Syllabus and Scheme of Examination

for

B.Sc. (Programme) Mathematical Sciences
(Operational Research)

(Choice-Based Credit System)

DEPARTMENT OF OPERATIONAL RESEARCH
FACULTY OF MATHEMATICAL SCIENCES
UNIVERSITY OF DELHI
DELHI – 110007

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I. Preamble

The real-world decision making necessitates the interface of multiple disciplines. Keeping this in mind, the Faculty of Mathematical Sciences at University of Delhi introduced an Undergraduate Programme B.Sc. (Mathematical Sciences). This programme integrates Mathematics, Operational Research, Computer Science, and Statistics. The changing market scenario clearly reflects that there is a huge demand of experts, who can handle complex datasets, communicate effectively, and fully understand the techniques, pitfalls, and potential of advanced decision making methods.

B.Sc. (Programme) in Mathematical Sciences is an undergraduate degree that combines courses apart from mathematics discipline courses from two other disciplines out of the three disciplines, namely Operational Research, Computer Science and Statistics. This programme will prepare students for the array of numerate and analytical professions that are found at the core of both modern research and the digital economy. On completion of the programme students will have a deep understanding of the techniques and methods of modern mathematical sciences, and a clear insight into the industrial and scientific areas.

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.

III. Programme Details

Programme Objectives:

The aim of the programme is to provide skills and knowledge from an exceptionally broad range of topics of Operational Research, shaping programme to fit the present need of the industries.

Programme Specific Outcomes:

The programme is designed to:

- Develop modelling and problem solving skills.
- Develop transferable skills including an analytical approach to problem solving, logical argument and deductive reasoning to make the students well equipped to work on complex issues.
- Appreciate, construct and analyse mathematical models of real-world situations.
- Impart comprehensive knowledge and understanding of theoretical fundamentals in operational research.
- Develop mathematical problem-solving skills for certain types of real-world problems and their variants in a variety of mathematical contexts.
- Provide hands-on training to the students in the form of practical's and project work, to address some significant issues faced by industries.

Programme Duration:

The programme will be spanning over a period of three years and spread across six semesters. Each year will be called an academic year and will be divided into two semesters. Each semester will consist of sixteen weeks.

Design of Programme:

The teaching-learning process involves both theory and practical classes (wherever applicable). The curriculum is delivered through various methods including chalk and talk, power-point presentations, E-learning/E-content, labs, seminars (talks by experts), workshops, projects, and class discussions. The assessment broadly comprise of Internal Assessment (Continuous Evaluation) and End Semester Examination. Each theory paper will be of 100 marks with 25% marks for Internal Assessment and 75% for End Semester examination. The internal Assessment will be through MCQ, test, assignment, oral presentation, and worksheets and short project. Each practical paper will be of 50 marks.

Programme Structure:

The programme consists of six-credit courses and two credit courses. All six credit courses comprise of theory classes (four credits) and practical (two credits) or theory classes (five credits) and Tutorial (one credit). Two credit courses will comprise of theory classes only (two credits). For theory classes, one credit indicates a one hour lecture per week while for practical classes one credit indicates a two-hour session per week. Each practical batch will be of fifteen students. A number exceeding fifteen (by at least ten) will be divided into two equal batches.

The programme includes Core Courses (CC) and elective courses. The core courses are all compulsory courses. There are four kinds of elective courses: Discipline Specific Elective (DSE), Project/Dissertation, Generic Elective (GE) and Skill Enhancement Course (SEC). In addition, there are Two Ability Enhancement Compulsory Course (AECC).

To acquire a degree in Mathematical Sciences a student must have to study Twelve Core Courses, Six Discipline Specific Electives, Four Skill Enhancement Courses and Two Ability Enhancement Compulsory Courses. The Core Courses and Discipline-Specific Electives, and Generic Electives are of six-credits. The Skill Enhancement Courses and Ability Enhancement Compulsory Courses are of two-credits. A student has to earn a minimum of 120 credits to get a degree in B.Sc. (Programme) Mathematical Sciences.

Out of Twelve Core Courses, Four courses of Mathematics discipline are compulsory, one in each first four semesters. For the remaining Eight Core Courses, Four courses each from two of the following three disciplines: Operational Research, Statistics, and Computer Science, one each from the chosen discipline in first four semesters.

Out of Six Discipline Specific Electives, Two courses of Mathematics discipline are compulsory, one in each fifth and sixth semester. For the remaining Four Discipline Specific Electives, Two courses each from two of the following three disciplines: Operational

Research, Statistics, and Computer Science, one each from the chosen discipline in fifth and sixth semester.

Four Skill Enhancement Courses, one each in third, fourth, fifth and sixth semester are to be chosen from one of the following four disciplines: Mathematics, Operational Research, Statistics, and Computer Science.

For the Two Ability Enhancement Compulsory Courses, one each in first and second semester is to be chosen either from Environmental Sciences, English, or MIL Communication.

Details of Courses Offered Under B.Sc. (Programme) Mathematical Sciences (CBCS)

Course	**Credits (No. of Courses X Credit of each Course)**	
	Theory + Practical	**Theory + Tutorial**
I. CORE COURSE		
(12 Courses) Four (04) courses of Mathematics discipline are compulsory Four courses each from two of the following three disciplines: Operational Research, Statistics, and Computer Science	12X4 = 48	12X5 = 60
Core Course Practical/Tutorial*		
(12 Practical/Tutorial) Four (04) courses of Mathematics discipline are compulsory Four (04) courses each from two of the following three disciplines: Operational Research, Statistics, and Computer Science	12X2 = 24	12X1 = 12
II. DISCIPLINE ELECTIVE COURSE#		
(06 Courses) Two (02) courses of Mathematics discipline are compulsory Two (02) courses each from two of the following three disciplines: Operational Research, Statistics, and Computer Science	6X4 = 24	6X5 = 30
(06 Practical/Tutorial) Two (02) courses of Mathematics discipline are compulsory Two (02) courses each from two of the following three disciplines: Operational Research, Statistics, and Computer Science	6X2 = 12	6X1 = 6
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	4X2 = 8	4X2 = 8
2. Skill Enhancement Course **(04 Courses)** Four (04) course are to be chosen from one of the following four disciplines: Mathematics, Operational Research, Statistics, and Computer Science	4X4 = 16	4X4 = 16
Total Credit	**132**	**132**

***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.Sc. (Programme) Mathematical Sciences (CBCS)

(Operational Research)

SEMESTER	COURSE CODE	NAME OF THE COURSE	LECTURES/PRACTICALS /TUTORIALS
CORE COURSE			
I	DCC 1	Introduction to Operational Research and Linear Programming (Theory and Practical)	L = 4, P = 2
II	DCC 2	Inventory and Marketing Management (Theory and Practical)	L = 4, P = 2
III	DCC 3	Optimization Techniques (Theory and Practical)	L = 4, P = 2
IV	DCC 4	Network Models and Scheduling Techniques (Theory and Practical)	L = 4, P = 2
DISCIPLINE SPECIFIC ELECTIVE COURSE			
V	DSE 1.1 **OR** DSE 1.2	Queueing and Reliability Theory (Theory and Practical) **OR** Quality Management (Theory and Tutorial)	L = 4, P = 2 **OR** L = 5, T = 1
VI	DSE 2.1 **OR** DSE 2.2 **OR** DSE 2.3	Integer Programming and Theory of Games (Theory and Practical) **OR** Logistics and Supply Chain Management (Theory and Tutorial) **OR** Dissertation/Project Work	L = 4, P = 2 **OR** L = 5, T = 1 **OR** L = 6
SKILL ENHANCEMENT COURSE			
III	SEC-OR 1	Operational Research Applications	L = 4
IV	SEC-OR 2.1 **OR** SEC-OR 2.2	Project Management **OR** Essentials of Data Analysis	L = 4
V	SEC-OR 3	Portfolio Optimization	L = 4
VI	SEC-OR 4	Business Data Analysis	L = 4

Acronyms: L - Lecture; P – Practical; T - Tutorial

Programme Structure and Course Distribution (Operational Research)

SEMESTER	CORE COURSE (04)	DISCIPLINE SPECIFIC ELECTIVE COURSE (02)	SKILL ENHANCEMENT COURSE (04)	ABILITY ENHANCEMENT COMPULSORY COURSE (02)
I	DCC 1: Introduction to Operational Research and Linear Programming (Theory and Practical)			AECC 1: Environmental Sciences/English/ MIL Communication

II	DCC 2: Inventory and Marketing Management (Theory and Practical)			AECC 2: Environmental Sciences/English/ MIL Communication
III	DCC 3: Optimization Techniques (Theory and Practical)		SEC-OR 1: Operational Research Applications	
IV	DCC 4: Network Models and Scheduling Techniques (Theory and Practical)		SEC-OR 2.1: Project Management **OR** SEC-OR 2.1: Essentials of Data Analysis	
V		DSE 1.1: Queueing and Reliability Theory (Theory And Practical) **OR** DSE 1.2: Quality Management (Theory and Tutorial)	SEC-OR 3: Portfolio Optimization	
VI		DSE 2.1: Integer Programming and Theory of Games (Theory and Practical) **OR** DSE 2.2: Logistics and Supply Chain Management (Theory and Tutorial) **OR** DSE 2.3: Dissertation/Project Work	SEC-OR 4: Business Data Analysis	

IV. Learning Outcome–Based Approach to Curriculum Planning

The Learning Outcomes-based Curriculum Framework (LOCF) for the B.Sc. (Programme) degree in Mathematical Sciences is designed to meet the requirements of the present market in terms of the knowledge about the recent operational research tools. 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 core 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. Furthermore, a wide range of elective courses are offered to the student including skill enhancement courses to impart skills other than the main decision making tools.

Graduate Attributes

Some of the characteristic attributes of graduate in Mathematical Sciences with Operational Research include:

- **Knowledge Acquisition:** gathers in-depth knowledge of basic and applied areas of operational research.
- **Core laboratory skills:** provide hands-on training to the students in the form of practical's and project work, to address some significant issues faced by industries.
- **Interdisciplinary approach:** becomes aware of the role of operational research in conjunction with allied subjects to solve real-world problems.
- **Scientific logic:** develop transferable skills including an analytical approach to problem solving, logical argument and deductive reasoning to make the students well equipped to work on complex issues.
- **Independence in thought:** cultivates independent thinking and ability to solve real-world problems in the form of an independent project based upon the tools of operational research.
- **Team work:** understands the importance and strengths of interacting with and working alongside people from diverse backgrounds.
- **Global perspective:** courses from the operational research impact both theoretical and practical aspects at par with other universities across the world.
- **Communication skills:** develops effective communication skills through oral presentations and the compiling of information in the form of project report.
- **Ethics:** acquires an awareness of work ethics and ethical issues in scientific research as well as plagiarism policies.
- **Self-motivation:** develops self-discipline, planning and organization skills, and time management skills.

V. Teaching-Learning Process

The B.Sc. (Programme) in Mathematical Sciences with Operational Research aims to make the student proficient in decision making tools based on the knowledge delivered in the classroom and in the laboratory. The classroom teaching is based on mainly blackboard and chalk, powerpoint presentations, problem-solving exercises and interactions. Also, hands-on training is provided to the students in the laboratory in the form of practical's and project work, to enable students to better understand the applications of the different courses.

VI. Assessment Methods

The learning outcomes of the students for the operational research courses are assessed based on both direct and indirect methods on a continuous basis. These methods include quizzes, home assignments, written and oral examinations, presentations, problem-solving exercises, case study presentations.

VII. Detailed Syllabus

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

Marks: 150 **Course Duration: 90 Hrs. (6 Credits)**

Course Objectives:

To create awareness about the term operational research (OR) and acquaint them with the methodologies, scope, limitations and applications of OR and to expose the students with the knowledge of formulation of real life problems using the linear programming method. To understand the theoretical basis of computational algorithms used in solving linear programming and related problems.

Course Learning Outcomes:

Students completing this course will be able to:

- Understand the need of using OR as a quantitative approach for effective decision making
- Be familiar with various definitions of OR, its historical perspective, characteristics and different phases of scientific study
- Describe the basic concepts of convex sets and basis
- Identify situations where linear programming problem (LPP) can be applied and appreciate the assumptions of linear programming method with a view to interpret the solution
- Formulate real-world problems as a linear programming model and describe the theoretical workings of the graphical and simplex method, demonstrate the solution process by hand and solver
- Appreciate the significance of duality and explain the relationship between a linear program and its dual, including strong duality and complementary slackness
- Perform sensitivity analysis to identify the direction and magnitude of change of a linear programming model's optimal solution as the input data change

Contents:

Unit I: Origin and development of OR, Different phases of OR study, Methodology of OR, Scope and limitations of OR, OR in decision making, Applications of OR. **(Chapter-1, Reference [3])**

Unit II: Linear independence/ dependence of vectors, Basis of a vector space, Convex set and its properties, Extreme points. General linear programming problem (LPP), Standard and canonical form of LPP, Problem formulation, Graphical solution,Theory of simplex method, Simplex algorithm, 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. **(Chapters-1, 2, 3 & 4, Reference [1])**

Unit III: Duality theory-Definition of the dual problem, Primal-dual relationships, Fundamental theorem of duality, Complementary slackness theorem, Economic interpretation of duality, dual-simplex method. **(Chapter-6, Reference [1] & Chapter-8, Reference [2])**

Unit IV: Sensitivity analysis- Shadow price, Graphical and simplex method based approach for changes in cost and resource vector. **(Chapter-6, Reference [1])**

Suggested Readings:

(i) Compulsory Reading

1. Bazara, M. S., Jarvis, J. J., & Sherali, H. D. (2010). *Linear programming and network flows* (4th ed.). New Jersey: John Wiley & Sons, Inc.
2. Hadley, G. (2002). *Linear programming*. New Delhi: Narosa Publishing House.
3. Ravindran, A., Phillips, D. T., & Solberg, J. J. (2007). *Operations research- principles and practice* (2nd ed.). New Delhi: Wiley India (Indian print).

(ii) Additional Reading

4. 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).
5. Taha, H. A. (2017). *Operations research-an introduction* (10th ed.). New Delhi: Pearson Prentice Hall (Indian print).
6. 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 1-2: Introduction to Operational Research: Definition, Different phases, Scope, Limitations, Methodology and application areas.

Week 3-4: Concept of Basis, Basic feasible solutions, Convex sets and Extreme points. Introduction to linear programming, formulations of various real-world problems such as product mix problem, nutrition problem, blending problem as linear programming problem.

Week 5-6: Assumptions of linear programming, Graphical method.

Week 7-10: Problem solving using Simplex method, Big-M method, Two-phase method including special cases in LPP.

Week 11-12: Primal-dual relationships, Construction of Dual problems, Duality theorems, Complementary slackness theorem, Dual-Simplex method.

Week 13-15: Sensitivity analysis related to both parameter and structural changes in linear programming model, Graphical and simplex method based approach for changes in cost and resource vector.

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

1. To solve Linear Programming Problem using Graphical method with
   (i) Multiple constraints
   (ii) Unbounded solution
   (iii) Infeasible solution
   (iv) Alternative or multiple solution
2. Solution of Linear Programming Problem with Simplex method.
3. Solution of Linear Programming Problem with unrestricted variables through Simplex method.
4. Problem solving using Charnes-M method.
5. Problem solving using Two Phase method.
6. Illustration of following special cases in LPP using Simplex method
   (i) Multiple constraints
   (ii) Unbounded solution
   (iii) Infeasible solution
   (iv) Alternative or multiple solution
7. Problems based on Dual simplex method.
8. Problems based on Sensitivity analysis.

Facilitating the achievement of Course Learning Outcomes

Unit No.	Course Learning Outcomes	Teaching and Learning Activity	Assessment Tasks
I	(i) Understand the need of using OR as a quantitative approach for effective decision making (ii) Be familiar with various definitions of OR, its historical perspective, characteristics and different phases of scientific study	(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 concepts to solve real-world problems using solver	• 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
II	(i) Describe the basic concept of convex sets and basis (ii) Identify situations where LPP can be applied and appreciate the assumptions of LPP with a view to interpret the solution (iii) Formulate real-world problems as linear programming model (ii) Describe the theoretical workings of the graphical and simplex method for linear programming and demonstrate their iterations by hand and solver		
III	(i) Appreciate the significance of duality (ii) Explain the relationship between a linear program and its dual, including strong duality theorem and complementary slackness		
IV	(i) Perform sensitivity analysis to identify the direction and magnitude of change of a linear programming model's optimal solution as the input data change for resource vector and cost vector (ii) Interpret shadow prices while solving using graphical and simplex approach		

Keywords: Operational research, Linear programming, Simplex method, **Duality, Sensitivity analysis**

Course-DCC 2: INVENTORY AND MARKETING MANAGEMENT (THEORY AND PRACTICAL)

Marks: 150 **Course Duration: 90 Hrs. (6 Credits)**

Course Objectives:

To acquaint students with the concept of inventory, significance of inventory control as well as various forms and functional role of inventory. To provide a framework to develop mathematical models for different types inventory systems.To understand the theory of marketing and its role in an organization. To discuss the uses and limitations of mathematical models in marketing and classification of marketing structure in competitive conditions.

Course Learning Outcomes:

After completion of the course, students will possess knowledge and skills required to

- Explain the meaning of Inventory control, various forms and functional role of Inventory
- Calculate the Economic Order Quantity (EOQ) for various deterministic and probabilistic inventory models
- Understand multi-item EOQ model with constraints, and inventory models with all-unit quantity discount
- Demonstrate solution methods for production scheduling problems
- Understand the role of marketing in an organization, different marketing decisions and scientific marketing analysis
- Derive joint optimization models of price, quality and promotional efforts
- Perform Brand switching analysis to find the equilibrium market share
- Formulate Media allocation problem for advertisement and apply the knowledge of various pricing strategies to grab maximum market share

Contents:

Unit I: Concepts and problems in inventory systems, Selective inventory classification and its use in controlling inventory, Different types of costs in inventory systems and method of their estimation. **(Chapters-1 & 2, Reference [3])**

Unit II: Deterministic Inventory models with and without lead time, and with and without shortages. Determination of reorder level (ROL) for all the models. **(Chapter-12, Reference [2] & Chapters-3 & 4, Reference [3])**

Unit III: Multi-item EOQ model with constraints, Inventory models with all-unit quantity discount, Single period probabilistic inventory models with discrete and continuous demand, Production scheduling problems. **(Chapter-14, Reference [2] & Chapters-4 & 5, Reference [3])**

Unit IV: Concept of marketing and its role in an organization. Marketing decisions, Scientific marketing analysis. Uses and limitations of mathematical models in marketing, Classification of market structure in competitive conditions. **(Chapters-1, 2, & 18, Reference [1])**

Unit V: Demand elasticity, Joint optimization of price, quality and promotional efforts. Pricing decisions, Media allocation for advertisement, Brand switching analysis. **(Chapters-10, 11 & 15, Reference [1])**

Suggested Readings:

(i) Compulsory Reading

1. Kotler, P., & Keller, K. L. (2008), *Marketing management* (13th ed.). New Delhi: Pearson Education Ltd.
2. Taha, H. A. (2017). *Operations research-an introduction* (10th ed.). New Delhi: Pearson Prentice Hall (Indian print).
3. Waters, D. (2003). Inventory control and management (2nd ed.). West Sussex: John Wiley & Sons Ltd.

(ii) Additional Reading

4. Axsäter, S. (2015). *Inventory control* (3rd ed.). New York: Springer.
5. Buffa, E. S., Sarin R. K. (2009). *Modern production/operations management* (8th ed.). New Delhi: Wiley India (Indian print).
6. Hooley, G. J., & Hussey, M. K. (1999). *Quantitative methods in marketing* (2nd ed.). London: International Thomson Business Press.
7. Johnson, L.A., & Montgomery, D.C. (1974). *Operations research in production planning, scheduling and inventory control*. New York: Wiley.

Teaching Plan:

Week 1-2: Concepts and problems in Inventory Systems, Selective inventory classification (ABC,FNSD,VED,HML,XYZ) and their use in controlling inventory, Different costs in Inventory Systems and method of their estimation.

Week 3-5: Deterministic Inventory models with and without lead time and with and without shortages. Determination of reorder level (ROL) for all the models.

Week 6-8: Multi-item EOQ model with constraints, Inventory models with all-unit quantity discount, Single period probabilistic inventory models with discrete and continuous demand, Production scheduling problems.

Week 9-10: Concept of marketing and its role in an organization. Marketing decisions, Scientific marketing analysis. Uses and limitations of mathematical models in marketing, Classification of market structure in competitive conditions.

Week 11-13: Demand elasticity, Joint optimization of price, quality and promotional efforts. Pricing decisions.

Week 14-15: Media allocation for advertisement, Brand switching analysis.

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 deterministic inventory models.
3. To solve multi-item inventory model with different constraints.
4. To solve all-unit quantity discount model.
5. To find optimal inventory policy for probabilistic inventory model with discrete demand.
6. To find optimal inventory policy for probabilistic inventory model with continuous demand.
7. Solution of procurement/production scheduling model.
8. Problems based on media allocation for advertisement.
9. Problems based on Brand switching analysis.

Facilitating the achievement of Course Learning Outcomes

Unit No.	Course Learning Outcomes	Teaching and Learning Activity	Assessment Tasks
I	(i) Explain the meaning of Inventory control, various forms and functional role of Inventory (ii) Apply various Selective inventory control techniques to classify inventory items into broad categories (iii) Understand different types of costs in inventory systems	(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 (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	• Class discussion and presentations • Weekly Assignments • Student presentation • Mid-Term examination • Group activities involving students to solve real-world problems using solver • Hold both announced and unannounced quizzes • End-term examination
II	(i) Calculate the Economic Order Quantity (EOQ) for various Deterministic and Probabilistic Inventory models (ii) Compute the Reorder Level (ROL)and to determine time of replenishment with known and unknown patterns of demand for inventory items		
III	(i) Understand Multi-item inventory model with constraints, Inventory models with all-unit quantity discount (ii) Develop Single period probabilistic inventory models with discrete and continuous demand (iii) Demonstrate solution methods for Production scheduling problems		
IV	(i) Understand the role of marketing in an organization (ii)Differentiate between old and new concept of marketing (iii) Explain the different marketing decisions and scientific marketing analysis (iv) Derive joint optimization models of price, quality and promotional efforts (v) Understand uses and limitations of mathematical models in marketing (vi) Classify market structure in competitive conditions		

V	(i) Apply demand elasticity for joint optimization of price, quality and promotional efforts (ii) Perform brand switching analysis to find the equilibrium market share (iii) Formulate media allocation problem for advertisement (iv) Apply the knowledge of various pricing strategies to grab maximum market share		

Keywords: Inventory management, Economic order quantity, Production scheduling, Marketing decisions

Course-DCC 3: OPTIMIZATION TECHNIQUES (THEORY AND PRACTICAL)
Marks: 150 **Course Duration: 90 Hrs. (6 Credits)**

Course Objectives:
To impart the knowledge about the formulations and solution techniques of non-linear programming problems as well as multi-objective goal programming problems.

Course Learning Outcomes:
Students completing this course will be able to:

- Identify different types of optimization problems which occur in real life and their characteristics
- Explain the theoretical concepts related to non-linear programming problems and demonstrate formulations and solution approaches for them
- Develop the concepts of multi-objective programming problem and demonstrate its solution using goal programming
- Use computer software to solve optimization problems

Contents:
Unit I: Concepts of linear algebra, convex and concave functions and their properties, make distinction between local, global and inflection extreme points. **(Chapter-7, Reference [1] & Chapters-4, 5 & 6, Reference [3])**

Unit II: Non-Linear Programming (NLP): Unconstrained optimization problem, basics of NLP, Method of Lagrange multiplier. **(Chapters-8 & 9, Reference [1] & Chapter-11, Reference [2])**

Unit III: Karush-Kuhn-Tucker (KKT) optimality conditions, Quadratic programming-Wolfe's method, Beale's method. **(Chapter-8, Reference [1] & Chapters-23 & 24, Reference [3])**

Unit IV: Goal Programming: Basics of goal programming, Weighted and pre-emptive goal programming, Formulation of goal programming problem, Graphical solution. **(Chapter-13, Reference [1] & Chapter-4, Reference [2])**

Suggested Readings:

(i) Compulsory Reading

1. Chandra, S., Jayadeva, & Mehra, A. (2013). *Numerical optimization with applications.* New Delhi: Narosa Publishing House.
2. Ravindran, A., Phillips, D. T., & Solberg, J. J. (2007). *Operations research- principles and practice* (2nd ed.). New Delhi: Wiley India (Indian print).
3. Sinha, S. M. (2006). *Mathematical programming- theory and methods* (1st ed.). New Delhi: Elsevier Science (Indian print).

(ii) Additional Reading

4. 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).
5. Taha, H. A. (2017). *Operations research-an introduction* (10th ed.). New Delhi: Pearson Prentice Hall (Indian print).
6. Wayne, Winston, L. (2003). *Operations research: applications and algorithms,* (4th ed.). Duxbury Press.

Teaching Plan:

Week 1-4: Basic concepts of non-linear programming problem- Definition, Applications, Formulation of different type of non-linear programming problems, Convex and concave function, Hessian matrix, Positive definite & semi-definite matrix, Negative definite & semi-definite matrix, Inflexion point, local & global optima.

Week 5-7 : Unconstrained optimization problems- Single and multiple variable problems, Necessary and sufficient conditions for finding extrema point, Bisection method, Dichotomous method, Newton method, Golden section method, Gradient search procedure.

Week 8-9: Constrained optimization problems- Equality constraints problems by lagrange multiplier method, Inequality constraints by KKT conditions.

Week 10-12: Quadratic programming problem-Wolfe's method & Beale's method.

Week 13-15: Goal Programming-Basics of goal programming, goal programming formulation, goal programming algorithms: Weights method & preemptive method, Graphical solution.

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

1. To determine local/Relative optima of a given unconstraint problem.
2. Test whether the given function is concave/convex.
3. Test whether the given matrix is positive definite/negative definite/semi positive definite/ semi negative definite
4. Solution of optimization problems using KKT conditions.
5. Solution of Quadratic programming problem by Wolfe's method..
6. Graphical solution of weighted Goal programming.
7. Graphical solution of pre-emptive Goal programming
8. Applications of NLP in real life problems.

Facilitating the achievement of Course Learning Outcomes

Unit No.	Course Learning Outcomes	Teaching and Learning Activity	Assessment Tasks
I, II & III	(i) Identify different types of optimization problems which occur in real life and their characteristics (ii) Application of these problems will be realized by formulating variety of problems arising in different areas (iii) Algorithms for finding optimal solution of unconstrained non-linear programming problems will be learned (iv) Understanding of constrained non-linear optimization problems	(i) Students can be given different type of problems in the theory class to solve, for each topic (ii) Nature of problems should vary from simple to complex to increase their level of understanding (iii) Some real life problems in the form of case study can assigned for formulation &	• Solution of variety of problems in the theory class • Solution of variety of problems in the lab through software • Assignments • Class test • Case studypresentation • Oral question-answering in the class • Final exam

	(v) Techniques for finding optimal solution of these type of problems will be learned (vi) Understanding of the nature of quadratic programming problem and its solution techniques	solution through software (iv) Some project work can assigned as group activity (v) Students can be encouraged to give paper presentation	
IV	(i) Clarity of the concepts of multi-objective problems and all related concepts of goal programming problem (ii) Importance and application of these problems can be realized through formulation of variety of problems (iii) Learning of solution of goal programming problem through graphical method.		

Keywords: Unconstrained optimization, Non-linear programming, Optimality conditions, Quadratic programming, Goal programming

COURSE-DCC 4: NETWORK MODELS AND SCHEDULING TECHNIQUES (THEORY AND PRACTICAL)

Marks:150 **Course Duration: 90 Hrs. (6 Credits)**

Course Objectives:

The objective of this course is to make the students understand about the theory and practical application of transportation problems and assignment problems that requires problem solving and analytical skills from Operational Research. The course shall also deal with utility of project scheduling techniques, related network optimization and resource allocation models to handle managerial decision-making problems.

Course Learning Outcomes:

Students completing this course will be able to:

- Understand relevant concepts related to handling of transportation-based problems
- Develop an understanding towards formulating and solving assignment-based problems
- Do analysis of project schedule and analyze the cost-time tradeoffs in context of a project network
- Learn to solve different real-life problems through network optimization tools
- Learn skills to aid management decision making
- Learn basic concepts pertaining to resource allocation

Contents:

Unit I: Transportation Problem: Formulation as a linear programming problem, Methods to find initial basic feasible solution (NWCM, LCM, VAM) and optimal solution (MODI), Degeneracy, Unbalanced transportation problem, Prohibited transportation problem, Maximization type transportation problem, Transshipment problem. **(Chapter-3, Reference [1] & Chapter-5, Reference [2])**

Unit II: Assignment Problem: Formulation as a linear programming problem, Hungarian method, Degeneracy, Unbalanced assignment problem, Prohibited assignment problem, Maximization type assignment problem, Travelling salesmen problem-Branch and bound solution algorithm. **(Chapter-3, Reference [1] & Chapter-10, Reference [2])**

Unit III: Project Scheduling: Network representation of project, Project scheduling-Critical path method and PERT, Types of Floats, Crashing-Time and cost trade-off. **(Chapter-3, Reference [1], Chapter-6, Reference [2], Chapters-1,2,3,4,5 & 6, Reference [3])**

Unit IV: Network Optimization Models: Basic concepts, Shortest path problem, Minimum spanning tree problem. (**Chapter-3, Reference [1]**

Unit V: Resource Allocation Problem**:** Basic definitions and understanding of resource levelling and resource smoothing. (**Chapter-7, Reference [3])**

Suggested Readings:

(i) Compulsory Reading

1. Ravindran, A., Phillips, D. T., & Solberg, J. J. (2007). *Operations research- principles and practice* (2nd ed.). New Delhi: Wiley India (Indian print).
2. Taha, H. A. (2017). *Operations research-an introduction* (10th ed.). New Delhi: Pearson Prentice Hall (Indian print).
3. Wiest, J. D., & Levy, F.K. (1979). *A management guide to PERT/CPM, with GERT/PDM / DCPM and other networks* (2nd ed.). New Jersey: Prentice-Hall.

(ii) Additional Reading

4. 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).
5. Wayne, Winston, L. (2003). *Operations research: applications and algorithms,* (4th ed.). Duxbury Press.

Teaching Plan:

Week 1- 3: Formulation as a linear programming problem, methods to find initial basic feasible solution (NWCM, LCM, VAM) and optimal solution (MODI), Degeneracy, Unbalanced transportation problem, Prohibited transportation problem, Maximization type Transportation problem, Transshipment problem.

Week 4-6: Formulation as a linear programming problem, Hungarian method, Degeneracy, Unbalanced assignment problem, Prohibited assignment problem, Maximization type assignment problem, Travelling salesmen problem: Branch and bound solution algorithm.

Week 7-10: Network representation of project, Project scheduling-Critical path method and PERT, Types of Floats, Crashing-Time and cost trade-off.

Week 11-13: Basic concepts, Shortest path problem, Minimum spanning tree problem.

Week 14-15: Resource Allocation Problem**:** Basic definitions and understanding of resource levelling and resource smoothing.

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

1. Solution of Transportation Problem as a LPP.
2. Solution of Assignment Problem as a LPP.
3. Solution of Travelling Salesman Problem.
4. Solution of shortest path Problem as a LPP.
5. Project Planning (Deterministic case-CPM)
6. Project Planning (Probabilistic case-PERT)
7. Crashing of the Project
8. Solution of Shortest Path Problem
9. Solution of Minimum Spanning Tree Problem
10. Solution of a resource allocation problem

Facilitating the achievement of Course Learning Outcomes

Unit No.	Course Learning Outcomes	Teaching and Learning Activity	Assessment Tasks
I	(i) The student will be able to formulate and solve the transportation problems using various methods and will be able to develop linear programming models of the transshipment problem	Classroom lectures & presentations	• Hold Class discussion and presentations • Homework assignments • Mid-term exam and final exam • Group activities involving students to solve real-world
II	(i) The student will become familiar with the		

	types of problems that can be solved by applying an assignment model and will be able to formulate and solve the linear programming models based on the assignment problem. The student will also get insights into travelling salesman problem and algorithm to solve it		problems using solver • Hold both announced and unannounced quizzes
III	(i) The student will understand the role and application of PERT/CPM for project scheduling and how to compute the critical path and the project completion time (ii) The student will also learn about the crashing problem using time and cost trade-off		
IV	(i) The student will get familiar with the network optimization models and will learn to solve the shortest path and minimum spanning tree problems		
V	(i) The student will get basic knowledge of resource allocation and related problems		

Keywords: Network models, Scheduling techniques, Resource allocation, Transportation problem, Assignment problem

Course-DSE 1.1: QUEUEING AND RELIABILITY THEORY (THEORY AND PRACTICAL)

Marks: 150 **Course Duration: 90 Hrs. (6 Credits)**

Course Objectives:

This course will help the students to understand basic concepts of stochastic processes, queueing and reliability theory. In the process of learning these topics, students will also be exposed to the various areas of applications of queueing and reliability theory. The main objective is to develop analytical capability in queueing and reliability theory so as to enable the students to apply these to solve real world problems. Finally, to have hands-on experience on the topics, it will also include practical sessions using softwares.

Course Learning Outcomes:

Students on completing this course will be able to understand:

- The basic concepts of a stochastic process and its classifications
- The basic concepts of a queueing system
- Markovian queueing system and its applications
- Quantitative performance metrics of various Markovian queueing system and shall be able to compute them
- Reliability of a system and its various configurations
- How software can be used to obtain the performance measures of Markovian queueing systems and measures of reliability of a system

Contents:

Unit I: Introduction to stochastic processes, Markov chain and Markov process. **(Chapter-1, Reference [1] & Chapter-2, Reference [2])**

Unit II: General concepts of queueing system, Measures of performance, Probability distributions of arrival and service times, Kendall's notation, Little's formula, Birth process, Death process, Birth-death process. Markovian queueing systems: M/M/1/∞, M/M/1/K, M/M/c, queues with finite source. **(Chapters-1 & 2, Reference [1])**

Unit III: Design and control of queueing models, Applications of simple queuing decision models. **(Chapter-6, Reference [1])**

Unit IV: Basics of reliability, Classes of lifetime distributions, Reliability function, Mean time before failure (MTBF) and Hazard rate of Exponential and Weibull distributions. **(Chapter-2, Reference [3])**

Unit V: Reliability of various configurations- series, parallel, mixed configuration, k out of n system and stand-by system, Reliability models, Concepts and definitions of Preventive maintenance, Corrective maintenance and Age replacement policies. **(Chapters-4 & 9, Reference [3])**

Suggested Readings:

(i) Compulsory Reading

1. Gross, D., Shortle, J. F., Thompson, J. M., & Harris, C. M. (2008). *Fundamentals of queuing theory* (4th ed.). New Jersey: John Wiley & Sons, Inc.
2. Medhi, J. (2009). *Stochastic processes* (3rd ed.). New Delhi: New Age Science Ltd.
3. Rausand, M., & Hoyland, A. (2003). *System reliability theory: models, statistical methods and applications* (2nd ed.). New Jersey: John Wiley & Sons, Inc.

(ii) Additional Reading

4. 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).
5. Srinath, L. S. (2005). *Reliability engineering*. New Delhi: East West Press.
6. Trivedi, K. S. (2016). *Probability and statistics with reliability, queuing and computer science applications* (2nd ed.). New Jersey: John Wiley & Sons, Inc.

Teaching Plan:

Week 1-2: Introduction to stochastic processes, Markov chain and Markov process.

Week 3-4: General concepts of queueing system, Measures of performance, Probability distributions of arrival and service times, Kendall's notation, Little's formula, Birth process, Death process, Birth-death process.

Week 5-8: Markovian queueing systems: M/M/1/∞, M/M/1/K, M/M/c, queues with finite source.

Week 9-10: Design and control of queueing models, Applications of simple queuing decision models.

Week 11-12: Basics of reliability, Classes of lifetime distributions, Reliability function, Mean time before failure (MTBF) and Hazard rate of Exponential and Weibull distributions.

Week 13-15: Reliability of various configurations- series, parallel, mixed configuration, k out of n system and stand-by system, Reliability models, Concepts and definitions of Preventive maintenance, Corrective maintenance and Age replacement policies.

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

1. To determine the performance measures for M/M/1 queuing model.
2. To determine the performance measures for M/M/1/N queuing model.
3. To determine the performance measures for M/M/c/∞ queuing model.
4. To determine the performance measures for M/M/c/N queuing model.
5. Problems based on Simulation: Random number generation.
6. Problems based on Monte Carlo method.
7. Calculation of hazard rate, MTBF for series and parallel systems.
8. Calculation of hazard rate, MTBF for Mixed configurations.
9. Problems based on reliability optimization.

Facilitating the achievement of course learning outcomes

Unit No.	Course Learning Outcomes	Teaching and Learning Activity	Assessment Tasks
I	(i) Describe what a stochastic process is and understand its classification giving various examples	(i) Make the students understand the various areas of applications of	• Regular home assignments • Class presentations

II	(i) Understand the concept of a queueing system and its mathematical modelling (ii) Describe quantitative measures of performance of a queueing system (iii) Derive the analytical models of Markovian queues (birth-death models) and compute various measures of performance through these models	probability theory and stochastic processes (ii) Giving enough real-life examples so as to make teaching learning more interesting (iii) Encouraging the students to come up new ideas and appreciating them (iv) Giving home assignments (v) Group discussions	• Multiple choice questions • Real life case studies • Class tests • Mid-Term examination • End-term examination
III	(i) Understand the role of queueing in optimization (ii) Design an optimal queueing system		
IV	(i) Understand the basic concept of reliability and define it as a mathematical function (ii) Describe various lifetime distributions (iii) Describe and compute various reliability measures such as Mean time before failure (MTBF) and Hazard rate of Exponential and Weibull distributions		
V	(i) Compute the reliability of standard system configurations- series, parallel, mixed configuration, k out of n system and standby system (ii) Understand various system reliability models (iii) Understand the concepts and definitions of Preventive maintenance, Corrective maintenance and Age replacement policies		

Keywords: Queueing theory, Reliability theory, Stochastic processes, Markov chain

COURSE-DSE 1.2: QUALITY MANAGEMENT (THEORY AND TUTORIAL)

Marks:150 **Course Duration: (75 +15=90) Hrs. (6 Credits)**

Course Objectives:

The objective of this course is to put quality management into perspective, and to highlight its critical importance, as well as to present in-depth ideas on different methodologies, tools and techniques proposed for product and process improvement. This course will help students to understand opportunities for product/service or process improvement based on quality management principals.

Course Learning Outcomes:

Students completing this course will be able to:

- Understand the basic concepts of quality from an organizational point of view
- Cognize the concept of total quality management from Western and Japanese approach
- Understand opportunities for product/service or process improvement based on quality management principals
- Develop abilities to apply tools and techniques of total quality improvement including, statistical process control, and control charts
- Know international/national quality standards and describe the role and implementation of six sigma using DMAIC and DMADV.

Contents:

Unit I: Overview of quality, History of quality, Dimensions of quality, Competitive advantage, Industrial perspective, Taguchi Loss function concept. **(Chapters-1 &2, Reference [1] & Chapter-1, Reference [2])**

Unit II: Process and product quality, Causes of variations (assignable and unassignable), Statistical process control, Process control charts: variable controls charts (X-bar and R, X-bar and s) and attribute control charts (*np* and *p*, *c* and *u*), Sampling, Sampling distribution, Acceptance sampling plan, Consumer's risk, Producer's risk. **(Chapter-6, Reference [1] & Chapters-5, 6, 7 & 15, Reference [2])**

Unit III: Pareto chart, Cause and effect diagram, Check sheet, Histogram, Scatter diagram, Process control charts applications. **(Chapter-8, Reference [1])**

Unit IV: Variation, Causes of variations (natural and assignable), Process capability meaning-significance and measurement, Six Sigma-features, goals and implementation, DMAIC and DMADV, Introduction to ISO 9000-quality management systems and emerging standards. **(Chapters-7 & 17, Reference [1] & Chapter-5, Reference [2])**

Suggested Readings:

(i) Compulsory Reading

1. Charantimath, P.M. (2011). *Total quality management* (2nd ed.). New Delhi: Pearson Education.
2. Montgomery, D. C. (2009). *Introduction to statistical quality control* (6th ed.). New Jersey: John Wiley & Sons.

(ii) Additional Reading

3. Besterfield, D. H. (2009). *Quality control* (8th ed.). New Delhi: Pearson Education.
4. Gupta, S. C., & Kapoor, V. K. (2009). *Fundamentals of applied statistics*. New Delhi: Sultan Chand & Sons.

Teaching Plan:

Week 1-2: Overview of quality, History of quality, Dimensions of quality, Competitive advantage, Industrial perspective, Taguchi Loss function concept.

Week 3-5: Process and product quality, Causes of variations (assignable and unassignable), Statistical process control, Process control charts: variable controls charts (X-bar and R, X-bar and s) and attribute control charts (*np* and *p*, *c* and *u*).

Week 6-7: Sampling, Sampling distribution, Acceptance sampling plan, Consumer's risk, Producer's risk.

Week 8-9: Pareto chart, Cause and effect diagram, Check sheet, Histogram, Scatter diagram, Process control charts applications.

Week 10-11: Variation, Causes of variations (natural and assignable), Process capability meaning - significance and measurement.

Week 12-13: Six Sigma- features, goals and implementation, DMAIC and DMADV**.**

Week 14-15: Introduction to ISO 9000-quality management systems and emerging standards.

Facilitating the achievement of Course Learning Outcomes

Unit No.	Course Learning Outcomes	Teaching and Learning Activity	Assessment Tasks
I	(i) Explain the basic concepts related to quality management such as what is quality from an industrial perspective, need for quality management, evolution of quality management, dimensions of quality	(i) Giving examples during lectures (ii) Giving homework assignments (iii) Encouraging students to give class presentations (iv) Making students to participate in class discussion (v) Motivating the students to follow learning by doing approach (vi) Encouraging team work and asking the students to help fellow classmates	• Hold class discussion and presentation • Homework assignments • Mid-term exam and End-term examination • Group projects involving students to solve real-world problems • Hold both announced and unannounced quizzes
II	(i) Understand the concept of process and product quality (ii) Identify the causes of variations in process capability (iii) Explain theoretically statistical process control and process control charts both variable and attribute		
III	(i) Describe sampling and apply different sampling distributions (ii) Explain theoretically various statistical concepts like sampling plan, consumer's and producer's risk		
IV	(i) Understand and explain the meaning and significance of Process capability and its measurement (ii) Explain the concept and role of six-sigma in quality management (iii) Explain the theory and implementation of six sigma using DMAIC and DMADV (iv) Understand and define ISO 9000- quality standards		

Keywords: Process and product quality, Control charts, Six-sigma

Course-DSE 2.1: INTEGER PROGRAMMING AND THEORY OF GAMES (THEORY AND PRACTICAL)

Marks: 150 **Course Duration: 90 Hrs. (6 Credits)**

Course Objectives:

The objective is to acquaint students with an important class of mathematical programming problems called as 'Integer programming problems' and to introduce the solution techniques to solve such problems. This course also intends to introduce 'Game Theory-the science of strategy' to the students, which makes possible the analysis of the decision making process of interdependent subjects. It is aimed at explaining and predicting how individuals behave in a specific strategic situation, and therefore help improve decision making.

Course Learning Outcomes:

Students on completing this course will be able to:

- Formulate real life problems such as knapsack, capital budgeting, assignment, etc. as integer linear programming problems
- Solve integer programming problems using standard algorithms
- Identify the features of different types of decision-making environments and the appropriate decision making tools to be used in each type
- Apply the knowledge of game theoretical concepts to real-world decision making situations for identifying, analyzing strategic decisions to counter the consequences
- Demonstrate solution methods including graphs and linear programming approach to analyze and solve the two-person, zero-sum games

Contents:

Unit I: Introduction to Integer programming problems (IPP), Pure IPP and Mixed IPP, Applications of IPP: Capital budgeting, Fixed charge problem, Travelling salesman problem, Media allocation. **(Chapter-9, Reference [3])**

Unit II: Methods of solving IPP: Branch and bound method, Gomory's cutting plane method, 0-1 programming: applications, enumeration algorithm. **(Chapter-6, Reference [1])**

Unit III: Decision analysis: Decision making environment, Construction of Pay-off table, Decision under uncertainty, Decision under risk: Expected monetary value (EMV), Expected opportunity Loss (EOL), Expected value of perfect information (EVPI). **(Chapter-13, Reference [3])**

Unit IV: Introduction to game theory, Fundamental theorem of game theory, Formulation of two person zero sum rectangular games, min-max and max-min principle, Solution of rectangular games with saddle points, dominance principle, rectangular games without saddle point-mixed strategy games, Reduction of m x n game and solution of 2x2, 2 x s, and r x 2 cases by graphical method, algebraic and linear programming solution of m x n games. **(Chapter-14, Reference [2])**

Suggested Readings:

(i) Compulsory Reading

1. Chandra, S., Jayadeva, & Mehra, A. (2013). *Numerical optimization with applications.* New Delhi: Narosa Publishing House.
2. 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).

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

(ii) Additional Reading

4. 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 1-2: Concept of integer programming problem (IPP), pure IPP and mixed IPP, applications of IPP: capital budgeting, fixed charge problem, travelling salesman problem, media allocation.

Week 3-6: Branch and bound method, Gomory's cutting plane method, zero-one programming: application, enumeration algorithm.

Week 7-9: Decision making environment, construction of pay off table, decision under uncertainty, decision under risk: EMV, EOL, EVPI.

Week 10-15: Introduction to game theory, fundamental theorem of game theory, formulation of two person zero sum rectangular games, min-max and max-min principle, solution of rectangular games with saddle points, dominance principle, rectangular games without saddle point-mixed strategy games, reduction of m x n game and solution of 2x2, 2 x s, and r x 2 cases by graphical method, algebraic and linear programming solution of m x n games.

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. Finding EMV, EOL, EVPI.
8. Solution of two-person zero-sum pure and mixed strategy game.
9. Linear programming solution of game problem.

Facilitating the achievement of Course Learning Outcomes

Unit No.	Course learning outcomes	Teaching and learning activity	Assessment tasks
I	(i) Formulate IPP for real world problems such as capital budgeting, fixed charge problem, travelling salesman problem, media allocation	(i) Group discussions (ii) Class discussions on real life problems (iii) Presentations (iv) Case studies	• Weekly Assignments • Class Tests • MCQ • Student presentation • Mid-Term examination • End-term examination
II	(i) Understand the method of solving IPP, and implement algorithms such as branch and bound method, Gomory's cutting plane method (ii) Understand the applications of zero-one programming problems and solve such problems using enumeration algorithm		

III	(i) Construct pay-off table. (ii) Understand the principle of decision making under uncertainty and decision making under risk and should be able to evaluate EMV, EOL, EVPI		
IV	(i) Formulate two person zero sum rectangular games (ii) Understand min-max and max-min principle, and obtain solution of rectangular games with saddle points, (iii) Understand the dominance principle, concept of rectangular games without saddle point-mixed strategy games (iv) Understand reduction of m x n game and should be able to find solution of 2x2, 2 x s, and r x 2 cases by graphical method (v) Determine algebraic and linear programming solution of m x n games		

Keywords: Integer programming, Theory of games, Decision analysis

COURSE-DSE 2.2: LOGISTICS AND SUPPLY CHAIN MANAGEMENT (THEORY AND TUTORIAL)

Marks:150 **Course Duration: (75 +15=90) Hrs. (6 Credits)**

Course Objective:

The objective is to familiarize the students with the essential elements of Supply Chain Management (SCM). The course would help students to integrate and critically evaluate qualitative and quantitative information to make better decisions related to various SCM activities.

Course Learning outcomes:

- To understand and analyze the operations and supply chain management issues in a firm
- To understand the rationale behind, and fundamental principles of supply chain management
- To recognize the managerial benefits and potential challenges of the supply chain practices

Contents:

Unit I: Introduction to Logistics: Origin and definition of logistics, Types of logistics, Transportation, role of transportation in logistics, Warehousing-Nature and importance of warehousing, functions, layout and designing, Role of packaging and unitization. **(Chapters-11, 14 & 17, Reference [1], Chapter-11, Reference [2], Chapters-1, 12, 13, 31 & 36, Reference [4])**

Unit II: Inventory Management: Control of inventory, Distribution resource planning (DRP), Material requirement planning (MRP I), Manufacturing resource planning (MRP II). **(Chapter-2, Reference [4])**

Unit III: Supply Chain Management: Introduction to SCM and its development, Objectives and needs, Components of SCM, Key issues of SCM, Competitive and SC strategies, Achieving strategic fit, Supply chain integration, Push-based, Pull-based and Push-Pull based supply chain, Demand forecasting in a supply chain (CPFR Model). **(Chapters-1, 2, 3, 7, 10 & 17, Reference [1] & Chapter-6, Reference [4])**

Unit IV: Supply Cain Performance Drivers: Strategic alliances, Third party and fourth party logistics, Key enablers in supply chain improvement. Coordination in SCM, Bullwhip effect in SCM, Use of best practices and information technology in SCM, Benchmarking. **(Chapters-11, 14, 15 & 17, Reference [1] & Chapters-5 & 8, Reference [4])**

Suggested Readings:

(i) Compulsory Reading

1. Chopra, S., & Meindl, P. (2016). *Supply chain management: strategy, planning and operation* (6th ed.). New Delhi: Pearson Education.
2. Christopher, M. (2011). *Logistics & supply chain management: creating value-adding networks*. Pearson Education.
3. Rushton, A., Croucher, P., & Baker, P. (2014). *The handbook of logistics and distribution management: understanding the supply chain* (5th ed.). Kogan Page Ltd.
4. Simchi-Levi, D., Kaminsky, P., Simchi-Levi, E., & Shankar, R. (2008). *Designing and managing the supply chain: concepts, strategies and case studies* (3rd ed.). McGraw-Hill Education (India print).

(ii) Additional Reading

5. Harrison, A., & Van Hoek, R. I. (2005). *Logistics management and strategy: competing through the supply chain* (3rd ed.). Harlow: Pearson Education Ltd.

Teaching Plan:

Week 1-3: Origin and Definition, types of logistics, Transportation-role of transportation in logistics, warehousing-nature and importance of warehousing, functions, layout and designing, Role of packaging and Unitization.

Week 4-7: Control of inventory, Distribution resource planning (DRP), Material requirement planning (MRP I), Manufacturing resource planning (MRP II).

Week 8-11: Introduction to SCM, its development, objectives and needs, Components of SCM, Key issues of SCM, Competitive and SC strategies, Achieving strategic fit. Supply chain integration, Push-based, Pull-based and Push-Pull based supply chain, Demand forecasting in a supply chain (CPFR Model).

Week 12-15: Strategic alliances, Third party and fourth party logistics, Key enablers in supply chain improvement, Coordination in SCM, Bullwhip effect in SCM, Use of best practices and information technology in SCM, Benchmarking.

Facilitating the achievement of Course Learning Outcomes

Unit No.	Course learning outcomes	Teaching and learning activity	Assessment tasks
I	(i) Understand the basic concept and types of logistics (ii) Explain the role of transportation in logistic (iii) Explain the nature and importance of warehousing operations and functions; layout and designing (iii) Understand the role of packaging and unitization	(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 (iii) Give homework Assignments (iv) Encourage students to participate in class discussion (v) Encourage students to give short presentation (vi) Encourage students to apply concepts to real-world problems	• Class discussion and presentations • Weekly Assignments • Student presentation • Mid-Term examination, • Group activities involving students to solve real-world problems using solver • Hold both announced and unannounced quizzes • End-term examination
II	(i) Understand the meaning of Inventory control (ii) Explain the importance of (DRP), MRP I and MRP II		
III	(i) Explain Supply chain Management, Key drivers of SCM, various activities in SC (ii) Understand the role of forecasting in SCM		
IV	(i) Understand the importance of outsourcing, 3PL and 4PL in SC (ii) Realize coordination in SCM, Bullwhip effect in SCM (iii)Appreciate the use of best practices and information technology in SCM		

Keywords: Supply chain management, Logistics, Distribution resource planning, Manufacturing resource planning

COURSE- SEC-OR 1: OPERATIONAL RESEARCH APPLICATIONS

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

Course Objectives:

The objective of this course is to give students an introduction to the basic concepts and principles pertaining to Operational Research. The course introduces the notions pertaining to operational research practices. This course shall deal with the utility of techniques related to operational research in solving real life problems.

Course Learning Outcomes:

Students completing this course will be able to:

- Understand relevant concepts related to operation research
- Learn to solve different real-life problems faced by firms in their businesses
- Develop skills for understanding solving practical problems
- Learn skills to aid management decision making

Unit I: Media Management: Understanding different types of media, Difference between traditional media and online media, Media allocation problem. **(Chapter-18, Reference [2])**

Unit II: Problems pertaining to scheduling and selection: Production scheduling problem, Project selection, Knapsack problem. **(Chapter-3, Reference [1] & Chapters-3 & 9, Reference [5])**

Unit III: Problems Related to Transportation: Cargo loading problem, School bus routing problem using spanning tree, Fixed charge transportation problem. **(Chapters-8 & 9, Reference [1], Chapters-5 & 6, Reference [4] & Chapters-7 & 8, Reference [5])**

Unit IV: Some Related Problems: Set covering problem, Cutting stock problem, Simulation. **(Chapter-22, Reference [1], Chapter-9, Reference [3], Chapter-9, Reference [4] & Chapter-21, Reference [5])**

Suggested Readings:

1. 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).
2. Kotler, P., & Keller, K. L. (2008), *Marketing management* (13th ed.). New Delhi: Pearson Education Ltd.
3. Ravindran, A., Phillips, D. T., & Solberg, J. J. (2007). *Operations research- principles and practice* (2nd ed.). New Delhi: Wiley India (Indian print).
4. Taha, H. A. (2017). *Operations research-an introduction* (10th ed.). New Delhi: Pearson Prentice Hall (Indian print).
5. Wayne, W. L. (2003). *Operations research: applications and algorithms* (4th ed.). Duxbury Press.

Teaching Plan:

Week 1-2: Understanding different types of media, Difference between traditional media and online media, Media allocation problem.

Week 3-5: Production scheduling problem, Project selection, Knapsack problem.

Week 6-12: Cargo loading problem, School bus routing problem using spanning tree, Fixed charge transportation problem.

Week 13-15: Set covering problem, Cutting stock problem, Simulation.

Facilitating the achievement of Course Learning Outcomes

Unit No.	Course Learning Outcomes	Teaching and Learning Activity	Assessment Tasks
I	(i) The student will get to know about basic concepts related to various types of media available in the market and learn about optimal allocation of budget to different media	Classroom lectures & presentations	• Hold Class discussion and presentations • Homework assignments • Mid-term exam and final exam • Group activities involving students to solve real-world problems using solver • Hold both announced and unannounced quizzes
II	(i) The student shall develop the understanding towards scheduling and selection of activities for best outcome (ii) The student will be able to understand about selection of items with reference to optimal weight and value combination		
III	(i) The student shall develop his understanding towards the application of operational research tools for channelizing various transportation related problems		
IV	(i) The student will be able to understand about certain other types of optimization problems that exist in the market		

Keywords: Operational research, Real-world decision making, Media management, Transportation problem, Set-covering problem

COURSE-SEC-OR 2.1: PROJECT MANAGEMENT

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

Course Objectives:

The objective of this course is to provide comprehensive insights about management of industrial projects and to develop a framework demonstrating planning, scheduling, monitoring and controlling of industrial projects.

Course Learning Outcomes:

Students completing this course will be able to:

- Understand the theory and concepts of project planning and associated cost-benefit analysis.
- Identify and proactively manage project pitfalls
- Learn the art of planning and structuring a project
- Develop various strategies to deal with potential conflicts
- Know some tools and techniques which assist in managing projects

Contents:

Unit I: Introduction to Project Management, Organization Strategy and Project Selection, Objectives of Project Planning: Introduction, objectives and process of project planning, monitoring and control of Investment Projects. **(Chapters-1, 2 & 6, Reference [1] & Chapter-6, Reference [4])**

Unit II: Estimation of project times and cost. Cost of projects, Techniques of risk analysis, overview of projected cash flow, Balance Sheet Budget, Sources of funds, Project Auditing. **(Chapters-5 & 7, Reference [1], Chapter-3, Reference [2] & Chapters-1, 6 & 12, Reference [3])**

Unit III: Monitoring and Information Systems, Project control, Progress and performance measurement and evaluation, Project termination. **(Chapter-13, Reference [1] & Chapters-10, 11 & 13, Reference [3])**

Unit IV: Cost and Time Management issues in Project planning and management (PERT and CPM). **(Chapters- 8 & 9, Reference [3])**

Suggested Readings:

(i) Compulsory Reading

1. Larson, C. F., & Gray, E. W. (2013). *Project management: the managerial process* (5th ed.). McGraw-Hill Education.
2. Goodpasture, J. C. (2014). *Quantitative methods in project management* (1st ed.). Cengage Learning India.
3. Meredith, J. R., & Mantel Jr, S. J. (2011). *Project management: a managerial approach* (8th ed.). New Jersey: John Wiley & Sons, Inc.
4. Kerzner, H. (2003). *Advanced project management: best practices on implementation* (2nd ed.). New Jersey: John Wiley & Sons, Inc.

(ii) Additional Reading

5. Ravindran, A. R. (2016). *Operations research and management science handbook*. New York: CRC Press.

Teaching Plan:

Week 1-2: Objectives of Project Planning: Introduction, objectives and process of project planning, monitoring and control of Investment Projects. Relevance of social cost-benefit analysis, identification of investment opportunities. Pre-feasibility studies.

Week 3: Relevance of social cost-benefit analysis, identification of investment opportunities. Pre-feasibility studies.

Week 4-5: Technical Feasibility, Marketing feasibility and Technical Feasibility estimation of cost and demand analysis and commercial viability.

Week 6-8: Cost of projects, Techniques of risk analysis, Collaboration arrangement, overview of projected cash flow, Balance Sheet Budget, Sources of funds, Tax consideration in project preparation and legal aspects.

Week 9-11: Business Criterion of growth (elementary) Liquidity and Profitability, Social Cost benefit analysis in public and private sectors (Rational only) Investment Criterion and choice of techniques, Theoretical aspects of Shadow Prices and Social discount rate.

Week 12-15: Cost and Time Management issues in Project planning and management (PERT and CPM).

Facilitating the achievement of Course Learning Outcomes

Unit No.	Course Learning Outcomes	Teaching and Learning Activity	Assessment Tasks
I	(i) Understand the theory and concepts of project planning and associated cost-benefit analysis	Group discussion, Class discussion on applications of statistics to real-world problems, Presentations	• Hold Class discussion and presentations • Homework assignments • Mid-term exam and final exam • Group activities involving students to solve real-world problems using solver • Hold both announced and unannounced quizzes
II	(i) Identify and proactively manage project pitfalls		
III	(i) Learn the art of planning and structuring a project (ii) Develop various strategies to deal with potential conflicts		
IV	(i) Know some tools and techniques which assist in managing projects		

Keywords: Project planning and management, Social cost benefit analysis, Investment projects

COURSE-SEC-OR 2.2: Essentials of Data Analysis

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

Course Objectives:

This course will introduce the students to the various areas of statistics and probabilities which are essential for data analysis. The course will also enable the students to understand the application areas of different probability distribution in a subject like queueing theory and reliability.

Course Learning Outcomes:

Students completing this course will be able to understand:

- Basic concept of random experiment and algebra of events
- Random variable and its associated properties
- Definition, properties and applications of some important univariate distributions
- Concept of the stochastic process and its applications,

Contents:

Unit I: Concept of random experiment, Sample point, Sample space, Events and algebra of events, Classical and axiomatic definition of probability, Marginal and conditional probability, Independent events, Baye's theorem and its applications. **(Chapter-2, Reference [2])**

Unit II: Random variable, Discrete and continuous random variables, Probability mass function (pmf), Probability density function (pdf), and Cumulative density function (cdf), Expectations, Moments, Moment generating functions and cumulants, Joint distributions– Marginal and conditional distributions (bivariate only). **(Chapters-3 & 4, Reference [2])**

Unit III: Discrete univariate probability distributions: Binomial, Poisson, Geometric, Negative binomial and Hypergeometric (definitions, properties without proof and their applications), Continuous univariate probability distributions-Uniform, Exponential, Normal, Gamma, Erlang, Beta and Weibull distributions (definitions, properties without proof and their applications). **(Chapters-5 & 6, Reference [2])**

Unit IV: Markov and Chebychev's inequality, Weak laws of large numbers (WLLN) and Strong laws of large numbers (SLLN) (only statements and applications), Central limit theorem (CLT) for independent and identically distributed (iid) variates (only statement and application), Basic concept of sampling distribution, t, F and chi-square distribution (only definition and applications). **(Chapters-4 & 8, Reference [2])**

Unit V: Basic concept of stochastic process: Definition and classification with examples, Counting and Poisson process, Discrete-time Markov chain, Transition probability matrix and continuous-time Markov process and concept of birth and death process. **(Chapters-2, 3 &4, Reference [1])**

Suggested Readings:

(i) Compulsory Reading

1. Medhi, J. (2009). *Stochastic processes* (3rd ed.). New Delhi: New Age Science Ltd.
2. Miller, I., & Miller, M. (2014). *John E. Freund's Mathematical statistics with applications* (8th ed.). Essex: Pearson Education Ltd.

(ii) Additional Reading

3. Ross, S.M. (1995). *Stochastic processes* (2nd ed.). New Jersey: John Wiley & Sons, Inc.
4. Trivedi, K. S. (2016). *Probability and statistics with reliability, queuing and computer science applications* (2nd ed.). New Jersey: John Wiley & Sons, Inc.

Teaching Plan:

Week 1-3: Concept of random experiment, Sample point, Sample space, Events and algebra of events, Classical and axiomatic definition of probability, Marginal and conditional probability, Independent events, Baye's theorem and its applications.

Week 4-6: Random variable, Discrete and continuous random variables, pmf, pdf, and cdf, Expectations, Moments, Moment generating functions and cumulants, Joint distributions – Marginal and conditional distributions (bivariate only).

Week 7-10: Discrete univariate probability distributions: Binomial, Poisson, Geometric, Negative binomial and Hypergeometric (definitions, properties without proof and their applications), Continuous univariate probability distributions-Uniform, Exponential, Normal, Gamma, Erlang, Beta and Weibull distributions (definitions, properties without proof and their applications).

Week 11-12: Markov and Chebychev's inequality, WLLN and SLLN (only statements and applications), Central limit theorem (CLT) for iid variates (only statement and application), Basic concept of sampling distribution, t, F and chi-square distribution (only definition and applications).

Week 13-15: Basic concept of stochastic process: Definition and classification with examples, Counting and Poisson process, Discrete-time Markov chain, Transition probability matrix and continuous-time Markov process and concept of birth and death process.

Facilitating the achievement of Course Learning Outcomes

Unit No.	Course Learning Outcomes	Teaching and Learning Activity	Assessment Tasks
I	(i) Concept of random experiment, Sample point, Sample space, Events and algebra of events, Classical and axiomatic definition of probability, Marginal and conditional probability, Independent events, Baye's theorem and its applications.	(i) Pictorially demonstrate the various distributions using computer (ii) Give enough real-life examples so as to make teaching learning more interesting. (iii) Encouraging the students to come up new ideas and appreciating them. (iv) Give home assignments (v) Group discussions.	• Regular home assignments • Class presentations • MCQ • Real life cases • Class test • Semester examination
II	(i) Random variable, Discrete and continuous random variables, pmf, pdf, and cdf, Expectations, Moments, Moment generating functions and cumulants, Joint distributions – Marginal		

	and conditional distributions (bivariate only).		
III	(i) Discrete univariate probability distributions: Binomial, Poisson, Geometric, Negative binomial and Hypergeometric (definitions, properties without proof and their applications), Continuous univariate probability distributions-Uniform, Exponential, Normal, Gamma, Erlang, Beta and Weibull distributions (definitions, properties without proof and their applications).		
IV	(i) Markov and Chebychev's inequality, WLLN and SLLN (onlystatements and applications), Central limit theorem (CLT) for iid variates (only statement and application), Basic concept of sampling distribution, t, F and chi-square distribution (only definition and applications).		
V	(i) Basic concept of stochastic process: Definition and classification with examples, Counting and Poisson process, Discrete-time Markov chain, Transition probability matrix and continuous-time Markov process and concept of birth and death process.		

Keywords: Random variable, Probability theory, Stochastic process

Course-SEC-OR 3: PORTFOLIO OPTIMIZATION

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

Course Objectives:

To impart the knowledge of principles of capital markets, classical portfolio theory, and focus on portfolio optimization.

Course Learning Outcomes:

Students completing this course will be able to:

- Explain technical terminologies essential for the understanding of portfolio optimization including financial markets, investment objectives, types of assets, asset return, risk, short selling, liquidity
- Discriminate between different sources of risk and demonstrate the concept of diversification
- Demonstrate workings of two asset and multi-asset portfolio optimization and describe how to make optimal capital allocation and portfolio choice decisions on real-data set by hand
- Demonstrate measures to evaluate a portfolio's performance
- Demonstrate essential concepts of capital asset pricing model

Contents:

Unit I: Financial markets, Investment objectives, Types of assets, Concepts and measurements of return and risk, Portfolio of assets, Expected return and risk of portfolio, Diversification, Short selling, Mean-variance efficient frontier. **(Chapter-17, Reference [1] & Chapter-6, Reference [3])**

Unit II: Two asset portfolio optimization, Markowitz mean-variance portfolio selection model, Two fund theorem, Portfolio performance evaluation measures-Jenson ratio, Sharpe ratio, Treynor ratio. (**Chapter-17, Reference [1], Chapter-17, Reference [2] & Chapter-6, Reference [3])**

Unit III: Capital market theory, Capital assets pricing model, One fund theorem. (**Chapter-17, Reference [1] & Chapter-7, Reference [3])**

Suggested Readings:

(i) Compulsory Reading

1. Chandra, S., Jayadeva, & Mehra, A. (2013). *Numerical optimization with applications.* New Delhi: Narosa Publishing House.
2. Grinold, R.C., & Kahn, R.N. (1999). *Active portfolio management-a quantitative approach for producing superior returns and controlling risk* (2nd ed.). New York: McGraw-Hill.
3. Luenberger, D. G. (2010). *Investment science.* Delhi: Oxford University Press.

(ii) Additional Reading

4. Markowitz, H.M. (2000). *Mean-variance analysis in portfolio choice and capital markets*. New Jersey: John Wiley & Sons, Inc.

Teaching Plan:

Week 1-6: Financial markets, Investment objectives, Types of assets, Concepts and measurements of return and risk, Portfolio of assets, Expected return and risk of portfolio, Diversification, Short selling.

Week 7-8: Two asset portfolio optimization, Mean-variance efficient frontier.
Week 9-13: Markowitz mean-variance portfolio selection model, Two fund theorem. Portfolio performance evaluation measures: Jenson ratio, Sharpe ratio, Treynor ratio.
Week 14-15: Capital market theory, Capital assets pricing model, One fund theorem.

Facilitating the achievement of Course Learning Outcomes

Unit No.	Course Learning Outcomes	Teaching and Learning Activity	Assessment Tasks
I	(i) Explain technical terminologies essential for the understanding of portfolio optimization including financial markets, investment objectives, types of assets, asset return, risk, short selling (ii) Discriminate between different sources of risk and demonstrate the concept of diversification	(i) While introducing each topic examples will be laid out and discussed to encourage students to discover the relevant concepts (ii) Give extensive examples during lectures (iii) Give homework assignments (iv) Encourage students to participate in class discussion	• Hold Class discussion and presentations • Homework assignments • Final exam • Hold both announced and unannounced quizzes
II	(i) Demonstrate workings of two asset and multi-asset portfolio optimization and describe how to make optimal capital allocation and portfolio choice decisions on real-data set by hand (iii) Demonstrate measures to evaluate a portfolio's performance		
III	(i) Describe the theoretical workings of the capital asset pricing model and demonstrate its working by hand		

Keywords: Investment, Portfolio Optimization, Mean-variance Model, Capital Asset Pricing Model, Risk Measures

COURSE-SEC-OR 4: BUSINESS DATA ANALYSIS

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

Course Objectives:

The objective of this course is to acquaint students with analysis and synthesis of data pertaining to business decisions. The course will give an understanding to data processing, warehousing and data mining. It will let students understand on how data is stored, accessed and extracted for creating valuable decisions in the organizational operations.

Course Learning Outcomes:

Students completing this course will be able to:

- Develop and examine the process by which data can be used for strategic business decision
- Learn about the technologies that facilitate analytical work.
- Gather the understanding towards different techniques used for business data analysis.
- Differentiate between data warehousing and data mining
- Understand supervised and unsupervised learning in data analysis

Contents:

Unit I: Business Fundamentals: Importance of business data analytics, Evolution of business data analytics, Scope of business data analytics. **(Chapters- 1 & 2, Reference [1])**

Unit II: Data processing and data warehousing. **(Chapters- 3 & 8, Reference [1])**

Unit III: Data Management: Data summarization, Data cleaning, Data integration, Data reduction, Data warehousing, OLAP vs. OLTP, ROLAP, MOLAP techniques for data analysis. **(Chapters- 2, 3 & 4, Reference [1])**

Unit IV: Association Rule Mining: Market basket analysis, Prediction analysis, Unsupervised and supervised learning. **(Chapters- 5, 6, 7 & 8, Reference [1])**

Suggested Readings:

(i) Compulsory Reading

1. Tan, P. N., Steinbach, M., & Kumar, V. (2006). *Introduction to data mining*. New Delhi: Pearson (Indian print).

(ii) Additional Reading

2. Bartlett, R. (2013). *A practitioner's guide to business analytics: using data analysis tools to improve your organization's decision making and strategy*. New York: McGraw Hill.
3. Berson, A., & Smith, S. J. (1997). *Data warehousing, data mining, and OLAP*. New York: McGraw-Hill.
4. Gupta, G. K. (2006). *Introduction to data mining with case studies.* New Delhi: Prentice Hall of India.

Teaching Plan:

Week 1-3: Importance of business data analytics, Evolution of business data analytics, Scope of business data analytics.

Week 4-6: Data processing and data warehousing

Week 7-12: Data summarization, Data cleaning, Data integration, Data reduction, Data warehousing, OLAP vs. OLTP, ROLAP, MOLAP techniques for data analysis

Week 13-15: Market basket analysis, Prediction analysis, Unsupervised and supervised learning

Facilitating the achievement of Course Learning Outcomes

Unit No.	Course Learning Outcomes	Teaching and Learning Activity	Assessment Tasks
I	(i) The student will get to know about the fundamental concepts of business and learn about business data analytics	Classroom lectures & presentations	• Hold Class discussion and presentations • Homework assignments • Mid-term exam and final exam • Group activities involving students to solve real-world problems using solver • Hold both announced and unannounced quizzes
II	(i) The student shall develop the understanding towards techniques of data processing and data warehousing		
III	(i) The student shall learn data management and data analysis through various techniques		
IV	(i) The student will get familiar with data mining through different analytical approaches		

Keywords: Data management, Data warehousing, Data processing, Prediction analysis

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