DEPARTMENT OF OPERATIONAL RESEARCH

UNIVERSITY OF DELHI

UNDERGRADUATE PROGRAMME

(Courses effective from Academic Year ------)

(Choice-Based Credit System)
DRAFT 2
After meeting of CoC held on 06-05-2019

SYLLABUS OF COURSES TO BE OFFERED

General Elective (Operational Research) courses for students of B.A. (Hons.)/ B.Com. (Hons.)/B.Sc. (Hons.)

CONTENTS

I. Preamble

The real-world decision making necessitates the interface of multiple disciplines. The courses from the operational research discipline have been designed to impart both theoretical and practical aspects at par with other universities across the world. The discipline specific courses of the programme are designed to develop strong theoretical base in the subject and also acquaint students with the applied aspects. This will help students to pursue higher studies and apply the skills learnt in the programme to solve practical real-world problems in various industries.

II. Introduction to Choice Based Credit System

The Choice Based Credit System (CBCS) provides an opportunity for the students to choose courses from the prescribed courses comprising core, elective/minor or skill based courses. The courses can be evaluated following the grading system, which is considered to be better than the conventional marks system. Therefore, it is necessary to introduce uniform grading system in the entire higher education in India. This will benefit the students to move across institutions within India to begin with and across countries. The uniform grading system will also enable potential employers in assessing the performance of the candidates. In order to bring uniformity in evaluation system and computation of the Cumulative Grade Point Average (CGPA) based on student's performance in examinations, the UGC has formulated the guidelines to be followed.

Outline of Choice Based Credit System:

1. **Core Course:** A course, which should compulsorily be studied by a candidate as a core requirement is termed as a Core course.
2. **Elective Course:** Generally a course which can be chosen from a pool of courses and which may be very specific or specialized or advanced or supportive to the discipline/ subject of study or which provides an extended scope or which enables an exposure to some other discipline/subject/domain or nurtures the candidate's proficiency/skill is called an Elective Course.

   2.1 Discipline Specific Elective (DSE) Course: Elective courses may be offered by the main discipline/subject of study is referred to as Discipline Specific Elective. The University/Institute may also offer discipline related Elective courses of interdisciplinary nature (to be offered by main discipline/subject of study).

   2.2 Dissertation/Project: An elective course designed to acquire special/advanced knowledge, such as supplement study/support study to a project work, and a candidate studies such a course on his own with an advisory support by a teacher/faculty member is called dissertation/project.

   2.3 Generic Elective (GE) Course: An elective course chosen generally from an unrelated discipline/subject, with an intention to seek exposure is called a Generic Elective.

P.S.: A core course offered in a discipline/subject may be treated as an elective by other discipline/subject and vice versa and such electives may also be referred to as Generic Elective. A Dissertation/ Project work may be given in lieu of a Discipline Specific Elective Course.

3. **Ability Enhancement Courses (AEC)/Competency Improvement Courses/Skill Development Courses/Foundation Course:** The Ability Enhancement (AE) Courses may be of two kinds: AE Compulsory Course (AECC) and AE Elective Course (AEEC). "AECC" courses are the courses based upon the content that leads to Knowledge enhancement. They ((i) Environmental Science, (ii) English/MIL Communication) are mandatory for all disciplines. AEEC courses are value-based and/or skill-based and are aimed at providing hands-on-training, competencies, skills, etc.
3.1 AE Compulsory Course (AECC): Environmental Science, English Communication/ MIL Communication.
3.2 AE Elective Course (AEEC): These courses may be chosen from a pool of courses designed to provide value-based and/or skill-based instruction.

Details of courses under B.A (Honors), B.Com (Honors) & B.Sc. (Honors)

Course	**Credits (No. of Courses X Credit of each Course)**	
	Theory + Practical	**Theory + Tutorial**
I. CORE COURSE		
(14 Courses)	14X4 = 56	14X5 = 70
Core Course Practical/Tutorial*		
(14 Practical/Tutorial)	14X2 = 28	14X1 = 14
II. ELECTIVE COURSE#		
(04 Courses) A.1. Discipline Specific Elective	4X4 = 16	4X5 = 20
(04 Courses) A.2. Discipline Specific Elective Practical/Tutorial	4X2 = 8	4X1 = 4
(04 Courses) B.1. Generic Elective/Interdisciplinary	4X4 = 16	4X5 = 20
(04 Courses) B.2. Generic Elective/Interdisciplinary Practical/Tutorial	4X2 = 8	4X1 = 4
III. ABILITY ENHANCEMENT COURSES		
1. Ability Enhancement Compulsory Course **(02 Courses)** Two (02) courses to be chosen either from Environmental Sciences, English or MIL Communication	2X2 = 4	2X2 = 4
2. Skill Enhancement Course **(minimum 02 Courses)**	2X2 = 4	2X2 = 4
Total Credit	**140**	**140**

***For course with practical there is no tutorial and vice-versa**

#Option to opt for a Dissertation or Project Work in place of one Discipline Specific Elective Course (6 credits) in Sixth Semester

Courses Offered Under B.A (Honors), B.Com (Honors) & B.Sc. (Honors)

(Operational Research)

SEMESTER	COURSE CODE	NAME OF THE COURSE	CREDITS
GENERIC ELECTIVE COURSE			
I	ORGE 1	Introduction to Operational Research and Linear Programming (Theory and Practical)	L = 4, P = 2
II	ORGE 2	Inventory Management (Theory and Practical)	L = 4, P = 2
III	ORGE 3	Queueing and Reliability Theory (Theory and Practical)	L = 4, P = 2
IV	ORGE 4	Integer Programming and Theory of Games (Theory and Practical)	L = 4, P = 2

Acronyms: L - Lecture; P – Practical

Course-ORGE 1: INTRODUCTION TO OPERATIONAL RESEARCH AND LINEAR PROGRAMMING (THEORY AND PRACTICAL)

Marks: 100 **Course Duration: 60 Hrs. (4 Credits)**

Course Objectives:

This course can be divided into two parts. The first part is designed to give a brief introduction about the various stages of development of Operational Research and its utility in solving the real-life problems also highlighting the limitations of the subject while solving any given problem. The second part includes the mathematical formulation to a real-life problem through linear programming and then solving them through the various methods. Finally, in the lab section students will learn how the computer can be effectively used to solve different variations of the linear programming problems.

Course Learning Outcomes:

Students completing this course will be able to:

- Explain the meaning and scope of operational research
- Explain the idea of convex and its importance in the study of linear programming
- Apply the knowledge of linear programming concepts to formulate real-life problems
- Demonstrate the working of various methods to solve different type of linear programming problems
- Use computer software such as Excel Solver, Lingo, Octave to solve linear programming problems

Contents:

Unit I: Origin & development of OR, Different phases of OR study, Methodology of OR, Scope and limitations of OR, OR in decision making, Applications of OR.

Unit II: Basics of linear algebra: Vectors, Linear combination of vectors, Linearly independent/dependent vectors, Basis of a vector space, Convex set and its properties, Extreme points.

Unit III: General linear programming problem (LPP), Standard and canonical form of LPP, Formulation of LPP, Graphical solution.

Unit IV: Simplex method, Artificial variable techniques-Two phase method, Charnes-M Method, Special cases in LPP, Finding inverse of a matrix using simplex method, Solving system of linear equations using simplex method.

Unit V: Duality: Definition of the dual problem, Primal-dual relationships, Economic interpretation of duality, Dual simplex Method.

Unit VI: Sensitivity analysis: Shadow price, Graphical and simplex method-based approach for changes in cost and resource vector.

Suggested Readings:

Hadley, G. (2002). *Linear programming*. New Delhi: Narosa Publishing House.

Hillier, F.S., Lieberman, G. J., Nag, B., & Basu, P. (2017). *Introduction to operations research- concepts and cases* (10th ed.). New Delhi: Tata McGraw Hill (Indian print).

Ravindran, A., Phillips, D. T., & Solberg, J. J. (2007). *Operations research- principles and practice* (2nd ed.). New Delhi: Wiley India (Indian print).

Taha, H. A. (2017). *Operations research-an introduction* (10th ed.). New Delhi: Pearson Prentice Hall (Indian print).

Teaching Plan:

Week 1-2: Origin & development of OR, Different phases of OR study, Methodology of OR, Scope and limitations of OR, OR in decision making, Applications of OR.

Week 3-4: Basics of linear algebra: Vectors, Linear combination of vectors, Linearly independent/dependent vectors, Basis of a vector space, Convex set and its properties, Extreme points.

Week 5-6: General linear programming problem (LPP), Standard and canonical form of LPP, Formulation of LPP, Graphical solution.

Week 7-10: Simplex method, Artificial variable techniques-Two Phase Method, Charnes-M method, Special cases in LPP, Finding inverse of a matrix using Simplex method, Solving system of linear equations using simplex method.

Week 11-12: Duality: Definition of the dual problem, Primal-dual relationships, Economic interpretation of duality, Dual simplex method.

Week 13-15: Sensitivity analysis: Shadow price, Graphical and simplex method-based approach for changes in cost and resource vector.

Practical:

Marks: 50 **Course Duration: 60 Hrs. (2 Credits)**

Practical/Lab to be performed on a computer using easily available packages such as Excel Solver, Lingo, Octave.

1. Linear Programming Problem using Graphical Method.
2. Use of Graphical Method to demonstrate the case of
   (i) Multiple constraints
   (ii) Unbounded solution
   (iii) Infeasible solution
   (iv) Alternative or multiple solution
3. Solution of LPP with simplex method.
4. Solution of LPP with unrestricted variables through Simplex method.
5. Use of simplex to the inverse of a matrix.
6. Solving a system of linear equations using simplex.
7. Illustration of following special cases in LPP using Simplex method
   (i) Unrestricted variables
   (ii) Unbounded solution
   (iii) Infeasible solution
   (iv) Alternative or multiple solution
8. Problems based on Dual simplex method.
9. Problems based on sensitivity analysis.

Facilitating the achievement of Course Learning Outcomes

Unit No.	Course Learning Outcomes	Teaching and Learning Activity	Assessment Tasks
1.	(i) Explain the meaning and scope of operational research (ii) Demonstrate various phases of operational research (ii) Explain limitations of the operational research	(i) Give enough real-life examples so as to make teaching learning more interesting (ii) Encouraging the students to come up new ideas and appreciating them (iii) Give home assignments (iv) Group discussions (v) Practical classes using computer software.	• MCQ • Regular home assignments • Regular presentations by students • Solving small cases • Class test • Semester examination
2.	(i) Explain the concepts of vectors, linear combination of vectors, linearly independent / dependent vectors, basis of a vector space (ii) Define convex set and its properties, extreme points		
3.	(i) Demonstrate general LPP, Standard and canonical form of LPP (ii) Apply the knowledge of linear programming concepts to formulate real-life problems (iii) Demonstrate the utility and applicability of graphical method to solve LPPs		
4.	(i) Demonstrate the utility and applicability of variants of simplex method to solve LPPs (iii) finding Inverse of a matrix using Simplex method (iii) Demonstrate the use of simplex method to solve system of linear equations		
5.	(i) Define the concepts of duality (ii) Explain primal-dual relationships (iii) Demonstrate economic interpretation of duality (iv) Describe dual simplex method and demonstrate its application		
6.	(i) Describe the concepts of shadow price (ii) Explain the concept of sensitivity analysis and apply it to study changes in cost and resource vector		

COURSE -ORGE 2: INVENTORY MANAGEMENT (THEORY AND PRACTICAL)
Marks: 100 **Course Duration: 60 Hrs. (4 Credits)**

Course Objectives:
To familiarize students with the concept of inventory management, and its functional role in different organizations. To introduce the mathematical framework to develop and solve different types inventory models.

Course Learning Outcomes:
After completion of the course, students will possess knowledge and skills required to
- Gain an understanding of key concepts of inventory management and its role in various organizations
- Apply selective inventory control techniques and understand its significance
- Determine optimal order quantity for various deterministic and probabilistic Inventory models
- Understand multi-item EOQ model with constraints, and inventory models with all-unit quantity discount
- To apply and extend inventory models to analyse real world systems

Contents:
Unit I: Introduction to Inventory Management, Different types of costs in inventory system, Selective inventory classification (VED, XML, FNSD, ABC) and its use in controlling inventory.
Unit II: Deterministic continuous review models: Economic order quantity (EOQ) model with and without shortages, Finite replenishment rate Inventory models without and with planned shortages. Determination of reorder point for all the models.
Unit III: Multi-item EOQ model with constraints, Inventory models with all-unit quantity discount.
Unit IV: Probabilistic inventory models: Single period probabilistic inventory models with discrete and continuous demand.

Suggested Readings:
Buffa, E. S., Sarin R. K. (2009). *Modern production/operations management* (8th ed.). New Delhi: Wiley India (Indian print).

Hillier, F.S., Lieberman, G. J., Nag, B., & Basu, P. (2017). *Introduction to operations research- concepts and cases* (10th ed.). New Delhi: Tata McGraw Hill (Indian print).

Naddor, E. (1966). *Inventory systems*. New York: Wiley.

Silver, E. A., Pyke, D. F., & Peterson, R. (1998). *Inventory management and production planning and scheduling* (3rd ed). New Jersey: John Wiley & Sons, Inc.

Taha, H. A. (2017). *Operations research-an introduction* (10th ed.). New Delhi: Pearson Prentice Hall (Indian print).

Waters, D. (2003). Inventory control and management (2nd ed.). West Sussex: John Wiley & Sons Ltd.

Teaching Plan:

Week 1-3: Introduction to Inventory Management, Concepts and problems in Inventory Systems, various forms and functional role of Inventory, different types of costs in inventory system.

Week 4-5: Selective inventory classification (VED, XML, FNSD, ABC) and its use in controlling inventory.

Week 6-8: Formulation and solution of Economic order quantity (EOQ) models with and without lead time, and with and without shortages. Determination of reorder level (ROL) for all the models.

Week 9-10: Finite replenishment rate Inventory models without and with planned shortages. Determination of reorder point for all the models.

Week 11-13: Multi-item EOQ model with constraints, Inventory models with all-unit quantity discount.

Week 14-15: Single period probabilistic inventory models with discrete and continuous demand.

Practical:

Marks: 50 **Course Duration: 60 Hrs. (2 Credits)**

Practical/Lab to be performed on a computer using OR/Statistical packages.

1. Problems based on selective inventory classification. (ABC and FNS analysis).
2. To find optimal inventory policy for EOQ model.
3. To find optimal inventory policy for EOQ model with finite supply.
4. To find optimal inventory policy for EOQ model with backorders.
5. To solve multi-item inventory model with different constraints.
6. To solve All-units quantity discounts model.
7. To find optimal inventory policy for probabilistic inventory model with discrete demand.
8. To find optimal inventory policy for probabilistic inventory model with continuous demand.

Facilitating the achievement of Course Learning Outcomes

Unit No.	Course Learning Outcomes	Teaching and Learning Activity	Assessment Tasks
1.	(i) Explain the meaning of Inventory management, various forms and functional role of Inventory (ii) Understand different types of costs in inventory systems (iii) Apply various Selective inventory control techniques to classify inventory items into broad categories	(i) While introducing each topic some examples will be laid out and discussed with the students encouraging them to discover the relevant concepts (ii) Give extensive examples during lectures	• Class discussion and presentations • Weekly Assignments • Student presentation • Mid-Term examination • Group activities involving students to solve real-world problems using solver

<table>
<tr><td>2.</td><td>(i) Calculate the Economic Order Quantity (EOQ) for various deterministic inventory models without and with lead time
(ii) Compute the Reorder Level (ROL) and to determine time of replenishment with known and unknown patterns of demand for inventory items</td><td rowspan="3">(iii) Give periodic assignments
(iv) Encourage students to participate in class discussion
(v) Encourage students to give short presentation
(vi) Encourage students to apply concepts to solve real-world problems</td><td rowspan="3">• Hold both announced and unannounced quizzes
• End-term examination</td></tr>
<tr><td>3.</td><td>(i) Determine optimal inventory policies for multi-item inventory models with constraints
(ii) Understand all-unit quantity discount inventory model and determine the EOQ for the same</td></tr>
<tr><td>4.</td><td>(i) Understand probabilistic inventory models
(ii) Develop Single period probabilistic inventory models with discrete and continuous demand</td></tr>
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Course-ORGE 3: QUEUEING AND RELIABILITY THEORY (THEORY AND PRACTICAL)

Marks: 100 **Course Duration: 60 Hrs. (4 Credits)**

Course Objectives:
This course will first enable the students to understand the basic idea of random variables and their associated probability distributions as it is a prerequisite. Further, the course will also make the students to have an idea of stochastic processes and its applications in the field of queueing theory. The students will be exposed to the mathematical theory of queueing systems. The course will end with a brief introduction on system reliability and its various configurations. Finally, to have hands-on experience of the queueing and reliability models, the course will also include a practical session using softwares.

Course Learning Outcomes:
Students on completing this course will be able to understand:
- The basic concept of a random variable and its associated probability distribution
- The definition of stochastic process and its classifications
- Mathematical theory of queues and its applications
- Reliability of a system and its various configurations
- How software can be used to obtain the performance measures of queueing and reliability models

Contents:
Unit I: Random variable, discrete and continuous random variables, Expectations, Moment generating functions. Joint distributions–marginal and conditional distributions, standard probability distributions: Binomial, Poisson, Geometric, Exponential, Normal, Gamma and Weibull distributions (only definitions and properties without proof).

Unit II: Basic concept of stochastic process and its classification: Markov chain and Markov process. Basics of a queueing system, Kendall’s notation, performance measures, arrival and departure process, Little's formula, Birth-death process. Markovian queueing models: Single server with finite and infinite capacity, multi-server Markovian queues.

Unit III: Basics of reliability, classes of lifetime distributions, Reliability function, Mean time before failure (MTBF) and Hazard rate of Exponential and Weibull distributions.

Unit IV: Reliability of various system configurations- series, parallel, mixed configuration, k out of n system and stand-by system.

Suggested Readings:
Gross, D., Shortle, J. F., Thompson, J. M., & Harris, C. M. (2008). *Fundamentals of queuing theory* (4th ed.). New Jersey: John Wiley & Sons, Inc.
Hillier, F.S., Lieberman, G. J., Nag, B., & Basu, P. (2017). *Introduction to operations research- concepts and cases* (10th ed.). New Delhi: Tata McGraw Hill (Indian print).
Medhi, J. (2009). *Stochastic processes* (3rd ed.). New Delhi: New Age Science Ltd.
Srinath, L. S. (2005). *Reliability engineering*. New Delhi: East West Press.
Trivedi, K. S. (2016). *Probability and statistics with reliability, queuing and computer science applications* (2nd ed.). New Jersey: John Wiley & Sons, Inc.

Rausand, M., & Hoyland, A. (2003). *System reliability theory: models, statistical methods and applications* (2nd ed.). New Jersey: John Wiley & Sons, Inc.

Teaching Plan:

Week 1-2: Random variable, discrete and continuous random variables, Expectations, Moment generating functions, Joint distributions–marginal and conditional distributions.

Week 3-4: Standard probability distributions: Binomial, Poisson, Geometric, Exponential, Normal, Gamma and Weibull distributions (only definitions and properties without proof).

Week 5-7: Basic concept of stochastic process and its classification: Markov chain and Markov process. Basics of a queuing system, Kendall's notation, performance measures, arrival and departure process, Little's formula, Birth-death process.

Week 8-11: Markovian queueing models: Single server with finite and infinite capacity, multi-server Markovian queues.

Week 12-13: Basics of reliability, classes of lifetime distributions, Reliability function, Mean time before failure (MTBF) and Hazard rate of Exponential and Weibull distributions.

Week 14-15: Reliability of configurations- series, parallel, mixed configuration, k out of n system and standby system.

Practical:

Marks: 50 **Course Duration: 60 Hrs. (2 Credits)**

Practical/Lab to be performed on a computer using OR/Statistical packages

1. Working with-Binomial, Poisson, Geometric, Exponential, Normal, Gamma and Weibull distributions.
2. To determine the performance measures for M/M/1 queuing model.
3. To determine the performance measures for M/M/1/N queuing model.
4. To determine the performance measures for M/M/c/∞ queuing model.
5. To determine the performance measures for M/M/c/N queuing model
6. Problems based on Simulation: Random number generation.
7. Problems based on Monte Carlo method.
8. Calculation of hazard rate, MTBF for series and parallel systems.
9. Calculation of hazard rate, MTBF for Mixed configurations.

Facilitating the achievement of course learning outcomes

Unit No.	Course Learning Outcomes	Teaching and Learning Activity	Assessment Tasks
1.	(i) Define random variable, discrete and continuous random variables, Expectations, Moment generating functions, joint distributions – marginal and conditional distributions	(i) Pictorial demonstration of the various distributions using computer (ii) Giving enough real-life examples so as to make teaching learning	• Regular home assignments • Class presentations • Multiple choice questions • Real life case studies

	(ii) Probability distributions: Binomial, Poisson, Geometric, Exponential, Normal, Gamma and Weibull distributions	more interesting (iii) Encouraging the students to come up new ideas and appreciating them (iv) Giving home assignments (v) Having group discussions	• Class tests • Mid-Term examination • End-term examination
2.	(i) Define what a stochastic process is and understand its classification giving various examples (ii) Understand the concept of a queueing system and its mathematical modelling (iii) Define quantitative measures of performance of a queueing system (iv) Understand and derive the mathematical models of Markovian queues (birth-death models) and compute various measures of performance through these models		
3.	(i) Understand the basic concept of reliability and define it as a mathematical function. Define various lifetime distributions (ii) Define and compute various reliability measures such as Mean time before failure (MTBF) and Hazard rate of Exponential and Weibull distributions		
4.	(i) Compute the reliability of standard system configurations - series, parallel, mixed configuration, k out of n system and standby system		

Course-ORGE 4: INTEGER PROGRAMMING AND THEORY OF GAMES (THEORY AND PRACTICAL)

Marks: 100 **Course Duration: 60 Hrs. (4 Credits)**

Course Objectives:

The course will provide a comprehensive treatment of integer programming including theory, algorithms and applications. The course is also intended to introduce students to the novel concepts of Game Theory with special emphasis on its applications in diverse field.

Course Learning Outcomes:

Students completing this course will be able to:

- Describe the basic concepts of integer programming problem and demonstrate the formulations of real-world problems as a integer linear programming model
- Describe the theoretical workings of the solution methods including Branch & Bound method, Gomory's cutting plane method and demonstrate the solution process by hand and solver
- Describe the basic concepts of game theory and demonstrate the formulations of real-world problems as a game theory model
- Describe the theoretical workings of the solution methods for rectangular games with saddle and without saddle point and demonstrate the solution process by hand and solver
- Apply and analyze key concept of nash equilibrium

Contents:

Unit 1: Integer Programming Problem (IPP): Some classical examples, Formulations of IPP, Pure and mixed IPP, Methods for solving IPP-Branch & Bound method, Gomory's cutting plane method, Applications of IPP to real-world situations.

Unit II: Theory of Games: Introduction to game theory, Formulation of two-person zero-sum rectangular game, Solution of rectangular games with saddle points, dominance principle, rectangular games without saddle point-Mixed strategy, Graphical, algebraic and linear programming solution of m x n games, Games with perfect information, Strategic games, Concepts and examples, Nash equilibrium and existence properties.

Suggested Readings:

Hillier, F.S., Lieberman, G. J., Nag, B., & Basu, P. (2017). *Introduction to operations research- concepts and cases* (10th ed.). New Delhi: Tata McGraw Hill (Indian print).

Osborne, M. J. (2009). *An introduction to game theory*. New York: Oxford University Press.

Ravindran, A., Phillips, D. T., & Solberg, J. J. (2007). *Operations research- principles and practice* (2nd ed.). New Delhi: Wiley India (Indian print).

Taha, H. A. (2017). *Operations research-an introduction* (10th ed.). New Delhi: Pearson Prentice Hall (Indian print).

Thie, P. R., & Keough, G. E. (2008). *An introduction to linear programming and game theory* (3rd ed.). New Jersey: John Wiley & Sons.

Teaching Plan:

Week 1-3: Some classical examples, Formulations of IPP, Pure and mixed IPP.

Week 4-8: Methods for solving IPP-Branch & Bound method, Gomory's cutting plane method, Applications of IPP to real-world situations.

Week 9-10: Introduction to game theory, Formulation of two-person zero-sum rectangular game, Solution of rectangular games with saddle points, dominance principle.

Week 11-13: Rectangular games without saddle point-Mixed strategy, Graphical, algebraic and linear programming solution of m x n games.

Week 14-15: Games with perfect information, Strategic games, Concepts and examples, Nash equilibrium and existence properties.

Practical:

Marks: 50 **Course Duration: 60 Hrs. (2 Credits)**

Practical/Lab to be performed on a computer using OR/Statistical packages

1. Solution of IPP using Branch and Bound method.
2. Solution of IPP using Gomory's cutting plane method.
3. Solution of capital budgeting problem.
4. Solution of fixed charge problem.
5. Solution of cargo loading problem.
6. Solution of production planning problem.
7. Solution of two-person zero-sum pure and mixed strategy game.
8. Graphical solution of m x 2 and 2 x n games.
9. Linear programming solution of game problem

Facilitating the achievement of Course Learning Outcomes

<table>
<tr><th>Unit No.</th><th>Course Learning Outcomes</th><th>Teaching and Learning Activity</th><th>Assessment Tasks</th></tr>
<tr><td>1.</td><td>(i) Describe the basic concepts of integer programming problem and demonstrate the formulations of real-world problems as a integer linear programming model
(ii) Describe the theoretical workings of the solution methods including Branch & Bound method, Gomory's cutting plane method and demonstrate the solution process by hand and solver</td><td rowspan="2">(i) While introducing each topic examples will be laid out and discussed to encourage them to discover the relevant concepts
(ii) Give extensive examples during lectures
(iii) Give homework assignments
(iv) Encourage students to participate in class discussion
(v) Encourage students to give short presentation
(vi) Encourage students to apply</td><td rowspan="2">• Hold class room discussion and presentations
• Homework assignments
• Final exam
• Group activities involving students to solve real-world problems using solver
• Hold both announced and unannounced quizzes</td></tr>
<tr><td>2.</td><td>(i) Describe the basic concepts of game theory and demonstrate the formulations of real-world problems as a game theory model
(ii) Describe the theoretical workings of the solution methods for rectangular</td></tr>
</table>

	games with saddle and without saddle point and demonstrate the solution process by hand and solver (iii) Apply and analyze key concept of Nash equilibrium	concepts to solve real-world problems using solver	