\times1)-(5\times4)}{(3+1)-(5+4)} = \frac{-17}{-5}$$ $$V = 3.4$$ $$\text{From graph, } q_1 = 0.8, q_2 = 0.2 \text{ and } V = 3.4$$	**To find q_1 and q_2** $$q_1 = \frac{4}{4+1} = \frac{4}{5} = 0.8;$$ $$q_2 = \frac{1}{4+1} = \frac{1}{5} = 0.2;$$ $$q_1 + q_2 = 0.8 + 0.2 = 1.$$	2 2

4 a)

Assumptions

1. Only one job can be processed on a given machine at a time.
2. Once a job has begun on a machine, it must be completed before another job can begin on the same machine.
3. Only machine of each type is available.
4. The processing time on different machines are known and are independent of the order in which they are to be processed.

1x5 = 5

b)

The optimal sequences obtained are shown below

1	4	5	3	2	7	6

M/c A → ← M/c B

OR

1	5	3	2	4	7	6

M/c A → ← M/c B

3

Job	Machine A		Machine B		Idle time for machine B
	Time in	Time out	Time in	Time out	
1	0	3	3	11	3
4	3	9	11	17	0
5	9	19	19	31	2
3	19	34	34	44	3
2	34	46	46	56	2
7	46	55	56	59	0
6	55	66	66	67	7
Idle time for machine A		(67-66) = 1 hr			17 hrs

4

The total minimum processing time is 67 hrs.
Idle time for machine A is (67-66) = 1 hr.
Idle time for machine B is 17 hrs.

3

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Department of Mechanical Engineering

Test: III

Semester: VIII **Date:** 23.07.2020

Subject Name & Code: Operations Research (15ME81)

Duration: 60 Minutes **Max. Marks:** 30

Note: MCQ, each question carries 2 Marks

1. Operations research approach is

a) multidisciplinary
b) scientific
c) intuitive
d) all of the above

2. Decision variables are

a) controllable
b) uncontrollable
c) parameters
d) none of the above

3. A constraint in an LP model restricts

a) value of objective function
b) value of a decision variable
c) use of the available resources
d) all of the above

4.Alternative solutions exist of an LP model when

a) one of the constraints in redundant
b) objective function equation is parallel to one of the constraints
c) two constraints are parallel
d) all of the above

5. Which of the following is an assumption of an LP model?

a) divisibility
b) proportionality
c) additivity
d) all of the above

6.The graphical method of LP problem uses

a) objective function equation
b) constraint equations
c) linear equations
d) all of the above

7.For a maximization problem, the objective function coefficient for an artificial variable is
a) +M
b) -M
c) zero
d) none of the above

8.If an optimal solution is degenerate, then

a) there are alternative optimal solutions
b) the solution is infeasible
c) the solution is of no use to the decision maker
d) none of the above

9.The initial solution of a transportation problem can be obtained by applying any known method. However, the only condition is that

a) the solution be optimal
b) the rim conditions are satisfied
c) the solution not be degenerate
d) all of the above

10.The occurrence of degeneracy while solving a transportation problem means that

a) total supply equals total demand
b) the solution so obtained is not feasible
c) the few allocations become negative
d) none of the above

11.An alternate optimal solution to a minimization transportation problem exists whenever opportunity cost corresponding to unused route of transportation is

a) positive and greater than zero
b) positive with at least one equal to zero
c) negative with at least one equal to zero
d) none of the above

12. If an opportunity cost value is used for an unused cell to test optimality, it should be

a) equal to zero
b) most negative number
c) most positive number
d) any value

13.During an iteration while moving from one solution to the next, degeneracy may occur when

a) the closed path indicates a diagonal move
b) two or more occupied cells are on the closed path but neither of them represents a corner of the path
c) two or more occupied cells are on the closed path with minus sign are tied for lowest circled value
d) either of the above

14.The smallest quantity is chosen at the corners of the closed path with negative sign to be assigned at unused cell because

a) it improves the total cost
b) it does not disturb rim conditions
c) it ensures feasible solution
d) all of the above

15. The large negative opportunity cost value in an unused cell in a transportation table is chosen to improve the current solution because

a) it represents per unit cost reduction
b) it represents per unit cost improvement
c) it ensures no rim requirement violation
d) none of the above

Signature of the staff

Signature of HOD

Head of the Department
Department of Mechanical Engineering
BGSIT B G Nagar-571448

II Jai Sri Gurudev II

BGS Institute of Technology

Department of Mechanical Engineering

Test: III

Semester: VIII **Date:** 23.07.2020

Subject Name & Code: Operations Research (15ME81)

Scheme and Solutions

1. Operations research approach is

a) multidisciplinary 2 Marks
b) scientific
c) intuitive
d) all of the above

2. Decision variables are

a) controllable 2 Marks
b) uncontrollable
c) parameters
d) none of the above

3. A constraint in an LP model restricts

a) value of objective function
b) value of a decision variable
c) use of the available resources
d) all of the above 2 Marks

4.Alternative solutions exist of an LP model when

a) one of the constraints in redundant
b) objective function equation is parallel to one of the constraints 2 Marks
c) two constraints are parallel
d) all of the above

5. Which of the following is an assumption of an LP model?

a) divisibility
b) proportionality
c) additivity
d) all of the above 2 Marks

6.The graphical method of LP problem uses

a) objective function equation
b) constraint equations
c) linear equations
d) all of the above ✓ 2 Marks

7.For a maximization problem, the objective function coefficient for an artificial variable is
a) +M
b) -M ✓ 2 Marks
c) zero
d) none of the above

8.If an optimal solution is degenerate, then

a) there are alternative optimal solutions
b) the solution is infeasible
c) the solution is of no use to the decision maker
d) none of the above ✓ 2 Marks

9.The initial solution of a transportation problem can be obtained by applying any known method. However, the only condition is that

a) the solution be optimal
b) the rim conditions are satisfied ✓ 2 Marks
c) the solution not be degenerate
d) all of the above

10.The occurrence of degeneracy while solving a transportation problem means that

a) total supply equals total demand
b) the solution so obtained is not feasible ✓ 2 Marks
c) the few allocations become negative
d) none of the above

11.An alternate optimal solution to a minimization transportation problem exists whenever opportunity cost corresponding to unused route of transportation is

a) positive and greater than zero
b) positive with at least one equal to zero ✓ 2 Marks
c) negative with at least one equal to zero
d) none of the above

12. If an opportunity cost value is used for an unused cell to test optimality, it should be

a) equal to zero
b) most negative number ✓ 2 Marks
c) most positive number
d) any value

13. During an iteration while moving from one solution to the next, degeneracy may occur when

a) the closed path indicates a diagonal move
b) two or more occupied cells are on the closed path but neither of them represents a corner of the path ✓ 2 Marks
c) two or more occupied cells are on the closed path with minus sign are tied for lowest circled value
d) either of the above

14. The smallest quantity is chosen at the corners of the closed path with negative sign to be assigned at unused cell because

a) it improves the total cost
b) it does not disturb rim conditions
c) it ensures feasible solution ✓ 2 Marks
d) all of the above

15. The large negative opportunity cost value in an unused cell in a transportation table is chosen to improve the current solution because

a) it represents per unit cost reduction ✓ 2 Marks
b) it represents per unit cost improvement
c) it ensures no rim requirement violation
d) none of the above

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CBCS SCHEME

15ME81

USN

Eighth Semester B.E. Degree Examination, November 2020

Operations Research

Time: 3 hrs. Max. Marks: 80

Note: 1. Answer any FIVE full questions irrespective of modules.
2. Use of SQC table (area under normal curve only) is permitted.

Important Note: 1. On completing your answers, compulsorily draw diagonal cross lines on the remaining blank pages. 2. Any revealing of identification, appeal to evaluator and /or equations written eg, 42+8 = 50, will be treated as malpractice.

Module-1

1 a. What are the phases of solving an O.R. problem? (02 Marks)

b. ABC company owns a paint factory that produces both exterior and interior paints. The basic raw materials A and B are used to manufacture the paints. The maximum availability of A is 6 tonne/day and that of B is 8 tonne/day. The requirements of raw material per tonne of interior and exterior paints are given below:

Raw material	Exterior paint	Interior paint
A	1	2
B	2	1

The survey shows that maximum demand for interior paint is limited to 2 tonne/day. The price/tone is Rs. 3000 for exterior and Rs. 2000 for interior paint. How much interior and exterior paint the company should produce to maximize the gross income. Formulate and solve graphically. (07 Marks)

c. Solve the following LPP by graphical method:

$Z_{max} = 3x_1 + 4x_2$

Subject to constraints, $5x_1 + 4x_2 \le 200$

$3x_1 + 5x_2 \le 150$

$5x_1 + 4x_2 \ge 100$

$8x_1 + 4x_2 \ge 80$ $x_1, x_2 \ge 0$ (07 Marks)

2 a. Discuss applications of O.R. techniques. (02 Marks)

b. A company wishes to plan its advertising strategy for a new product. Two magazines are under consideration, one is a weekly and one is a monthly. The weekly has 2000 potential customers whereas the monthly has 3000 in one page of advertising. The cost of advertising per page in the weekly and monthly is Rs. 400 and Rs. 600 respectively. The company has a budget of Rs. 6000 per month for the advertisement. There is an important requirement that the total reach for the income group under Rs. 20,000 per annum should not exceed 4000 potential customers. The reach of the weekly and the monthly for this income group is 400 and 200 potential customers per page of advertisement. How many pages should be brought in two magazines to maximize reach? (07 Marks)

c. Solve the following LPP graphically:

Maximize, $Z = 300x_1 + 400x_2$

Subject to constraints,

$5x_1 + 4x_2 \ge 200$

$3x_1 + 5x_2 \ge 150$

$5x_1 + 4x_2 \ge 100$

$8x_1 + 4x_2 \ge 80$ and $x_1, x_2 \ge 0$ (07 Marks)

Module-2

3 Solve the following LPP by Big-M method :

Max $Z = x_1 + 2x_2 + 3x_3 - x_4$

Subject to constraints, $x_1 + 2x_2 + 3x_3 = 15$

$2x_1 + x_2 + 5x_3 = 20$

$x_1 + 2x_2 + x_3 + x_4 = 10$

$x_1, x_2, x_3, x_4 \geq 0$

(16 Marks)

4 Solve the given problem using Big-M method:

Maximize $Z = -2x_1 - x_2$

Subject to constraints, $3x_1 + x_2 = 3$

$4x_1 + 3x_2 \geq 6$

$x_1 + 2x_2 \leq 4$

$x_1, x_2 \geq 0$

(16 Marks)

Module-3

5 a. Products are to be transported from factories A, B and C to destinations D_1, D_2, D_3 and D_4. The factory capacities are 1000, 700 and 900. The destination requirements are 900, 800, 500 and 400. The unit transportation costs from various factories to destinations are given in the table. The units return from factories are Rs. 8, 7 and 9 respectively. Decide an optimum transportation schedule.

	D1	D2	D3	D4
A	2	2	2	4
B	3	5	3	2
C	4	3	2	1

(08 Marks)

b. A company has 5 tasks and 5 persons to perform. Determine the optimum assignment that minimizes the total cost.

Jobs	Machines				
	A	B	C	D	E
P	6	7	5	9	4
Q	7	5	10	9	6
R	5	4	3	6	5
S	8	3	5	6	4
T	4	7	5	6	6

(08 Marks)

6 a. A product is produced by four factories A, B, C and D. The unit production costs in them are Rs. 2, 3, 1 and 5 respectively. The production capacities are 50, 70, 30 and 50 respectively. These factories supply the product to four stores. The demand of which is 25, 35, 105 and 20 units respectively. Unit transportation cost in rupees from each factory to each store is given in the table below:

Factory	Stores 1	2	3	4
A	2	4	6	11
B	10	8	7	5
C	13	3	9	12
D	4	6	8	3

Determine the optimum transportation schedule so that the cost is minimum. (08 Marks)

b. A travelling salesman has to visit 5 cities. The distance between the cities is given in the matrix. Determine optimum route to reduce the distance travelled.

	1	2	3	4	5
1	∞	0	15	15	0
2	0	∞	9	14	1
3	0	1	∞	12	2
4	4	0	14	∞	5
5	2	0	17	19	∞

(08 Marks)

Module-4

7 a. Explain the following :
(i) Crashing of networks
(ii) Free float
(iii) Difference between PERT and CPM (04 Marks)

b. Find the ES, EF, LS, LF, TS and FS times for the following project using critical path algorithm.

Activity	1 – 2	1 – 3	1 – 4	2 – 5	3 – 5	4 – 6	5 – 6
Duration	8	4	6	10	6	8	4

(06 Marks)

c. In a hair dress saloon with one barber, the customer arrived follows Poisson distribution at an average rate of one in every 45 minutes. The service time is exponentially distributed with a mean of 30 minutes. Find :
(i) Average number of customer in the saloon
(ii) Average waiting time of customer before service
(iii) Average idle time of barber. (06 Marks)

8 a. What are the characteristics of waiting lines? (02 Marks)

b. The following table lists the jobs of network along with 3 time estimates:
(i) Draw the network
(ii) Calculate length and variance of critical path
(iii) What is the probability that jobs on the critical path are completed by the due date of 41 days?
(iv) What is the probability that jobs on the next most critical path will be completed by the above due date?
(v) What is the probability that the project is completed 2 days earlier than the expected date? (08 Marks)

Job	1 – 2	1 – 6	2 – 3	2 – 4	3 – 5	4 – 5	6 – 7	5 – 8	7 – 8
t_0	3	2	6	2	5	3	3	1	4
t_m	6	5	12	5	11	6	9	4	19
t_p	15	14	30	8	17	15	27	7	28

c. At what average rate must a clerk at super market work in order to ensure a probability of 0.9 that the customer will not have to wait longer than 12 minutes? It is assumed that there is only one counter to which customer arrive in a Poisson fashion at an average rate of 15/hr. The length of service by the clerk has an exponential distribution. (06 Marks)